Small-Scale Habitat Selection and Activity Trends of the Diamondback Terrapin in West Galveston Bay, Texas As Determined by Acoustic Telemetry

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INTRODUCTION

The Diamondback terrapin (*Malaclemys terrapin)* is the only Chelonian species that resides exclusively in brackish water habitat and may serve as a keystone species. They belong to the *Chrysemys* evolutionary line of Emydidae, which also includes basking turtles such as the painted turtle and map turtle (Orenstein 2001). Their range extends from the Northern Atlantic coast down through the Gulf of Mexico to South Texas. They are normally found in *Spartina alterniflora* salt marsh, tidal creeks and mangrove forests (Brennessel 2006, Orensein 2001). Female diamondback terrapin are typically much larger than males, possessing a larger head width and gape, and have thinner tails with the cloacal opening anterior to the edge of the plastron (Brennessel 2006).

Terrapin are characterized by a type III survivorship curve with a clutch size averaging 12 eggs (Roosenburg and Dunham 1997) and a maximum life span of over 50 years (Roosenburg 1990, Tucker et al 2001), although some studies have found the average life span to be closer to six years (Tucker et al 2001). This life history leaves terrapin extremely susceptible to population depletion due to human induced adult mortality. Population levels were depleted in the 1800s and early 1900s due to overharvest, and most have not recovered. The species is now protected in Rhode Island and Massachusetts, and is considered a "species of concern" in North Carolina, Alabama, Louisiana, Virginia, Delaware, and Georgia. In all other coastal states, the exact status of the terrapin is unknown.

Even though terrapin are presently protected from overharvest, there are still many threats to the survival of the species. Drowning in blue crab pots, often referred to as bycatch, is one of the biggest sources of terrapin mortality, along with injury from boat propellers and nesting habitat destruction (Rosenburg 1990). With little known about the life history of terrapin in their southern range, knowledge of small scale movements and activity patterns could be vital to conservation. There is little to no literature on the short term temporal distribution of terrapin, their movement, and habitat use as observed with acoustic telemetry. Our data provides unique insight on the daily and nightly habits and movement of diamondback terrapin.

METHODS

Between 2009 and 2010, we tagged 25 terrapin with VEMCO V13 acoustic transmitters and assembled an array of 7 VEMCO VR2W acoustic receivers around the perimeter and main creek of South Deer Island in Galveston Bay, Texas (Figure 1). South Deer Island measures 25 ha and is composed of a complex system of tidal creeks, inlets, and saltmarsh dominated by *Spartina alterniflora, Spartina patens,* and Batis and Salicornia spp. Due to the limited lifespan of the tags and differential tagging dates, the maximum data collected on any tag was obtained for a 16 month period, and was collected on ten of the tags. We used the receiver data from these ten terrapin from June 2009 to October 2010 to determine swimming activity and patterns. Nine of these terrapin were female and one was male, however, the females did differ significantly in size. We also utilized passive trapping and active hand capture techniques on land and water to provide useful information on habitat use and activity patterns. We estimated the percentage of these 16 months the terrapin spent swimming by dividing the total number of hours each transmitter was being picked up by the acoustic receiver by the total time the acoustic receivers were collecting data. This is comparable to a CPUE of swimming activity and can be used to estimate a minimal swimming activity time. We calculated these values for each month spanning our study to show annual and seasonal trends, as well as for the nocturnal swimming activities of each month. We performed a one-way ANOVA to identify any differences in swimming activities between months, and a two-way ANOVA to identify differences in nocturnal swimming activity between months. We also conducted linear regression analysis to determine any correlation between swimming activity and terrapin meristics and temperature. Temperature was recorded for the time period using HOBO tidbits placed in the water adjacent to South Deer Island.

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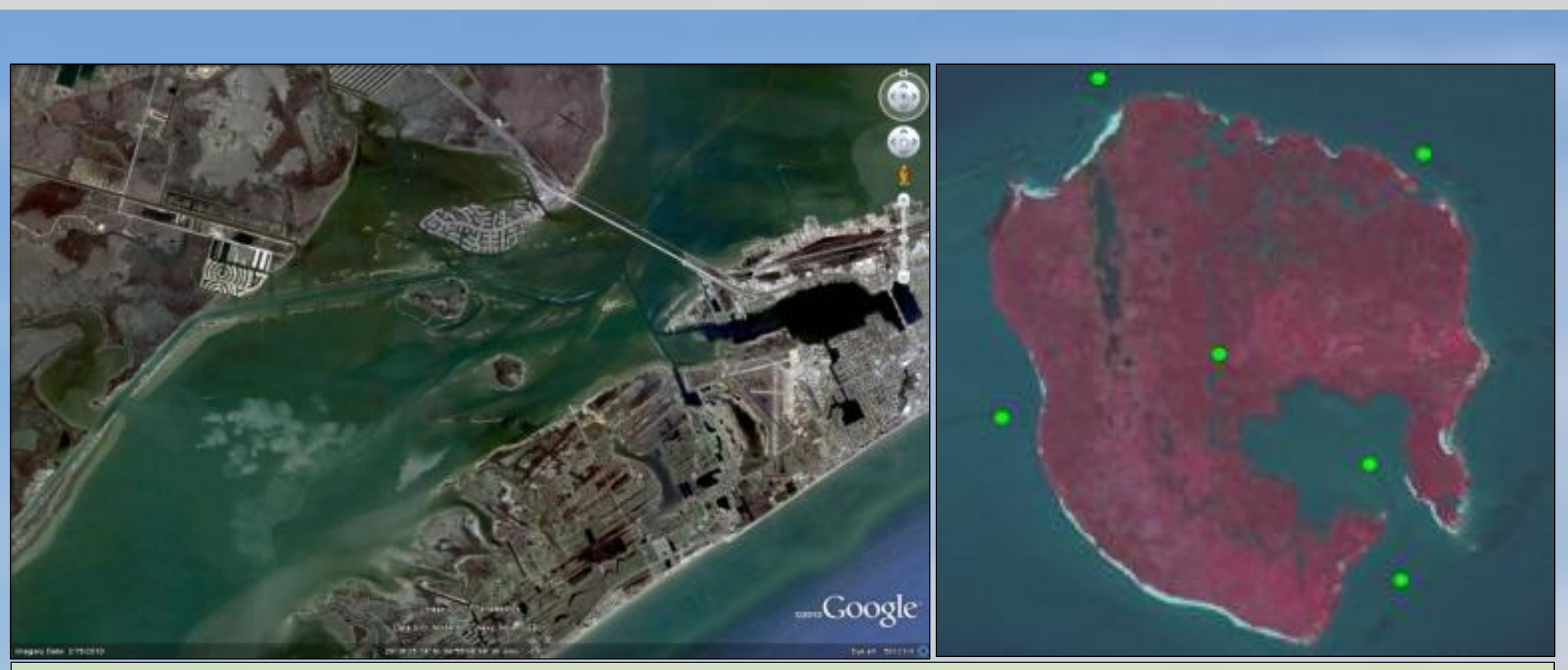

Figure 1. Acoustic receiver array around South Deer Island in Galveston Bay, Texas.

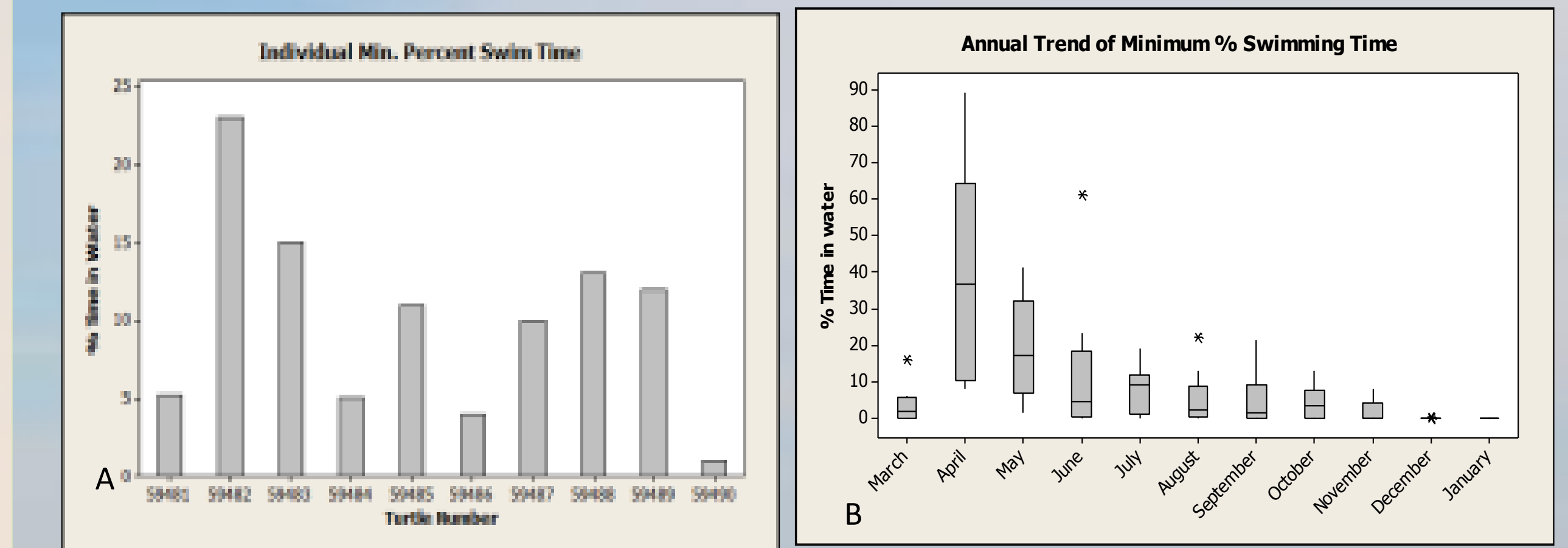

Figure 2. A. This shows the total minimum percent time spent in water by each of the 10 tagged terrapin over the entire sampling period. Percent time in water was calculated by dividing the total number of hours each transmitter was being picked up by the acoustic receiver by the total time the acoustic receivers were collecting data. This number is a minimal estimate of the total amount of time spent in the water. **B.** This shows the total minimum percent time spent in water by each of the 10 tagged terrapin during each month of a one year period. When data existed for a two year period, the percent swimming time for each month was averaged between the two years.

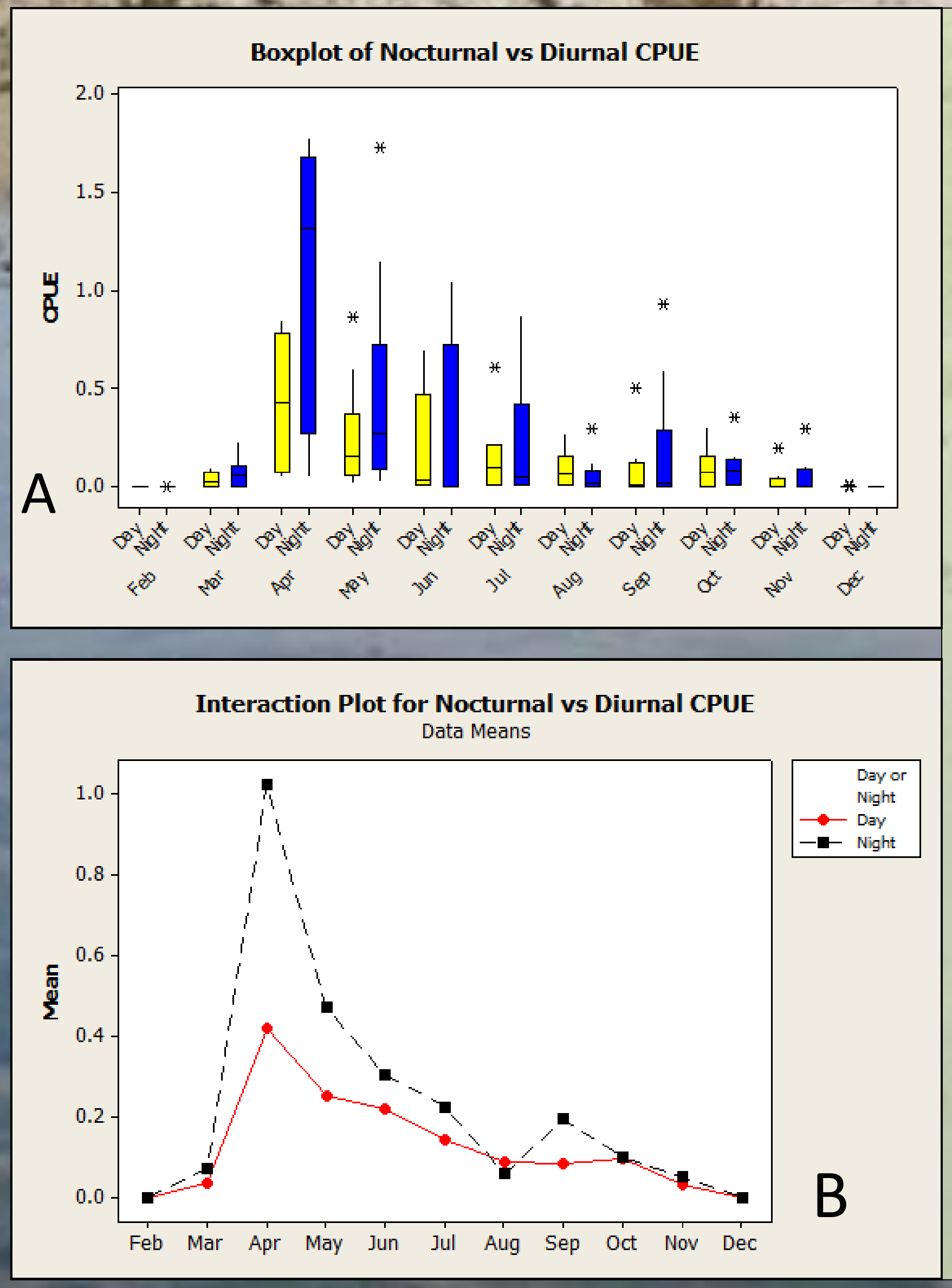

Figure 5A. Percentage of total time of each month in which transmissions were received, diurnal vs nocturnal. This boxplot shows the differences between nocturnal and diurnal swimming rates between months in 2010. This value was calculated by dividing the number of day and night hours each terrapin's transmitter was detected by the total number of diurnal and nocturnal hours monitored by VEMCO receivers each month. This effectively provides a nocturnal and diurnal swimming CPUE per month (y axis). A two way ANOVA showed significant difference between both diurnal vs. nocturnal swimming activity, and monthly diurnal and nocturnal swimming activity (p = 0.005), with a **Figure 5 B. Interaction plot showing percentage of total time of each month in which transmissions were received during diurnal vs. nocturnal periods.** This shows a significant amount of interaction between the monthly and diel fluctuations in terrapin activity (p = 0.017).

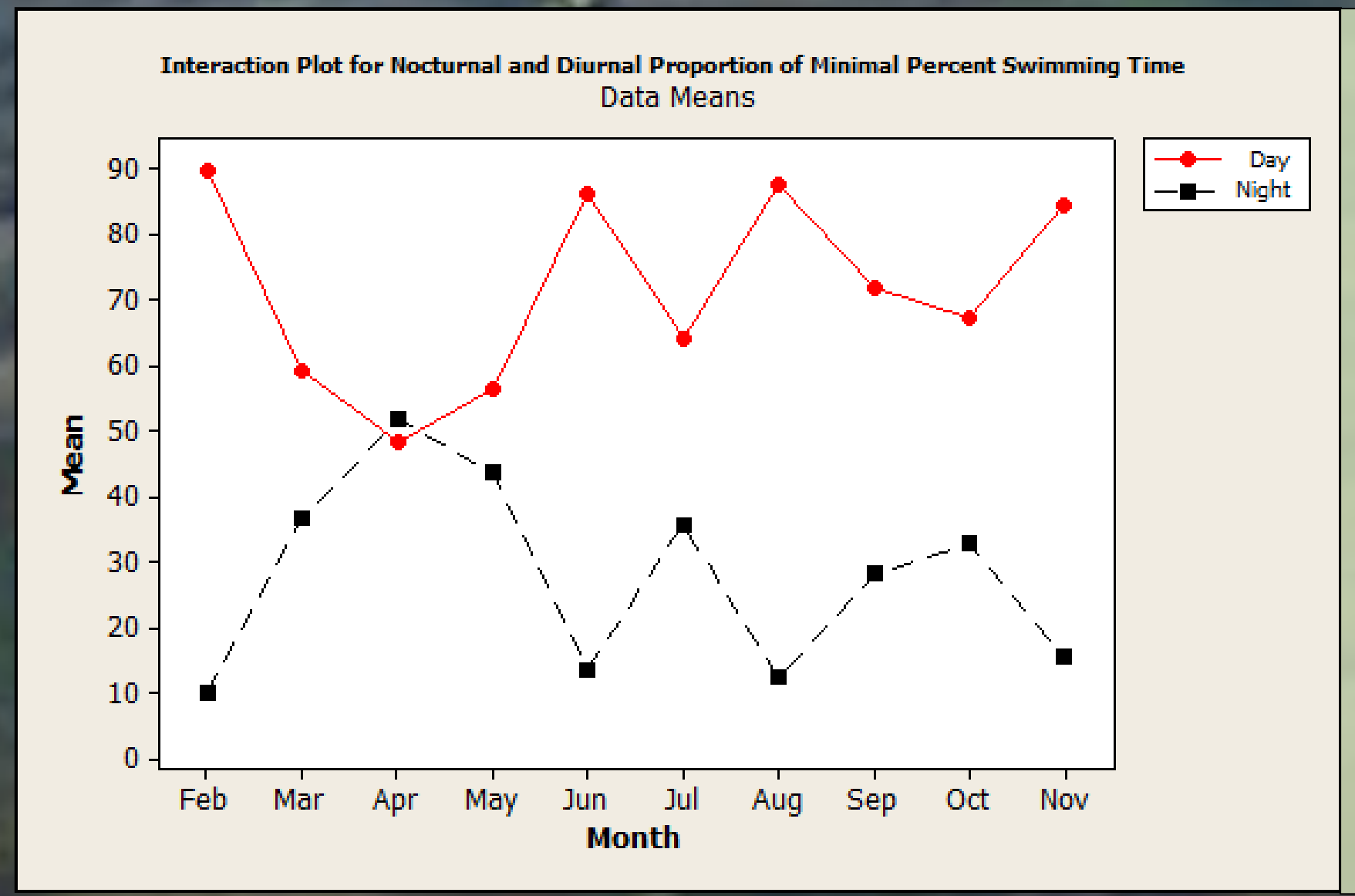

Figure 7. The percentage of total time terrapin were detected during day and night periods. This mean value was calculated by dividing the number of hours the receiver detected a terrapin swimming nocturnally per month by the total number of hours the terrapin was detected swimming per month. This shows what percent of each individual's total swimming time was spent swimming nocturnally vs diurnally each month.

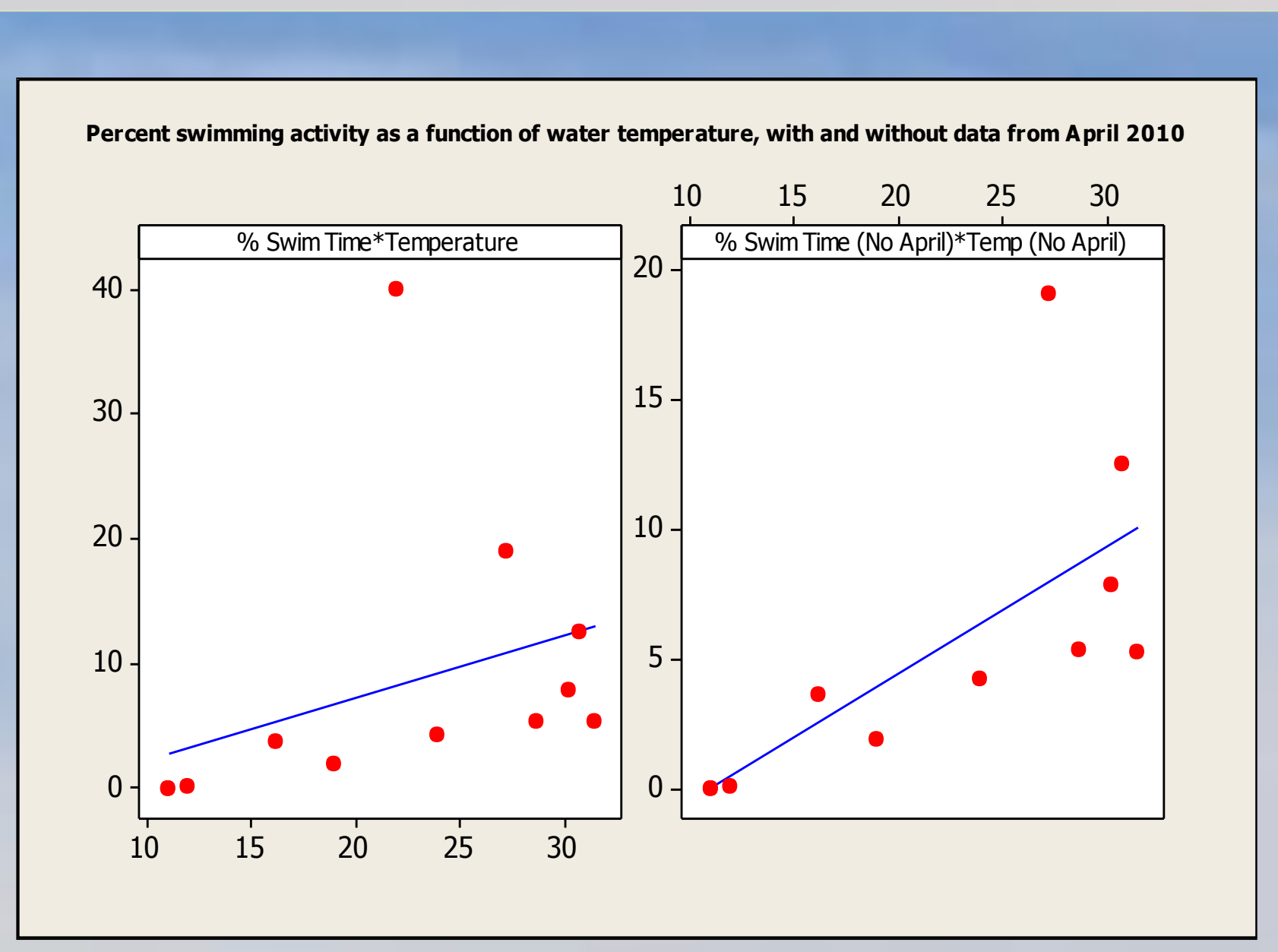

Figure 3. The percent swimming activity as a function of water temperature, with and without data from April 2010. The graph on the left includes April 2010 data and therefore has no significant correlation (p = 0.274). The graph on the right does not include data from April 2010, and has a significant correlation (p value of 0.017, % time = - 5.37 + 0.492 water temp, and r^2 = 48.7%), showing increasing temperature correlates with increasing swimming activity. Percent swimming activity (y-axis) was calculated by dividing the total number of hours each transmitter was being picked up by the acoustic receiver by the total time the acoustic receivers were collecting data, and is comparable to CPUE. Water temperature (x-axis) was measured with a HOBO tidbit and averaged for the months.

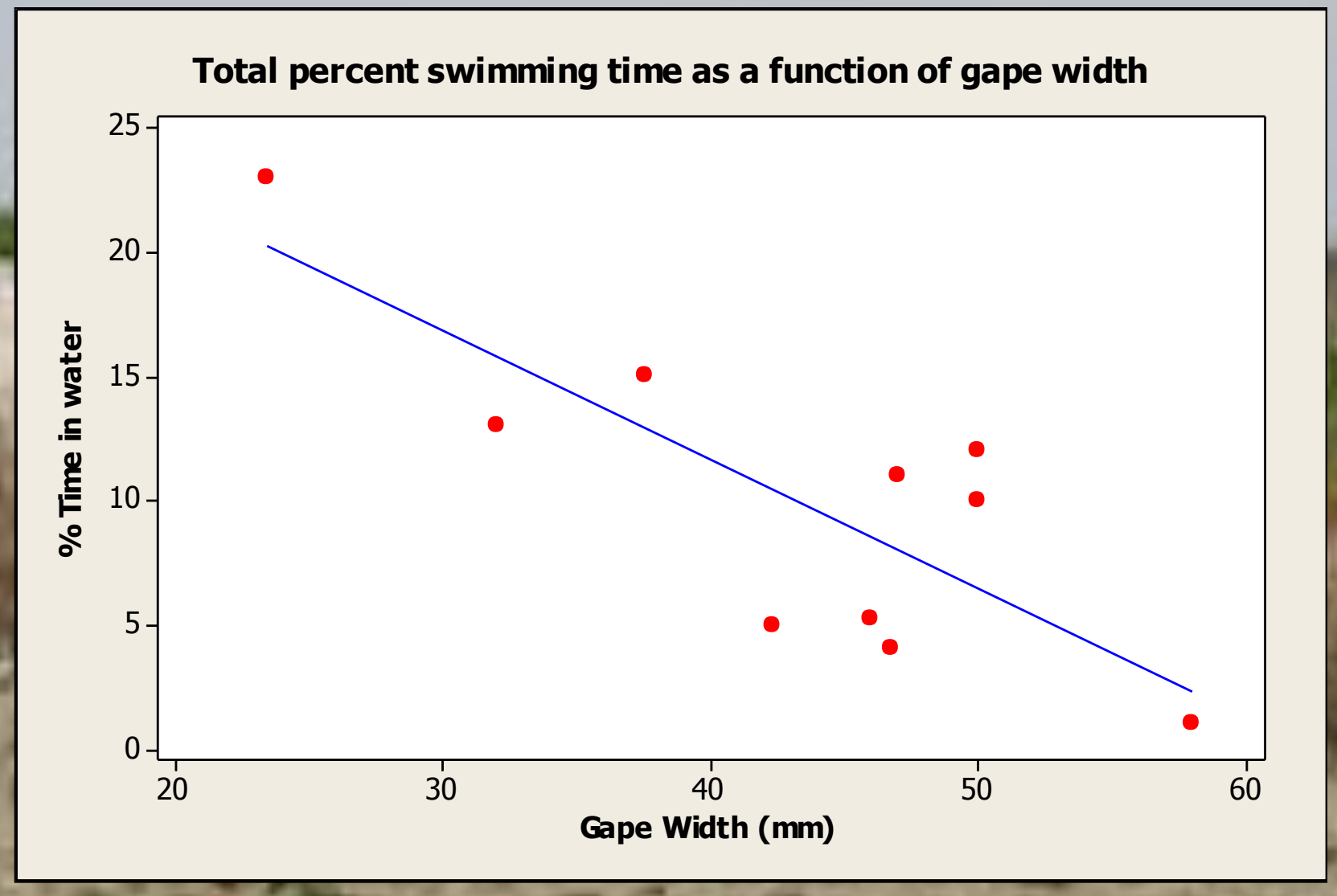

Figure 4. Minimal percent swimming time as a function of gape width of ten acoustic tagged terrapin. (p = 0.005, % Time in Water = 32.4 - 0.519 Gape Width, and r^2 = 64.7%) Gape width was recorded as the widest section of the head in mm. % Time in water was calculated by dividing the total number of hours each transmitter was being picked up by the acoustic receiver by the total time the acoustic receivers were collecting data. This number is a minimal estimate of the total amount of time spent in the water, and is comparable to CPUE.

A female (left) and male (right) Diamondback terrapin, showing sexual dimorphism.

Diamondback terrapin with V13 acoustic tags attached with epoxy.

RESULTS

The ANOVA showed a significant difference between the mean rates of minimal percent swimming time between the months, with the maximum swimming activity occurring in April (Figure 2). When compared to aquatic temperature, the CPUE data for April showed as an unusual residual, and the relationship was not significant. Because April is a period of "unusual activity" that does not necessarily occur in other months (i.e., mating), and migrations may occur outside of the month of April, we removed this data from the temperature regression. When the data from the month of April was removed, the regression relationship between water temperature and percent swimming time was significantly correlated (p value = 0.017), showing that increasing temperature correlated with increasing swimming activity (Figure 3).

We found a significant inverse correlation between gape width and minimal % swimming activity (p-value = 0.005), as well as a significant inverse correlation between carapace length and plastron length and minimal % swimming activity (p value = 0.005 and 0.017, respectively). This indicates that larger terrapin may spend a significant less amount of time swimming or actively in the water (Figure 4). We found no correlations between nocturnal swimming times and terrapin meristics or abiotic factors. However, there is a high variability in nocturnal swimming activity. Two way ANOVA results documented significant differences in monthly and diel CPUE, with a peak of nocturnal activity in April (Figure 5). The ANOVA showed higher rates of nocturnal swimming throughout the year, with the exception of August. However there was a significant interaction between these two factors (Figure 6 and 7).

CONCLUSION

The significant inverse correlation between gape size, plastron length, and carapace length and percent time spent swimming indicates that larger terrapin spend less time inhabiting the near shore open bay areas in which the receivers are set. While this correlation does not show causation, we can hypothesize that this may be due to foraging constraints. Tucker et al (1995) found that females with larger gapes prefer larger periwinkle snails because of their higher energy value, while smaller terrapin are not physiologically able to eat larger snails due to their smaller gapes. Due to this habitat partitioning, they found larger females often moved further from the creeks and water bodies to access the larger periwinkle snails that inhabited the higher marsh areas. It is therefore possible that smaller terrapin spend a higher percentage of time in the water foraging on grass shrimp or other smaller prey that live in adjacent seagrass beds and possibly oyster reefs. Another possible explanation could be that these larger females may be migrating further away from the island to other sites in the bay for activities such as mating and nesting, and are therefore picked up the receivers less.

There was a significant correlation between temperature and swimming activity after April data was removed, but including the April data resulted in no significant correlation. Because the majority of observed mating activity occurs in April, this may show that typical foraging activity is influenced by by water temperature, but mating activity may be determined by other factors. Other studies have found similar trends in terrapin activity. In South Carolina, Gibbons et al (2001) observed the highest levels of terrapin activity in April, with a second peak of male activity in October. However, terrapins remain active from early March until late November (Butler 2002). Butler (2002) noted highest terrapin activity at a water temperature of 25ºC and a salinity of 20 ppt. Hurd et al (1979) noted a decrease in population size (or capture rate) as the summer progressed.

The high variability in nocturnal swimming levels is a very interesting observation in light of the fact that no correlations could be found between this data and any abiotic or meristic factors. Understanding the diurnal and nocturnal habits of terrapin is important for conservation and management plans. For example, if terrapin were not found in the water at night, then the potential impacts from nocturnal crab trap deployment would be minimal. However, our data shows high rates of nocturnal swimming activity in the open bay, which refutes this concept. Future work needs to be done to further analyze the causation of differential nocturnal swimming activities, as well as general patterns in swimming activity and aquatic habitat selection.

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