Sea Turtle Navigation and Migration: a Literature Review

and

An Ecological Study of the Diamondback Terrapin (*Malaclemys terrapin*)

Population in Jamaica Bay, New York

A Master's Thesis in Two Parts

by

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General Introduction

This paper consists of two parts. The first section contains a literature review of what is currently known about sea turtle migration and navigation. Included are discussions of field experiments and molecular work, as well as suggestions for future research in these areas. A variety of aspects are covered, including the orientation behavior of hatchling sea turtles, the "lost year" of juveniles, behavior in foraging grounds, and adult sea turtle migration behavior. I hope that this will serve to bring together the large amount of literature in this area, which has generally been rather scattered and disjunct. I found that by bringing all this literature together and making it into a more cohesive unit, I was able to gain more of a general understanding of the field and of what still needs to be done.

The second section of this paper concerns a study conducted on the diamondback terrapin (*Malaclemys terrapin*) population in Jamaica Bay, New York. This study took place from early May through early September, 2001. The diamondback terrapin is an organism whose ecology and life history parallel those of sea turtles in several ways. First, terrapins can tolerate a wide variety of salinities, and are found in coastal areas in up to full strength seawater. Diamondback terrapins may also share nearshore foraging habitats with sea turtles in many areas, and both terrapins and more marine turtles lay their eggs on land and exhibit at least some degree of nesting beach homing. I considered the *M. terrapin* population in Jamaica Bay, New York, which historically has been one of the largest populations of this species in New York State and perhaps in the entire Northeastern United States, to present an interesting system in which to study issues of migration and navigation without the large-scale satellite telemetry studies required for sea turtles. Little is known about diamondback terrapins in open water, especially in the Northeast, as most research has focused on nesting areas. I hope to introduce the reader to this study system, relate the results of this research, as well a present some discussion of the challenges of working in this area and possible future research goals.

Acknowledgments

I would like to thank Dr. Jeffrey Levinton for his patience and his help both as an advisor on the terrapin work and as an editor on this paper. I also thank Alan Kowalski, whose constant and reliable help on the terrapin project was invaluable. Thanks to all the volunteers who came out and helped with the trapping efforts. Finally, I'd like to thank Dr. Russell Burke for introducing me to the Jamaica Bay terrapins and helping the research get started.

Part II: An Ecological Study of the Diamondback Terrapin (*Malaclemys terrapin*) Population in Jamaica Bay, New York

Figures and Tables

Introduction

The diamondback terrapin (*Malaclemys terrapin*) can be found along the Atlantic and Gulf Coasts of North America. *M. terrapin* inhabits both coastal and more inland areas, and is able to tolerate a wide range of salinities (Davenport and Macedo, 1990), including full seawater for several months. Although terrapins are not sea turtles, (they belong to the family Emididae, which includes box turtles, *Terrapene*, and painted turtles, *Chrysemys picta*), their ecological characteristics and life histories are similar in some important ways to those of their more marine relatives. Both sea turtles, particularly juveniles, and diamondback terrapins feed in nearshore salt-water habitats, and in some locations sea turtles and terrapins may be found together. In addition, terrapins exhibit at least some degree of nesting beach homing, returning to the same beach year after year to lay their eggs (Burke and Feinberg, unpublished data). Those interested in questions of turtle movement patterns and homing may find that the diamondback terrapin represents a more easily accessible system for research.

Diamondback terrapins represent an understudied system for looking at population movement patterns. While a number of studies have been conducted on different aspects of terrapin reproduction (e.g. Montevecchi and Burger, 1975; Burger, 1977, and Ricklefs, 1977) information on terrapin distribution and movement patterns is greatly lacking. This makes it difficult to design successful conservation strategies for this species. The purpose of this study was to gather additional data on the ecology and habitat use of *M. terrapin* in Jamaica Bay, New York. The diamondback terrapin population in Jamaica Bay has historically been one of the largest populations of this species in New York State, and perhaps even the entire Northeastern United States. It has been estimated on the basis of egg and nesting female counts that over 1800 terrapin nests were laid every year in the Jamaica Bay area (Feinberg and Burke, unpublished data), at least prior to 2000. Even though female terrapins will nest repeatedly over the course of a nesting season, this still implies a large overall population size. However, because of the longevity of individuals of this species, it is difficult to assess the status of this population without additional data. Previous work in the area has focused solely on nesting females, and little is known about males, juveniles, and non-gravid females.

The area where this research was conducted is part of the Gateway National Recreation Area. The Jamaica Bay unit of the GNRA is an estuarine refuge that comprises about 9,155 acres. It is located in the southwestern area of Long Island, and is composed of one main and a larger number of smaller islands. The large area of productive wetlands in the GNRA represents ideal terrapin foraging and nesting habitat (Morreale, 1992). However, the continued persistence of *M. terrapin* in this area is threatened by several factors. Prior to 1990, diamondback terrapins nests were subject to low levels of predation (Cook, 1989). Raccoons were introduced into the area during the early 1990's, and predation on terrapin eggs has increased to approximately 100% (Feinberg and Burke, unpublished data). In addition, the Jamaica Bay area is becoming increasingly urbanized, and pollutants such as estrogen imitators may be affecting the physiology of the terrapins. In addition, a recent study suggests that the Jamaica Bay wetlands are rapidly deteriorating (Hartig et al., 2002), leading to the loss of valuable habitat for terrapins as well as other organisms.

As one of the larger vertebrate predators in Jamaica Bay, terrapins play an important ecological role in their ecosystem. They feed on a variety of organisms such as crabs, mollusks, crustaceans, as well as other invertebrates (Tucker et al., 1995), and have been shown to greatly impact the abundance of *Littorina* (Levesque and Fauth, 1999). They also move a large amount of energy from their saltwater habitat into the terrestrial environment when they lay eggs. These eggs are a valuable source of nutrition to a variety of predators, such as foxes, crows and gulls, and, more recently, raccoons.

This study was conducted from early May to early September 2001, the period during which the terrapins are most active. It focused on gathering ecological baseline and habitat use data on *M. terrapin* in the Jamaica Bay area, by collecting terrapins both on land and in the water using large wire mesh traps. Custom designed traps as well as more conventional crab pots were used. This approach yielded a more complete picture of the terrapin distribution in this area, and points to interesting areas of future research as well.

Materials and Methods

Trap Design and Placement

Both custom-built and conventional crab pots were used in this study for trapping. The custom traps were designed in 2001 by Alan Kowalski, then an undergraduate at Stony Brook. They consisted of a PVC frame with holes drilled through to allow water to enter the pipes, and a heavy-duty wire mesh covering. The dimensions of the traps were 1.83 m (6 feet) by 0.61 m (2 feet) by 0.61 m (2 feet). Two openings were constructed near the bottom of the trap. These were obtained from a fishing supply store and were the same as those used in regular-sized crab pots. Both wire mesh and plastic openings were used.

The traps were attached to 3.05 m (10 foot) wooden poles which were driven into the substrate. Brightly colored buoys were attached near the top of each trap to prevent submergence at high tide as well as to make them more visible to boaters. The floating traps allowed terrapins to come up to breathe at all stages of the tide cycle, preventing the high rates of terrapin mortality that are regularly observed in crab pots with no buoys or terrapin excluder devices (Roosenburg, 1997; Bishop, 1983). This also allowed for constant trapping rather than daily placement of the traps.

Eight custom traps and four conventional crab pots were placed around the Jamaica Bay area (Figure 1). The appearance of a custom-built trap at low and high tide can be seen in Figure 2. The location of the traps and comments on their placement can be found in Table 1.

Traps were checked at regular intervals. During the beginning of the 2001 season, traps were checked once daily. Once it was found that the average trapping rate was low, they were checked every two days.

Collection of Nesting Females

A survey of the Jamaica Bay Wildlife Refuge (JBWR), which is located adjacent to the major terrapin nesting beach in the area, was conducted during most field days. Females found on land were collected and brought back to the lab for measurements. A number of females were also obtained from Little Egg Marsh with the assistance of Sylwia Ner, a graduate student at Hofstra University.

Terrapin Data Collection

Once an animal was trapped or collected at the JBWR, it was brought back to a laboratory at Hofstra University, where it was weighed and a series of measurements were taken. The sex of each animal was determined by looking at the weight and appearance of the carapace of each animal. Mature male terrapins are generally much smaller than mature females, and the carapace of a mature male terrapin will have more rings and signs of wear than that of an immature animal. Mature females are much larger than the males. The tail length of the males is usually also much longer than that of females.

Pictures were taken of both the carapace and plastron of the majority of the animals captured. Each animal was fitted with a lightweight metal tag on its carapace (Figure 3). These metal tags were imprinted with a unique number and a message offering a reward for the return of the tag. Waterproof putty and glue was used so that the tag could be easily pried off and returned for the reward. In addition, as the animals grow, the tag should eventually fall off, preventing carapace deformations. A passive integrated transponder (PIT) tag was also injected behind the hind leg of each terrapin. Information on PIT tag numbers can be found in Table 2. Each terrapin was kept in the laboratory in Jamaica Bay water until it could be released on the next trip into the field.

Sonic Tagging

Sonic tags were attached to the carapaces of two terrapins. This method was chosen for tracking finer-scale movements of individuals because of their relative accuracy, lower cost, and adequate range (approximately 3000 meters). These tags weighed 8 grams and measured 65 mm in length and 18 mm in diameter.

Terrapin Surveys

A number of surveys were sent out to approximately 150 institutions, museums, and fishing supply stores in the New York, Connecticut and New Jersey area that were thought to have information on terrapin distributions. Below is the text of the survey as it was sent.

Diamondback Terrapin Survey Form

Please answer the questions below (please number your answers). If you need more space please use the back of this form or attach an additional page. Thank you!

1. Name
2. Contact information (please include e-mail address if available)
3. (If applicable.) Does your institution have a collection of preserved diamondback terrapins? If so, how many and from which years? Where were these animals collected? (Please mark location on attached map with a "1".)
4. Is there a diamondback terrapin population in your area? If so, could you provide an estimate as to its size? Where is this population located? (Please mark location on attached map with a "2".)
5. If there are diamondback terrapins in your area, do you believe the population has historically increased in size, decreased in size, or remained the same? Please explain.
6. Are you aware of any diamondback terrapin research that has been done in your area? Any names and contact information would be very helpful.
7. Do you have any other information regarding diamondback terrapins which may be useful for our study?
8. Would you like to be kept informed about the results of this study? If so, please provide an e-mail address so we can add you to a mailing list. You will receive infrequent messages updating you of the progress of this study as well as the results of this survey. You can be removed from the list at any time.

A map of the lower Hudson River was attached to the survey, as well as a brief description of the research being conducted.

Results

Trapping Results

A total of 63 different terrapins were collected, including those in the traps as well as those found on land. No mortality or injuries were observed among the trapped terrapins. There were 33 terrapins collected in the traps during the period from May 6th, 2001 through September 3rd, 2001, and 28 females collected in the JBWR and on Little Egg Marsh during the same time period. Weights and measurements were obtained for all of the trap-caught terrapins, and for all but two of the females collected in the Refuge and Little Egg Marsh. Two terrapins caught in the traps were recollected at a later date in the JBWR. Table 2 shows a summary of the data collected.

All but one of the terrapins was trapped in the custom-built traps. One mature male was collected on August 1st in one of the crab pots. Of the 33 trapped terrapins, 7 were mature males, 4 were large juveniles (probably female), and 22 were mature females. Between the 18th and the 25th of June, 2001, 4 gravid females were trapped. No other gravid females were found in our traps at any other time. Table 1 shows the trap types, locations, and catch rates.

The catch rates overall were low, with catch rates ranging between 0 and 0.078 terrapins per day. The most terrapins were trapped near Pumpkin Patch Marsh and East Stony Marsh. Two of the gravid females were trapped in West Pond, which is located within the Jamaica Bay Wildlife Refuge and close to the major terrapin nesting areas.

One of the females was trapped relatively close to the nesting areas in the refuge (trap 409), while another was trapped some distance away (trap 403).

In order to ensure that there were no terrapins escaping from the traps, and that males were not more likely to escape because of their smaller size, a "trap door" was added to the openings midway through the season. This allowed the terrapins to come into the trap but made it more difficult for them to get out. No difference in subsequent catch rates was observed, thus indicating that terrapins were not previously escaping from the traps.

The ratio of females to males caught in traps was 1: 3.14 and that of adults to juveniles was 1:7.25. Small juveniles were not expected to be caught because they should have been able to escape the trap due to their small size, and probably would not have entered the traps with the added trap doors because they would not have been able to push their way in. A Fisher's exact test on the female to male ratio yields a p-value of 0.02.

On June 8th, a dead terrapin thought to be a mature male was found in an abandoned crab pot, which was subsequently removed. A number of crab pots that had been set in the area were checked on each field day to collect data on possible terrapin mortality. It appeared that these traps were regularly checked and rebaited by local fishermen, and no dead or live terrapins were found.

Data on Individual Terrapins

The weight distribution of all *Malaclemys terrapin* collected is shown in Figure 2. Figure 3 shows the weight distribution for trapped terrapins only, and Figure 4 includes only data from those collected on land. Figure 5 and 6 show the data for all females and males, respectively. Summary statistics are included below each figure.

The correlation between weight and length was, as expected, highly significant ($p<0.0001$). There were two outliers, which were lighter than would be expected for their size. Interesting, the gravid females were not seen to deviate from this curve, and the growth curve for males and females did not appear to be significantly different.

The correlation between relative tail length (measured as the ratio of tail length to curved carapace length) and sex was highly significant ($P<0.001$). This is interesting because it lends support to the use of tail measurements as a reliable method of determining sex in these animals, since tail length was not the determining factor used in deciding upon the sex of individuals. There was very little variance among individuals in the ratio of tail length to curved carapace length, although this may have been confounded by the small sample size of the males.

Sonic Tagging

The range of the sonic transmitters that were used was much less than expected, even taking into account the reduction in strength expected because of the salinity of the water. A signal could only be detected within about 100 yards, and it was lost when there was an area of marsh between the boat and the sonic transmitter. One of the turtles that was fitted with a sonic transmitter, JB 012, was followed by listening to the signal immediately upon its release. The signal was very clear for a short time but abruptly faded and ended when the terrapin moved further in the direction of the marsh. The terrapin may have dug itself into the marsh area and rendered the signal inaudible. The signals for both of the animals fitted with sonic transmitters were regularly monitored during different times of the day; however, no further signals were detected subsequent to the day of their release. Since diamondback terrapins are thought to spend much of their time dug into the marshes, sonic tagging may not be a good choice in this case, unless one is able to constantly monitor the frequencies. In this way, one may be able to detect the animals during their periods of activity.

Survey Results

Only nine surveys were returned. They indicate a general lack of knowledge about the distribution patterns of *Malaclemys terrapin* along the Hudson River. I did not receive any replies with information about preserved speciments. One respondent stated that he has looked for terrapins in the New Haven, Connecticut area, but has not found any. There are historical records of *M. terrapin* being present in that area. The survey replies also indicate that terrapins have historically been present on Long Island, and decent-sized populations may still exist. One respondent stated that he was aware of about 5-10 terrapins a year reported from the Nissaquoge area.

Another survey respondent addressed the presence of *M. terrapin* on Staten Island, New York. He stated that, since 1980, several females were found walking on the South side of Staten Island during the months of June and July. Four of these came from Great Kills Park. Other areas where terrapins were reported from were Lemon Creek, Wolfe’s Pond Park and the beaches of Gateway National Recreation Area (where this study was conducted). An oil spill occurred during the winter of 1988 or 1989 in the Arthur Kill area. “Numerous” (no number specified) dead terrapins were found there as well as a number of live animals. These were transported to the Staten Island Zoo for treatment but most died. The respondent also sighted several terrapins in 1997 swimming in Old Place Creek near the Goethals Bridge and near Kills Harbor. In addition, he found a dead female on a road in Keansburg, New Jersey, which is located a few miles across the Raritan Bay to Great Kills Harbor.

Discussion

The low total number of animals captured suggests that the population of *Malaclemys terrapin* in the Jamaica Bay area may not be as large as has been believed. Despite continued nesting in the Jamaica Bay Wildlife Refuge, and low rates of nesting on Little Egg Marsh and Canarsie Pol (Ner, personal communication), the low number of juveniles that were trapped (as compared to both male and female adults) raises concerns about rates of recruitment into the population. Even if juvenile males were too small to be caught in the traps, a larger number of young females (which are larger) would still have been expected. More work is needed to see if this trend continues for some time. A trapping study using conventional crab pots (Bishop , 1983) yielded more males than females, and the largest male was only 128 mm. Thus, it is clear that traps using crab pot opening can catch and retain smaller animals.

Two recaptures were obtained; both were females that were caught in traps and recollected on land before or after nesting. Although this cannot be tested statistically because of the low sample size, the fact that two of the animals caught were recaptures relative to the low total number of terrapins, also suggests that the population size may not be as large as has been thought previously. More data is needed on this, since one would also expect recaptures to be more common near the nesting beach, where localized movements appear to be common. In addition, a number of local fishermen have independently confirmed that the number of terrapin heads they have observed has declined significantly over the past several years. Despite the anecdotal nature of this information, it is important that additional work be done in this area to determine the status of the *Malaclemys terrapin* population in Jamaica Bay. As has often been observed in sea turtles and other long-lived animals, a population may appear to be stable (especially if the population size estimate is based on the number of mature, nesting females) until it suddenly crashes due to low recruitment and increasing mortality of the remaining mature females. It is important to ensure that work is done in the Jamaica Bay area that will allow for the development and implementation of a conservation plan before such a dramatic decline in the number of nesting females takes place. Unfortunately, such a decline may have already occurred.

It is apparent that terrapins travel at least some distance; a gravid female found in trap 403, which is at least half a mile away from any of the plausible nesting areas, must have made her way to a nesting area at some later date. In addition, since male and female terrapins often mate near the nesting beach, a significant amount of migration within the Jamaica Bay area must be occurring prior to mating. The mature males that were trapped were distributed rather evenly around the JB area, indicating that they too must have migrated some distance for mating. The 4 juveniles that were trapped were all found near fertile foraging grounds (traps 402, 403, and 407) and at some distance from the nesting and mating areas. The two terrapins (a mature male and a mature female) that were caught in the traps set near Canarsie Pol (traps 408 and 415), which is located several miles away from the most plausible nesting areas, suggests that some animals may indeed migrate a significant distance to these areas. Very little nesting was observed on Canarsie Pol during 2000 and 2001, with only 2 terrapins nesting there during this time period (Ner, personal communication). Even if the female caught in the Canarsie Pol trap was preparing to nest there, the fact that only 2 nestings were observed in two years suggests that it is not a site used for repeated nestings (female terrapins will lay several times over the course of the nesting season).

The statistically significant skewed sex ratio may be a natural phenomenon, or may be due to several other factors. It is possible that the larger relative number of females is due to an increase in average temperature in the area, since diamondback terrapins have temperature dependent sex determination (TSD), with higher temperatures producing females. This could be a great concern if the average temperature maintains an upward trend, which could eventually lead to the production of solely female hatchlings. The importance of environmental factors on the sex ratio of hatchling turtles has been demonstrated by a number of studies (e.g. Janzen, 1994; Vogt and Bull, 1984). In a study of several populations of map turtles (*Graptemys* spp.), Vogt and Bull (1984) found that the distribution of nest sex ratios was bimodal, with nests being mostly either all male or all female. In addition, there was an overall excess of female hatchlings. "Male" nests tended to be found in cooler, more vegetated sites, while "female" nests were found in more sunny, sandy areas. Marsh degradation, which affects vegetation patterns could also have an effect on sex ratio. Janzen (1994) also stressed the importance of vegetation to the production of male hatchlings of the Western painted turtle, *Chrysemys picta bellii*.

In addition, compounds present in the environment, such as estrogen imitators, may prevent the development of male terrapins into mature adults, or lead to the feminization of males (Janzen and Paukstis, 1991). A study on the effects of using estrogenic compounds to produce female hatchlings for conservation purposes suggests that there are many dangers associated with this method (Girondot et al., 1998). Often, treatment with such compounds causes the production of thin gonads ("hypogonads"), and can lead to the arrest of the lengthening of the Mullerian ducts or the opening of the caudal end in the Wolffian ducts. Both of these prevent eggs from passing out of the oviducts (Girondot et al., 1998). Thus, estrogenic compounds present in the water could have significant deleterious effects on the reproductive health of the population. This is an interesting topic for further study.

Terrapin mortality in crab pots does not appear to be a significant concern in our study area. The Gateway National Recreation Area is protected year-round from recreational and commercial harvest; however, not all areas of Jamaica Bay are part of the GNRA. As most of our data was collected within the GNRA, it may be that crab pot mortality is more of an issue in the areas of JB that are outside of the GNRA.

The use of floating buoys on the custom-built traps might have been thought to reduce the rate of terrapin capture at high tide. At low tide and midway through the tide cycle on most days, the traps were set on the substrate, which would make them as effective as traditional crab pots. In addition, the custom built traps were attached to poles, preventing large amounts of vertical movement. This may explain the increased catch rate observed in the custom traps as compared to the conventional crab pots, as these were not attached to poles but simply had buoys attached.

The single dead terrapin that was collected from an abandoned crab pot yields additional evidence that the low catch rate was not due to the trap design, but rather that terrapin population may not be as large as has been thought. The crab pot had obviously been abandoned for quite some time; the rope attached to it was covered in invertebrates and algae, and the terrapin inside was at an advanced stage of decomposition. If the terrapin population consists of several thousand individuals, as has been estimated, a larger number of terrapins would have been expected to have been caught in the crab pot. In addition, the regularly checked crab pots that were monitored during this study for a period of several weeks never had a terrapin inside. Assuming that these crab pots were monitored a maximum of several times a day by the fishermen, I would still have expected a larger number of terrapins to have been trapped with a population size that large.

The general consensus that was obtained from the returned terrapin surveys was that little is known about the distribution of the diamondback terrapin along the Hudson River. Those that did have some knowledge of terrapin distributions observed that they have not seen any *M. terrapin* during recent years.

These results, while preliminary, suggest that there is cause for concern about the *Malaclemys terrapin* population in Jamaica Bay, and along the Hudson River in general. The low catch rates combined with the relatively lower catch rates of juveniles, as well as the skewed sex ratio, raise questions about the long-term stability of this population. The nesting rate of terrapins may remain at a relatively high level for several years; however, this may hide an underlying population structure that consists of aging adults and a small number of juveniles.

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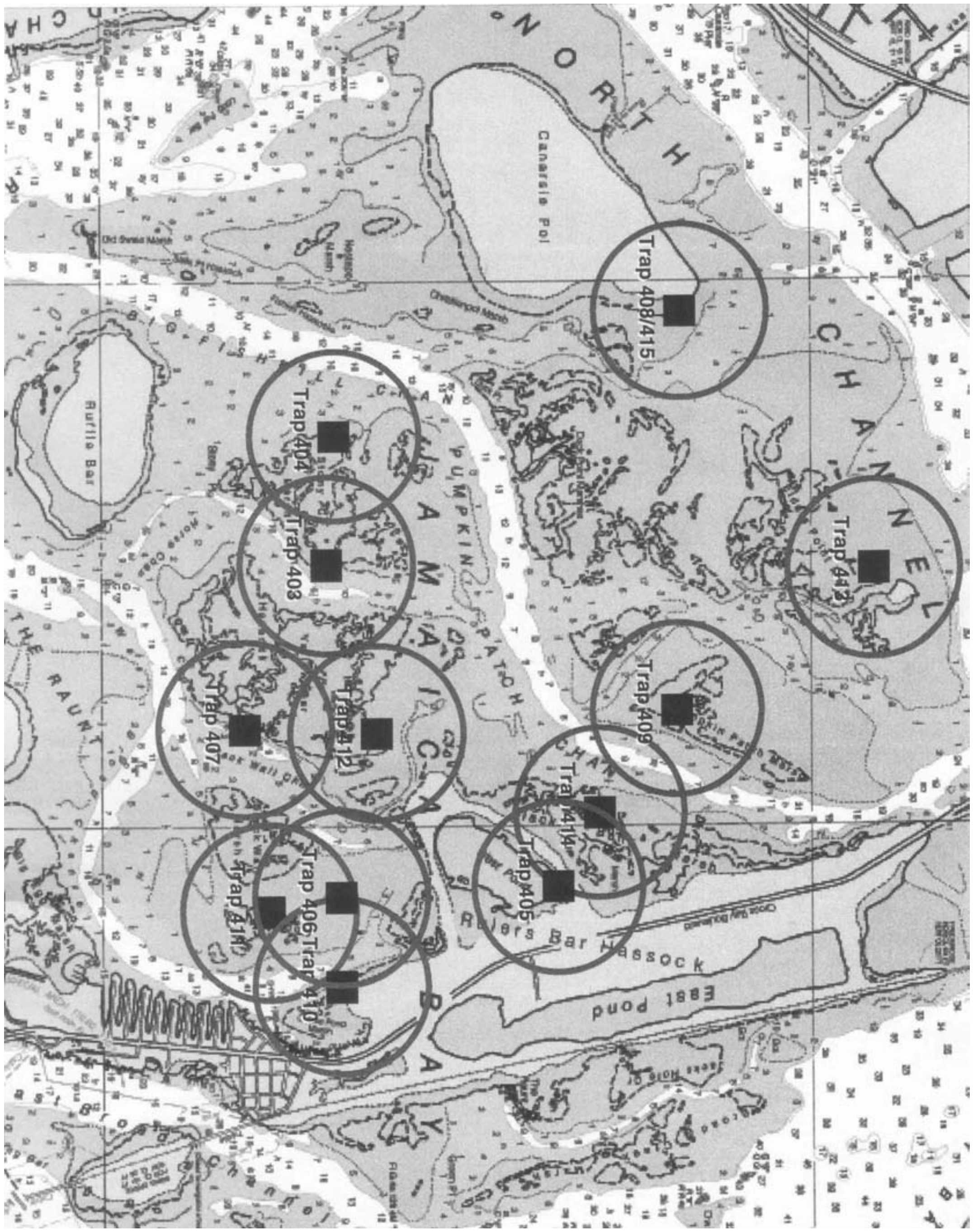

Figure 1: Placement of traps around Jamaica Bay. Trap 402 is not shown since it was at approximately the same location as Trap 404. Traps 408 and 415 were at exactly the same location.

Figure 2: The appearance of custom-built traps at high and low tide.

Figure 3: Juvenile female (JB 011) with lightweight metal tag fitted on carapace.

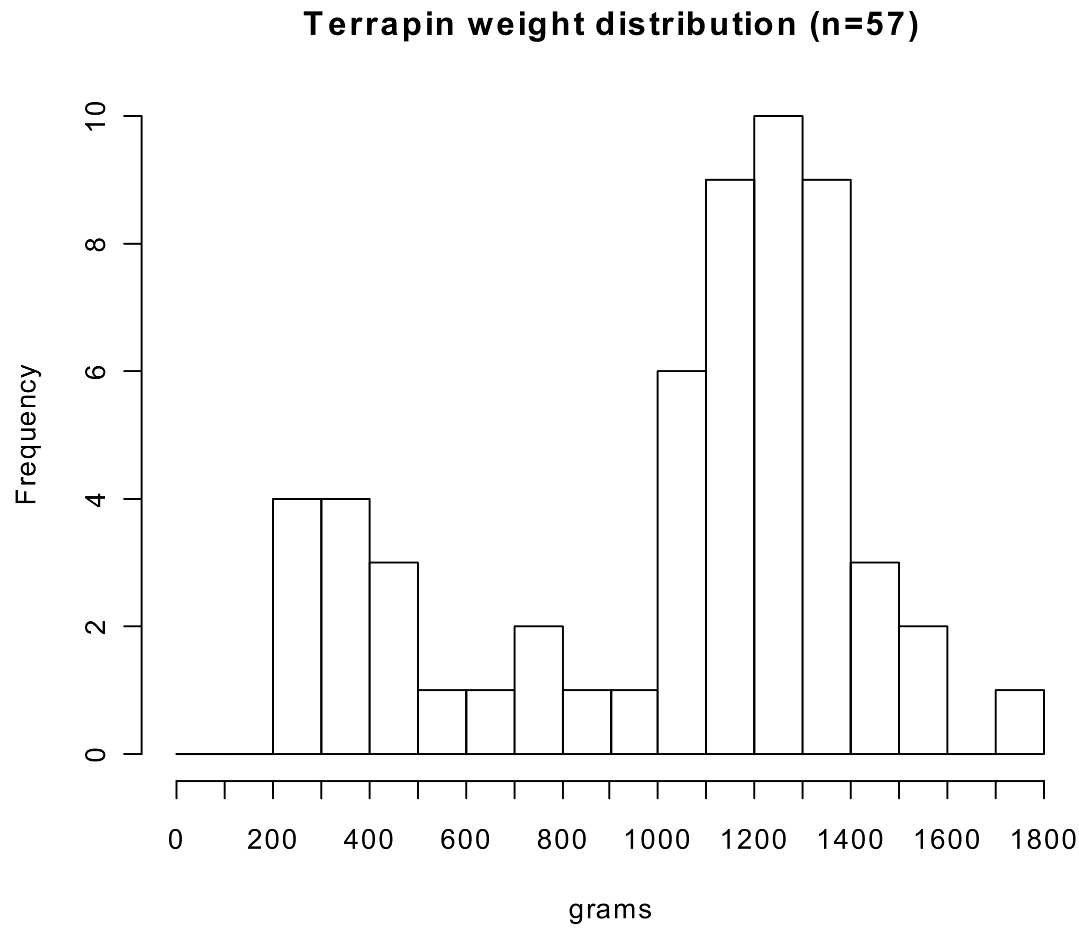

Figure 4: Weight distribution of all *Malaclemys terrapin* collected.

<u>Summary Statistics</u>

Mean
1043 g

Variance
395 g

Min
245 g

Max
1720 g

Median
1180 g

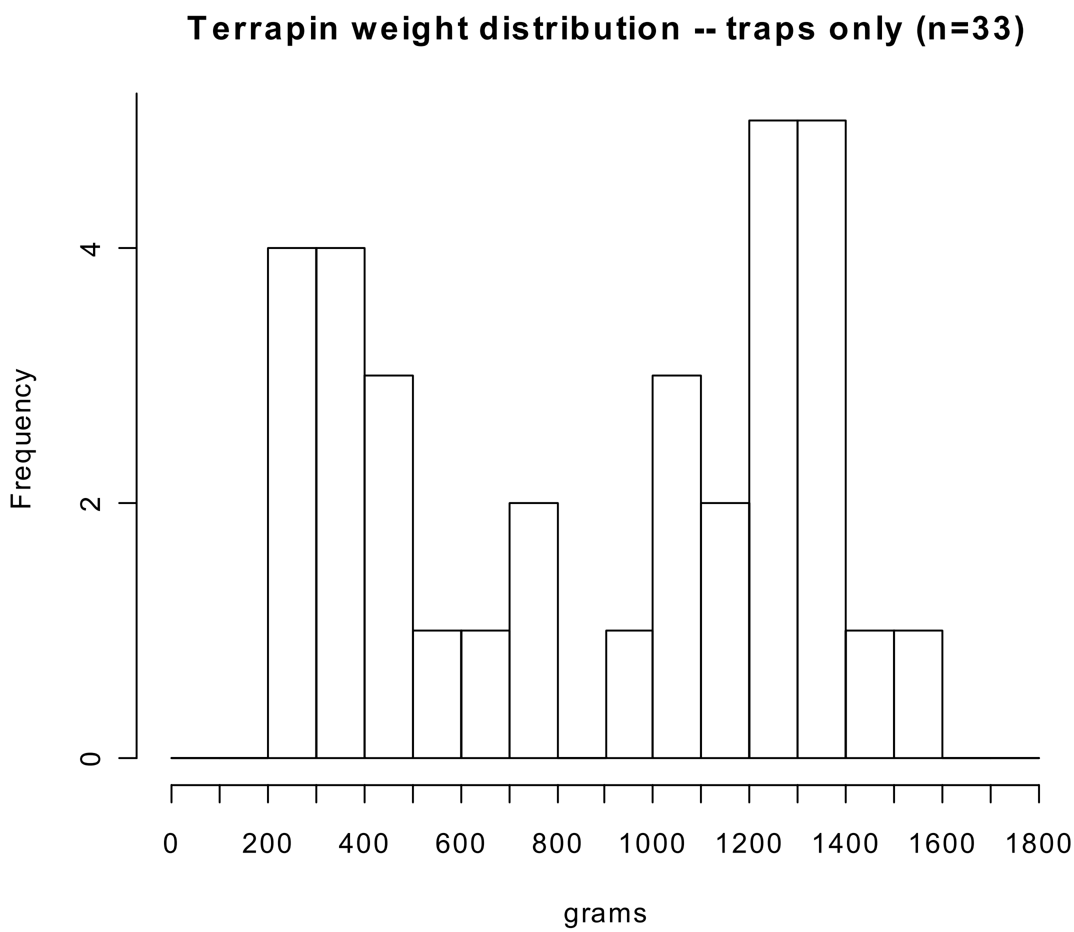

Figure 5: Weight distribution of *Malaclemys terrapin* caught in traps.

<u>Summary Statistics</u>

Mean
891 g

Variance
437 g

Min
245 g

Max
1510 g

Median
1050 g

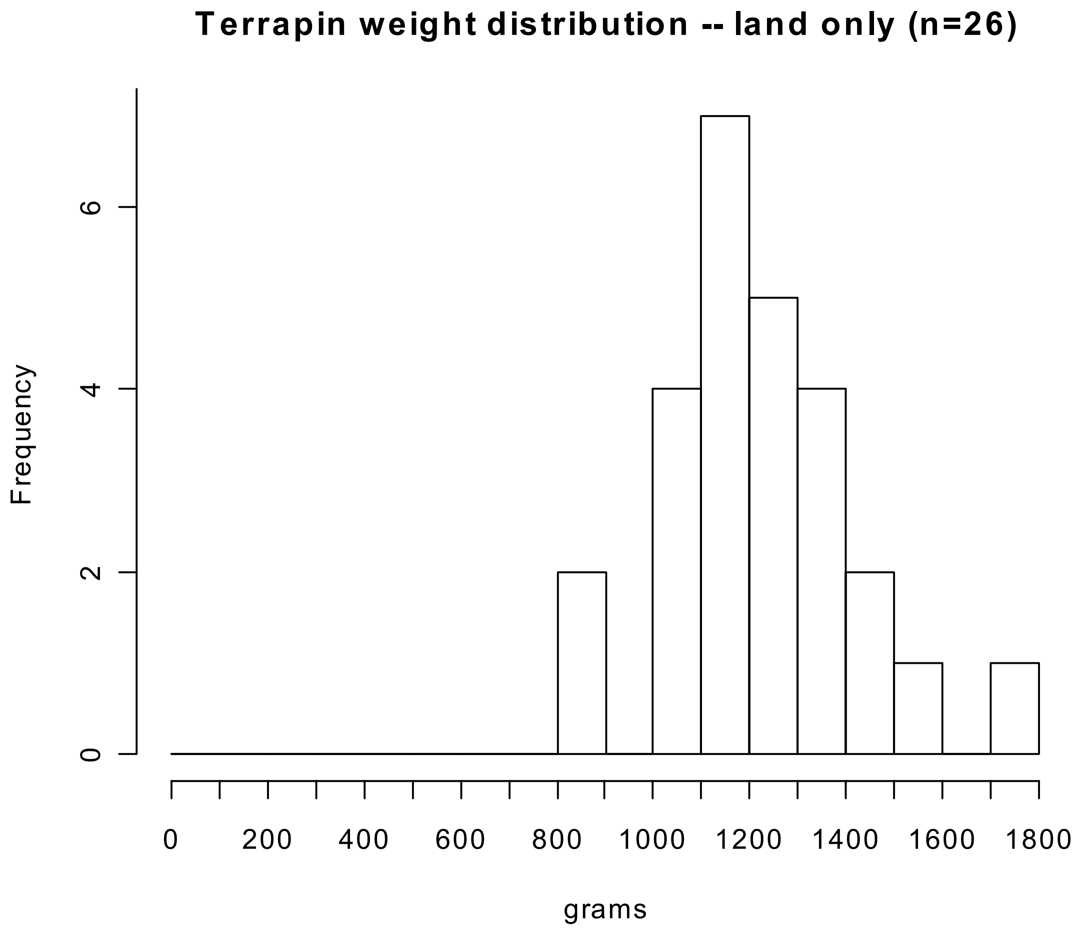

Figure 6: Weight distribution of *Malaclemys terrapin* collected on land (all females).

Summary Statistics

Mean
1228 g

Variance
201 g

Min
850 g

Max
1720 g

Median
1203 g

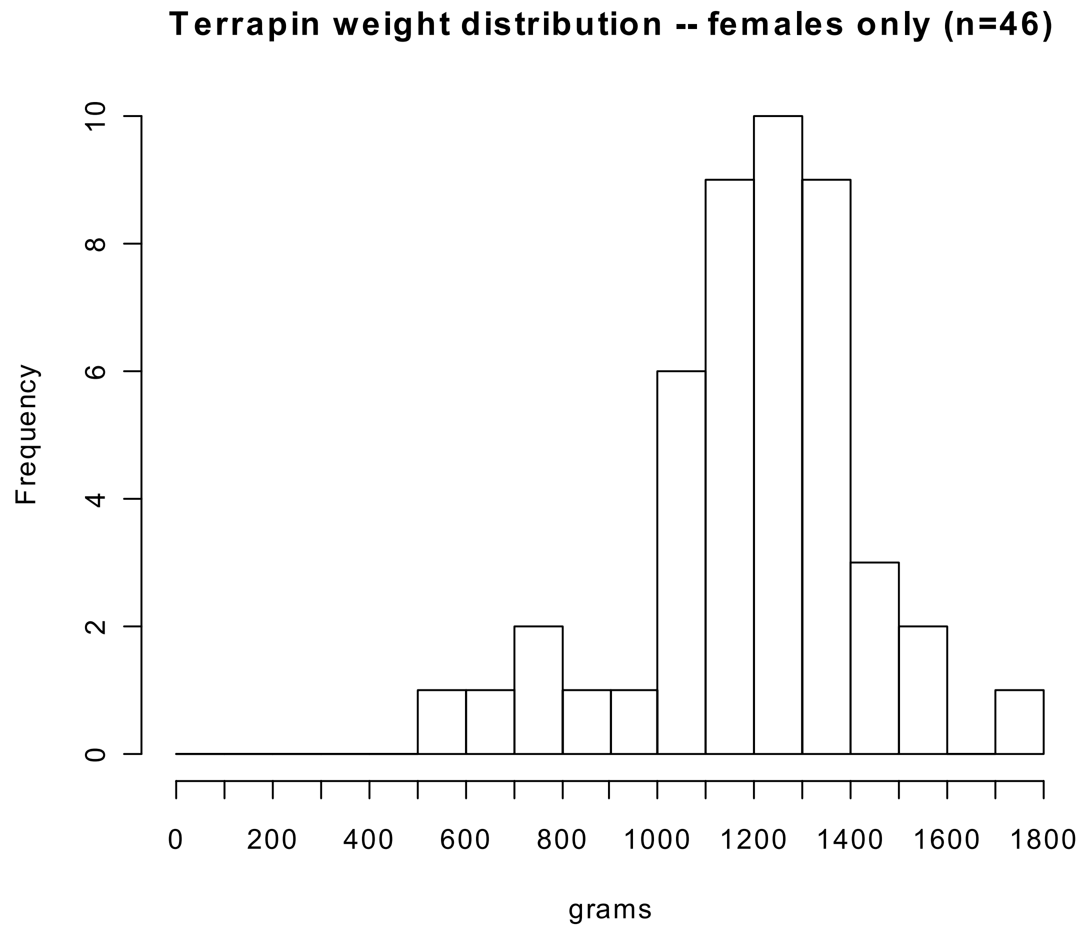

Figure 7: Weight distribution of female *Malaclemys terrapin* caught in traps and collected on land.

<u>Summary Statistics</u>

Mean
1207 g

Variance
225 g

Min
589 g

Max
1720 g

Median
1225 g

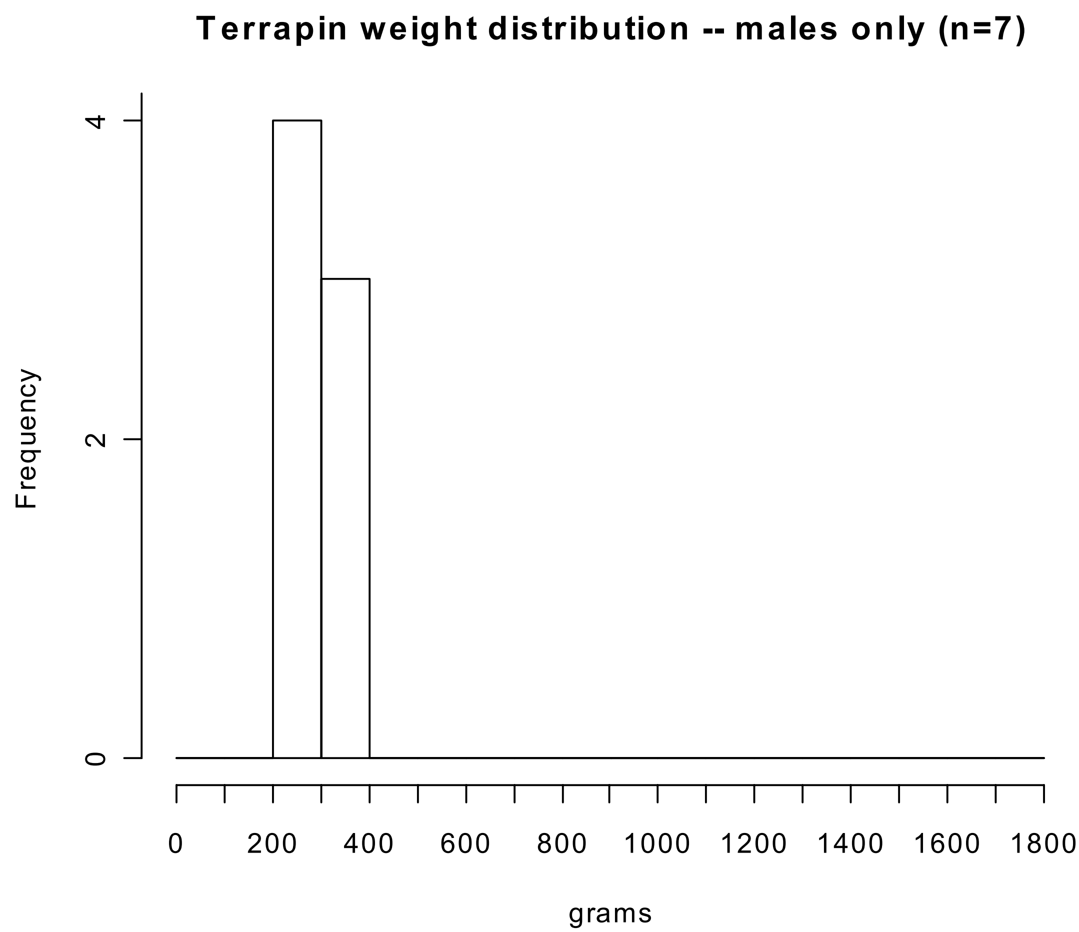

Figure 8: Weight distribution of male *Malaclemys terrapin* caught in traps.

<u>Summary Statistics</u>

Mean
309 g

Variance
48 g

Min
245 g

Max
380 g

Median
290 g

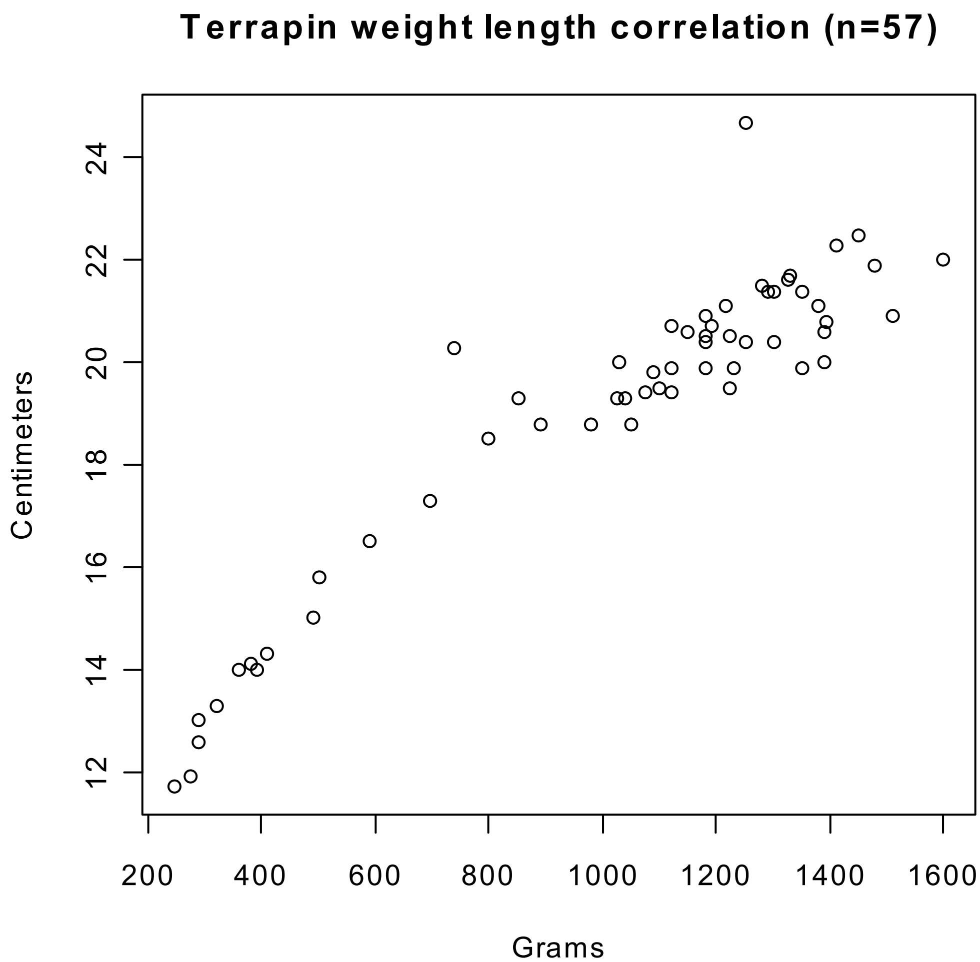

Figure 9: Weight/Length correlation for all the terrapins collected.

<u>Summary Statistics</u>

Multiple R-squared: 0.8815
Adjusted R-squared: 0.8793
F-statistic: 409 on 1 and 55 DF
p-value: < 2.2e-16***

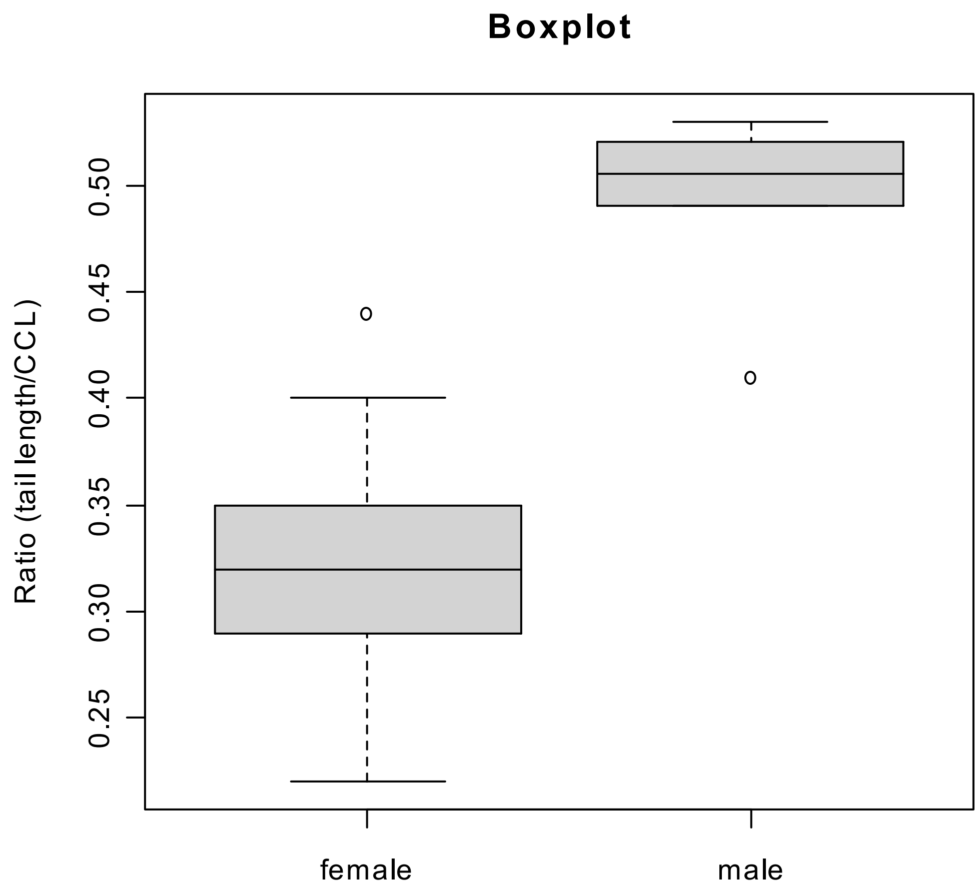

Figure 10: Boxplot showing the differences in the ratio of tail length to curved carapace length (CCL) in female and male *Malaclemys terrapin*.

Summary Statistics

F-statistics: 77.313 (1 DF)

p-value: 1.013e-11***

Means

female	male
0.3208696	0.4933333

Variance

female	male
0.04540319	0.04320494

Trap	Date Set	Time	Location	Area	Removed	Time Removed	Days	Tot	Males	Fem	Juv	Catch Rate
402	5/8/01	17:25	40 36.67 N 73 51.43W	W. Stony Marsh	5/15/01	lost -- 404 placed nearby	6	2	1	0	1	0.333333333
403	5/10/01	14:15	40 36.63 N 73 50.95 W	E. Stony Marsh	9/3/01	12:50	115	9	2	5	2	0.07826087
404	5/18/01	10:33	40 36.65N 73 51.42 W	W. Stony Marsh	9/3/01	12:00	108	0	0	0	0	0
405	5/23/01	14:35	40 37.28 N 73 49.77W	West Pond	9/3/01	N/r	103	4	0	4	0	0.038834951
406	5/23/01	14:57	40 36.67N 73 49.73W	Rulers Bar (nest b.)	9/3/01	N/r	103	4	0	4	0	0.038834951
407	5/24/01	15:47	40 36.4N 73 50.35W	E. Yellow Bar Hassock	8/20/01	9:45	87	4	2	1	1	0.045977011
408	5/27/01	14:07	40 37.63 N 73 51.88W	N. Canarsie Pol	7/26/01	lost-replaced by 415	59	2	1	1	0	0.033898305
409	6/15/01	12:14	40 37.62 N 73 50.42 W	S. Pumpkin Patch Marsh	9/3/01	10:10	77	6	1	5	0	0.077922078
410 (crab pot)	6/14/01	14:19	40 36.67 N 73 49.41W	Goose Pond Marsh	8/22/01	12:12	67	1	1	0	0	0.014925373
411 (crab pot)	6/14/01	14:45	40 36.47 N 73 49.68 W	Rulers Bar	8/22/01	12:15	67	0	0	0	0	0
412 (crab pot)	6/15/01	14:34	40 36.77 N 73 50.34 W	N. Yellow Bar Hassock	8/22/01	12:00	66	0	0	0	0	0
413	6/25/01	11:48	40 38.18 N 73 50.93W	N. Elders Point Marsh	9/3/01	11:50	87	0	0	0	0	0
414 (crab pot)	6/26/01	13:11	40 37.40 N 73 50.04 W	Black Bank Marsh	8/29/01	16:52	81	1	0	1	0	0.012345679
415	7/31/01	16:20	40 37.63 N 73 51.88W	N. Canarsie Pol	8/29/01	17:15	28	0	0	0	0	0
408+415							87	2	1	1	0	0.022988506
402+404							114	2	1	0	1	0.01754386

Table 1: Trap placement information. The capture data for traps 408 and 415, and for 402 and 404 were combined since these traps were located in the same positions.

Date	Number	Trap	Sex	Capture Time	Weight (g)	CCL (cm)	PL (cm)
11-May	JB 001	402	juv (female?)	16:05	390	14.0	11.0
14-May	JB 002	402	adult female	14:00	740	20.3	16.8
23-May	JB 003	403	adult female	12:50	980	18.8	16.1
24-May	none						
24-May	JB 004	403	adult male	16:39	245	11.7	8.8
24-May	JB 005	403	adult female	16:39	1300	20.4	16.5
25-May	JB 006	407	adult male	15:28	275	11.9	8.8
27-May	JB 007	406	adult female	15:50	1250	24.7	17.4
30-May	JB 008	406	adult female	12:21	1390	20.0	16.4
30-May	JB 009	405	adult female	12:50	1350	19.9	17.9
5-Jun	JB 010	405	adult female	18:13	1075	19.4	16.7
8-Jun	dead	crab pot	prob male	16:43			
12-Jun	JB 011	407	adult male	11:49	290	13.0	10.3
13-Jun	JB 012	403	juv (female?)	12:49	410	14.3	11.4
13-Jun	JB 013	406	adult female	13:46	1225	19.5	16.6
13-Jun	JB 014	refuge	adult female	15:53	1720	22.4	18.7
13-Jun	JB 015	refuge	adult female	16:04	1325	21.6	18.1
14-Jun	JB 016	refuge	adult female	17:06	1250	20.4	16.8
15-Jun	JB 017	403	adult female	13:15	695	17.3	14.6
15-Jun	JB 018	refuge	adult female	16:00	1350	21.4	18.1
18-Jun	JB 019	409	adult female	14:25	1050	18.8	16.3
18-Jun	JB 020	Little Egg	adult female	13:13	1150	20.6	17.8
20-Jun	JB 021	406	adult female	9:49	800	18.5	15.3
20-Jun	JB 022	403	adult female	11:05	1180	20.4	17.4
20-Jun	JB 023	405	adult female	12:55	1230	19.9	17.5
20-Jun	JB 024	refuge	adult female	13:10	1225	20.5	17.5
20-Jun	JB 025	refuge	adult female	13:11	1025	19.3	17.2
20-Jun	JB 026	refuge	adult female	13:26	1180	20.5	17.4
25-Jun	JB 027	refuge	adult female	14:25	1090	19.8	16.6
25-Jun	JB 028	405	adult female	14:29	1510	20.9	19.1
25-Jun	JB 029	Little Egg	adult female		1450	22.5	18.2
26-Jun	JB 030	refuge	adult female	15:50	1120	19.9	17.4
28-Jun	JB 031	refuge	adult female	15:45	1390	20.6	18.3
28-Jun	JB 032	refuge	adult female	16:00	1120	19.4	16.2
29-Jun	JB 033	414	adult female	14:22	589	16.5	13.0
30-Jun	JB 034	Little Egg	adult female		1215	21.1	18.7
30-Jun	JB 035	refuge	adult female	17:53	1040	19.3	17.4
30-Jun	JB 036	Little Egg	adult female		1190	20.7	17.7
2-Jul	JB 037	refuge	adult female	10:23	1300	21.4	18.0
5-Jul	JB 038	Little Egg	adult female		850	19.3	16.5

Table 2: Summary of all the terrapin data collected (continued on next page).

Date	Number	Trap	Sex	Capture Time	Weight (g)	CCL (cm)	PL (cm)
5-Jul	JB 039	Little Egg	adult female		890	18.8	15.9
5-Jul	JB 040	Little Egg	adult female			21.0	17.4
5-Jul	JB 041	409	adult male	9:55	360	14.0	10.9
5-Jul	JB 042	407	juv (female?)	11:01	490	15.0	12.3
5-Jul	JB 043	refuge	adult female	13:15	1600	22.0	19.2
5-Jul	JB 044	refuge	adult female	13:15	1030	20.0	16.5
7-Jul	JB 045	403	juv (female?)	11:52	500	15.8	12.7
7-Jul	JB 046	403	adult male	11:52	380	14.1	10.9
9-Jul	JB 026 (recapture)	refuge	adult female	14:43			
12-Jul	JB 047	408	adult male	13:36	320	13.3	10.7
12-Jul	JB 048	408	adult female	13:36	1330	21.7	18.2
12-Jul	JB 049	409	adult female	13:57	1180	19.9	17.3
16-Jul	JB 050	refuge	adult female	15:15	1360	21.0	18.3
18-Jul	JB 051	409	adult female	9:16	1380	21.1	18.5
18-Jul	JB 052	refuge	adult female	12:06	1120	20.7	17.7
18-Jul	JB 053	refuge	adult female	12:34	1180	20.9	17.8
18-Jul	JB 054	refuge	adult female	12:38	1280	21.5	17.7
18-Jul	JB 055	refuge	adult female	12:41	1480	21.9	18.9
21-Jul	JB 027 (recapture)	refuge	adult female				
23-Jul	JB 056	407	adult female		1100	19.5	16.4
28-Jul	JB 057	403	adult female	16:02	1410	22.3	18.0
1-Aug	JB 058	411	adult male	18:40	290	12.6	9.9
22-Aug	JB 059	409	adult female	11:45	1290	21.4	18.9
22-Aug	JB 060	409	adult female	11:45	1395	20.8	17.5

Table 2: Summary of all the terrapin data collected (continued on next page).

Date	Number	PV (cm)	VT (cm)	Gravid	Tag no.	PIT no.
11-May	JB 001	1.4	n/r		415	
14-May	JB 002	2.4	3.5		416	
23-May	JB 003	3.0	3.0		417	
24-May	none					
24-May	JB 004	3.8	3.1	n/a	418	
24-May	JB 005	2.8	3.0		419	
25-May	JB 006	3.5	3.0	n/a	420	
27-May	JB 007	3.2	2.8		421	047-045-578
30-May	JB 008	2.0	3.7	no	422	047-032-792
30-May	JB 009	2.7	3.5	no	423	
5-Jun	JB 010	2.8	4.1		424	047-118-369
8-Jun	dead					
12-Jun	JB 011	1.6	2.9	n/a	425	047-116-780
13-Jun	JB 012	2.4	3.1		426	046-872-809
13-Jun	JB 013	3.5	4.6	no	427	047-309-046
13-Jun	JB 014	2.7	4.3	yes	428	047-281-549
13-Jun	JB 015	2.3	3.1	no	429	047-264-276
14-Jun	JB 016	2.3	4.3	yes	430	047-323-104
15-Jun	JB 017	2.2	4.2	no	431	047-120-079
15-Jun	JB 018	2.4	3.9	yes	432	047-364-595
18-Jun	JB 019	3.4	3.5	yes	433	047-363-355
18-Jun	JB 020	2.5	4.2	no	434	047-031-883
20-Jun	JB 021	2.1	3.6	no	435	047-291-543
20-Jun	JB 022	2.8	3.7	yes	436	047-376-781
20-Jun	JB 023	3.3	3.9	yes	437	047-344-554
20-Jun	JB 024	2.3	4.2	no	438	047-525-297
20-Jun	JB 025	3.1	3.9	no	439	047-123-099
20-Jun	JB 026	2.0	4.2	no	440	047-360-316
25-Jun	JB 027	2.4	4.3	no	441	047-033-884
25-Jun	JB 028	2.0	4.5	yes	442	047-114-281
25-Jun	JB 029	3.1	3.8		443	047-328-329
26-Jun	JB 030	2.4	3.9	yes	444	047-308-605
28-Jun	JB 031	2.8	3.9	yes	445	047-354-866
28-Jun	JB 032	2.6	3.6	yes	446	047-114-294
29-Jun	JB 033	2.0	2.9	no	447	047-093-009
30-Jun	JB 034	2.9	3.4		448	046-813-821
30-Jun	JB 035	3.4	3.8	yes	449	047-121-862
30-Jun	JB 036	2.5	4.4		450	047-333-595
2-Jul	JB 037	3.2	4.2	no	451	047-279-611
5-Jul	JB 038	2.6	4.0		452	047-333-827

Table 2: Summary of all the terrapin data collected (continued on next page).

Date	Number	PV (cm)	VT (cm)	Gravid	Tag no.	PIT no.
5-Jul	JB 039	3.0	3.5		453	047-339-124
5-Jul	JB 040	4.2	4.4		454	047-275-568
5-Jul	JB 041	4.4	3.6	n/a	455	047-261-808
5-Jul	JB 042	2.2	3.5	n/a	456	047-377-022
5-Jul	JB 043	2.6	4.0	yes	457	047-518-034
5-Jul	JB 044	2.4	4.2	no	458	047-347-620
7-Jul	JB 045	2.0	3.0	n/a	459	047-095-059
7-Jul	JB 046	4.2	3.4	n/a	460	047-115-317
9-Jul	JB 026 (rec)			yes		
12-Jul	JB 047	3.9	3.2	n/a	461	047-115-329
12-Jul	JB 048	3.2	3.7	no	462	047-381-366
12-Jul	JB 049	2.5	4.4	no	463	047-323-124
16-Jul	JB 050	2.8	3.7	yes	464	047-376-599
18-Jul	JB 051	3.5	4.6	no	465	047-304-060
18-Jul	JB 052	2.8	4.2	no	466	047-115-610
18-Jul	JB 053	2.3	3.9	no	467	047-072-863
18-Jul	JB 054	2.9	4.1	yes	468	047-380-071
18-Jul	JB 055	3.2	4.5	yes	469	047-262-299
21-Jul	JB 027 (rec)					
23-Jul	JB 056	3.0	3.6	no	470	
28-Jul	JB 057	3.7	4.1	no	471	047-031-360
1-Aug	JB 058	2.6	2.7	n/a	472	047-348-096
22-Aug	JB 059	2.5	4.4	no	473	047-323-876
22-Aug	JB 060	2.9	4.0	no	474	047-115-830

Table 2: Summary of all the terrapin data collected (continued on next page).

Date	Number	Released	Time	Location
11-May	JB 001	23-May	12:39	40 36 40 N 73 51 25 W
14-May	JB 002	25-May	15:42	40 36 38 N 73 51 27 W
23-May	JB 003	25-May	16:11	40 36 27 N 73 51 14 W
24-May	none		16:13	40 36 20 N 73 50 24 W
24-May	JB 004	28-May	11:05	40 36 44 N 73 50 55 W
24-May	JB 005	28-May	11:05	40 36 44 N 73 50 55 W
25-May	JB 006	1-Jun	14:47	40 36 21 N 73 50 23 W
27-May	JB 007	5-Jun	14:26	40 36 40 N 73 49 54 W
30-May	JB 008	4-Jun	12:28	40 36 53 N 73 49 48 N
30-May	JB 009	1-Jun	12:47	40 37 16 N 73 49 48 W
5-Jun	JB 010	6-Jun	9:30	40 37 18 N 73 49 48 W
8-Jun	dead			
12-Jun	JB 011	14-Jun	14:55	at trap 407
13-Jun	JB 012			
13-Jun	JB 013	14-Jun	14:04	40 36.835 N 73 49.739 W
13-Jun	JB 014	14-Jun	14:04	40 36.835 N 73 49.739 W
13-Jun	JB 015	14-Jun	14:04	40 36.835 N 73 49.739 W
14-Jun	JB 016	15-Jun	14:34	40 36.972 N 73 50.302 W
15-Jun	JB 017	18-Jun	16:01	40 36.504 N 73 50.954 W
15-Jun	JB 018	18-Jun	16:45`	at trap 406
18-Jun	JB 019	20-Jun	10:15	40 37.567 N 73 50.374W
18-Jun	JB 020	19-Jun	16:14	40 35.724 N 73 50.559 W
20-Jun	JB 021	24-Jun	11:40	at trap 406
20-Jun	JB 022	24-Jun	12:15	at trap 403
20-Jun	JB 023	24-Jun	14:39	40 37.308 N 73 49.791 W
20-Jun	JB 024	24-Jun	11:45	at trap 406
20-Jun	JB 025	24-Jun	11:46	at trap 406
20-Jun	JB 026	24-Jun	11:47	at trap 406
25-Jun	JB 027	26-Jun	13:32	40 36.811 N 73 49.723 W
25-Jun	JB 028	26-Jun	15:40	40 37.309 N 73 49.789W
25-Jun	JB 029	26-Jun	14:09	40 36.020 N 73 50.519 W
26-Jun	JB 030	27-Jun	14:10	at trap 406
28-Jun	JB 031	29-Jun	14:41	at trap 406
28-Jun	JB 032	29-Jun	14:43	at trap 406
29-Jun	JB 033			
30-Jun	JB 034	30-Jun	14:40	
30-Jun	JB 035	2-Jul	11:07	40 36.895 N 73 49.883 W

Table 2: Summary of all the terrapin data collected (continued on next page).

Date	Number	Release date	Time	Location
30-Jun	JB 036	5-Jul		40 36.275 N 73 51.494 W
2-Jul	JB 037	5-Jul	10:42	40 36.834 N 73 49.745 W
5-Jul	JB 038			
5-Jul	JB 039			
5-Jul	JB 040			
5-Jul	JB 041	12-Jul	14:05	at trap 409
5-Jul	JB 042	12-Jul	15:08	at trap 407
5-Jul	JB 043	12-Jul	14:27	at trap 406
5-Jul	JB 044			
7-Jul	JB 045	14-Jul	15:57	at trap 403
7-Jul	JB 046	12-Jul	15:21	at trap 403
9-Jul	JB 026 (recapture)	14-Jul	11:35	40 36.914 N 73 49.815 W
12-Jul	JB 047	14-Jul	16:25	at trap 408
12-Jul	JB 048	14-Jul	16:25	at trap 408
12-Jul	JB 049	14-Jul	16:46	at trap 409
16-Jul	JB 050	18-Jul	9:39	at trap 406
18-Jul	JB 051	20-Jul	10:16	at trap 409
18-Jul	JB 052	20-Jul	10:35	at trap 406
18-Jul	JB 053	20-Jul	10:35	at trap 406
18-Jul	JB 054	20-Jul	10:35	at trap 406
18-Jul	JB 055	21-Jul	10:39	at trap 406
21-Jul	JB 027 (recapture)	26-Jul	12:35	40 36 920 N 73 49.893 W
23-Jul	JB 056	26-Jul	12:35	40 36 920 N 73 49.893 W
28-Jul	JB 057	31-Jul	16:46	at trap 407
1-Aug	JB 058	2-Aug	18:56	at trap 411
22-Aug	JB 059	3-Sep	11:53	40 37.557 N 73 50.366 W
22-Aug	JB 060	3-Sep	11:53	40 37.557 N 73 50.366 W

Table 2: Summary of all the terrapin data collected