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An Ecological Study of a Natural Population of Diamondback Terrapins (*Malaclemys t. terrapin*) in a Delaware Salt Marsh

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ABSTRACT: A two-year study of a population of the northern diamondback terrapin (*Malaclemys t. terrapin*) was undertaken in a salt marsh in Delaware. Population size estimates based on mark-release-recapture data indicate an early season mean population size of 1655 individuals during June of 1975, declining to a mean of 378 by August. Captures per unit effort declined during this same period, supporting this trend. The decline is a result of later season dispersal. Data from 1976 indicate that this pattern may have been repeated, and that the population had experienced no significant new recruitment between years. Size class frequency data reveal a lack of juveniles in the sampled population, which could not readily be attributed to sampling techniques. The estimated size of the terrapin population from this study indicates that terrapins may be important, though frequently overlooked, components of the marsh food web.

Introduction

The northern diamondback terrapin (*Malaclemys t. terrapin*) is euryhaline and occurs in brackish water habitats throughout much of the northeastern United States (Carr 1952). Studies on this and other subspecies have dealt principally with captives and have been concerned chiefly with growth rates, longevity and reproductive output (Barney 1922; Hildebrand 1932; Allen and Littleford 1955; Burns and Williams 1972).

Some information is available for wild populations of other subspecies. This includes primarily sizes of individuals (Cagle 1952; Schwartz 1955) and feeding (Babcock 1919). The nesting behavior of adults, as well as behavior of hatchlings and other features of the reproductive biology of *M. t. terrapin* have been documented (Burger and Montevecchi 1975; Montevecchi and Burger 1975; Burger 1976).

There is a paucity of information concerning population dynamics and ecological relationships of diamondback terrapins in nature. We present the results of a two-year study of a population of *M. t. terrapin* in Delaware, designed to shed light on some seasonal population phenomena related to its ecology.

Study Area

The study site consisted of the lower 0.9 km of Canary Creek in Lewes, Sussex County, Delaware, near the University of Delaware's marine field station (Fig. 1). Canary Creek is a 6 km long tidal creek which drains approximately 200 ha of ditched *Spartina alterniflora* marsh.

The lower portion of the creek ranges in width from approximately 17–25 m at high tide to between 8 and 12 m on spring low tides. Channel depth at low water is 1.3–1.7 m, with occasional holes to 3 m. Maximum recorded current velocities are 1.45 m/sec (2.8 knots) on the flood tide, and 1.21 m/sec (2.37 knots) on the ebb tide, although typical

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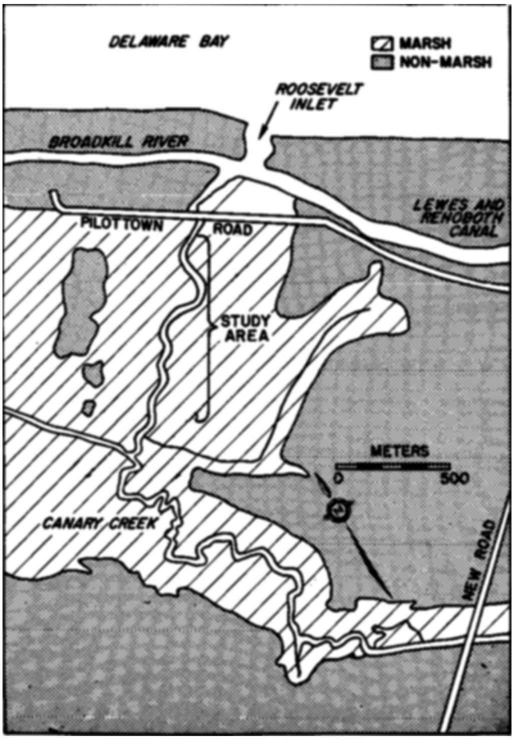

Fig. 1. Study site in Canary Creek Marsh, Lewes, Delaware (see text for description).

peak current velocities are 50–60% of these values. The normal tidal prism is approximately 200,000 m^3, with a range of 100,000–400,000 m^3 during the summer. Salinity may vary between 10 and 30‰ over a tidal cycle throughout the year.

Methods

Sampling was carried out at intervals during the summer months of 1975 and 1976. Turtles were taken at low slack water ± 2 hr along 0.9 km of the lower creek (Fig. 1) by trawling repeatedly along the entire length (usually four times) until increasing flood currents became prohibitive. The 6 m otter trawl used has dimensions of 3 m × 1 m at the mouth, with 5.0 cm mesh at the collecting bag. Trawl speed was approximately 2.4 kph, but was adjusted to keep the trawl on or near the bottom at all times.

Studies done on other species of turtles in habitats other than salt marshes (e.g., Ream and Ream 1966) have indicated that any single sampling method is likely to bias estimates of population size and sex ratio in nature. Our choice of sampling technique is based on considerations of the observed characteristics of our particular study site. The trawl method made it possible to capture relatively large numbers of individuals in a single day. This was necessary to our population size estimates based on the Lincoln Index (see below). Seining, baited traps and Fyke nets yielded low sample sizes in our marsh system, and were not reliable techniques due to the current velocities and hydrography of the marsh. Further, none of these alternative techniques resulted in capturing larger or smaller individuals than those obtained in trawl samples.

Sampling further upstream was prohibited by abrupt narrowing and meandering of the creek channel; however, from previous observation the lower portion of the creek appeared to contain the majority of terrapins in the marsh. Attempts at sampling during high tides yielded poor capture results, perhaps because increased volume of water allowed many terrapins to evade the net.

Captured terrapins were marked with numbered plastic pennant tags by drilling a hole through one of the postcentral marginal scutes at the rear of the carapace, and fixing the tag with brass wire. Terrapins were sexed and the mid-carapace length measured. They were then released in the creek to allow them to disperse.

Population size was estimated using the Lincoln Index (Southwood 1966) for mark-release-recapture information: $N = MC/R$, where the population size estimate (N) is dependent upon the number of marked individuals in the population from the previous sample (M), the total number of individuals captured in the sample (C), and the number of recaptured (marked) individuals (R). This index is insensitive to changes in absolute sample size, providing samples are at random from the population. However, there are some built-in assumptions of this model: the marking technique must not grossly affect the behavior of the animal, released animals mingle (at random) with the population, and that there is no differential loss from the population of marked animals. We will deal with these assumptions later. This method has been used for other turtle species (e.g., Ernst 1976).

Results

A total of 547 individuals was marked and released in 1975; 245 additional ones were marked and released in 1976. In addition to the smaller sample size in 1976, the reduction in numbers of individuals between the two years was disproportionate between the two sexes (30% fewer males and 57% fewer females).

There was no difference in size distribution of male individuals between the two years (Fig. 2). However, there was a disproportionate decrease from 1975 to 1976 in females with mid-carapace lengths of <155 mm (Fig. 3), and a chi-square contingency test for size classes of <120 mm, 125–155 mm, and >155

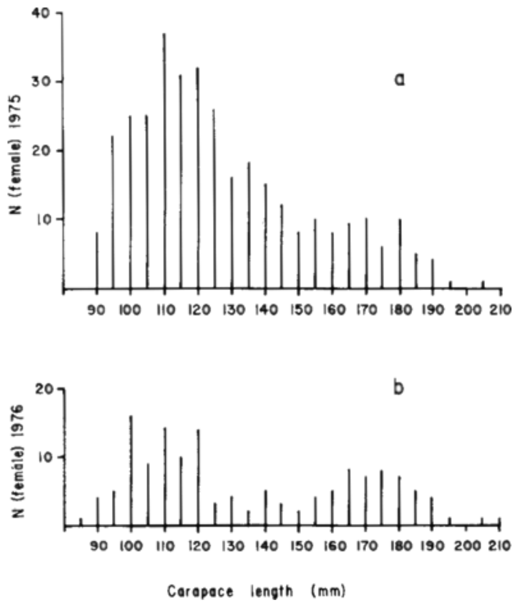

Fig. 3. Length-frequency graph for females, including all individuals captured in each year. Mid-carapace length was used, rounded to the nearest 5 mm. Total number of individuals captured in 1975 was 336, and in 1976 was 144.

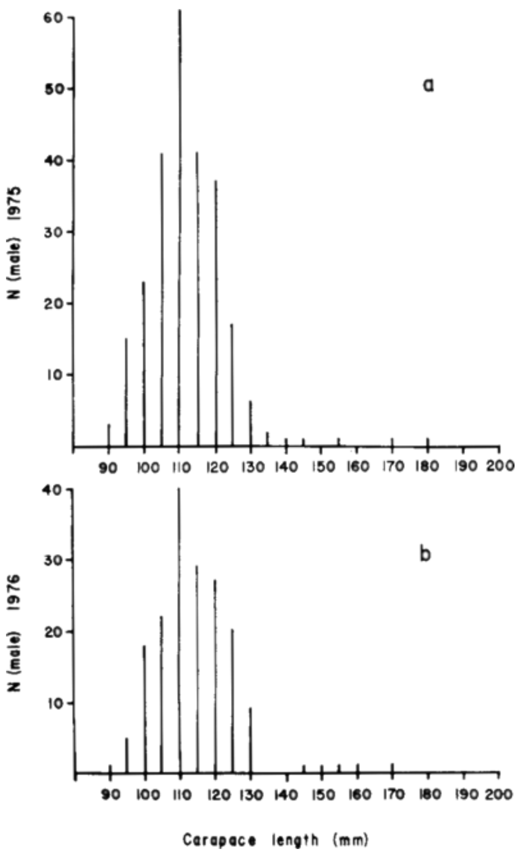

Fig. 2. Length-frequency graph for males, including all individuals captured in each year. Mid-carapace length was used, rounded to the nearest 5 mm. Total number of individuals captured in 1975 was 251, and in 1976 was 176.

mm was highly significant ($P < 0.005$). There was no significant difference in size class frequency between early and late season terrapins during either year.

Captures per unit effort in 1975 showed an appreciable decline over the season (early season mean = 77, late season mean = 27; $t_{10} = 8.50$, $P < 0.001$), indicating a reduction in population size. Although there was no significant differential loss between sizes of terrapins, the ratio of males to females increased from an early season mean of 0.58 to a late season mean of 1.43 ($t_{11} = 2.56$, $P < 0.05$). It therefore appears that the population decline was in part due to a disproportionate loss of females of all sizes later in the season.

Mark-recapture estimates from successive sampling dates also indicate a difference in population size between early and late season 1975 (Table 1). Even when all estimates made on the basis of $R < 2$ are ignored, the early season mean $N = 1655$, and the late season mean $N = 378$, which are significantly different ($t_4 = 9.81$, $P < 0.001$). When estimates are made from individuals marked on a given date during the early part of the season, and then recaptured at any other time during that

TABLE 1. Mark-recapture data for 1975.

Date	C_{i+1}	M_i	Total M	R_{i+1}	Total R	N_i
6–11	95	67	67	4	4	1591
6–17	73	91	158	4	8	1661
6–24	79	65	223	3	6	1712
7–2	73	73	296	1	7	5329
7–16	15	66	362	1	2	990
7–23	74	13	375	0	9	—
7–31	24	65	440	3	7	520
8–4	15	17	457	2	4	128
8–11	41	11	468	1	14	451
8–12	36	27	495	2	10	486
8–13	29	26	521	1	13	754
8–14	15	17	538	0	6	—
8–15	—	9	547	—	—	—

[a] C_{i+1} = total number of individuals captured on next following sample date; M_i = number of individuals marked on given sample date; R_{i+1} = number of individuals recaptured on next following sample date from those marked on date given; Total M = cumulative number of marked individuals as of date given; Total R = number of individuals recaptured on next following sample date from all previous sample dates; population estimate $N_i = (M_iC_{i+1})/R_{i+1}$.

part of the season, the estimates made from successive sampling dates are supported. The same is true for estimates made from late season marks and all subsequent recaptures.

Mark-recapture estimates could not be made from successive sampling dates in 1976 because of the almost total lack of successive day recaptures. This was because of the small sample sizes due to frequent equipment failure and inclement weather, especially during July. However, captures per unit effort were significantly lower during August (mean = 15) than June (mean = 48) ($t_8 = 3.79$, $P < 0.01$). No samples could be taken in July. It is therefore possible that the population was declining seasonally as in 1975.

Discussion

The results indicate that Canary Creek contains a large population of *M. t. terrapin.* Based on the early season estimates for 1975, approximately 1.8 individuals were found per linear meter of creek. Although the feeding habits for terrapins in this creek are not fully known, many captured individuals excreted shell fragments of the blue mussel (*Mytilus edulis*), a species common on the creek banks. The natural diet of *M. t. terrapin* consists largely of crustaceans and mollusks (Carr 1952; Babcock 1919; Spagnoli and Marganoff 1975), many species of which are abundant in Canary Creek. It is therefore likely that the terrapin is an important component of the food web in this marsh, though its economic importance has declined in recent years (Ernst and Barbour 1972).

The validity of our use of the Lincoln Index during 1975 depends upon meeting some assumptions inherent in this model, as mentioned earlier. One of these is that marking does not significantly affect behavior of the released marked individual. The position and small size of the plastic tag make it unlikely that the tag was noticed, or interfered with a released individual's movements. Further, no weight loss was recorded for any recaptured individual, even several recaptured three or four times, indicating that the marking procedure had no measurable adverse effect on feeding. Finally, the trawling procedure used made it unlikely that previously captured animals could either avoid or be attracted to the sample net more than naive animals.

Another assumption of the Lincoln model is that marked and released individuals mingle at random with the population, so that the probability of a marked animal being recaptured is equal to that of any other individual in the population. Whether or not released terrapins mingled at random before the next sampling period is unknown. However, we trawled the entire 0.9 km at each sampling. Therefore, even if marked individuals were not randomly distributed along the creek, they would still be susceptible to capture in proportion to their numbers.

The percentage of recaptured marked individuals in successive samples during the season will increase if marked animals are accumulated. This is to be expected if marked animals do not disproportionately leave the population, otherwise these individuals would not be available for later samples. These values were calculated using data from Table 1: (Total R/C_{i+1}) × 100 = % marked in sample, and were found to increase seasonally during 1975 from 4% on 11 June to 40% by 15 August.

Our population estimates are based on small absolute numbers of successive day recaptures, due to the relatively small sample taken from a large population. In spite of the "noise" caused by the statistics of small numbers, however, these estimates are reasonably consistent for both parts of the season in 1975. In any case, the early season estimates are consistently higher than the late season estimates. The population decline evidently took place during the last half of July, although our recapture numbers (Table 1) are too low to permit accurate assessment of the actual rate of decline.

Our 1976 results indicate that the population in the sampled portion of the creek was not significantly altered by immigration of new individuals during 1975, and that the cumulative number marked during a given period of time (early or late season) was present and available for sampling during that period. Sampling in this case follows a hypergeometric distribution, and the expected number of recaptures and variance can be calculated using the estimates obtained from the Lincoln Index (Lotrich 1975). The total recaptures (Table 1) are within the expected range ($P < 0.05$) for each date, with the exception of the recaptures on 31 July.

Eleven out of 42 individuals captured on 26 May 1976 (the first sampling date in 1976) were marked during 1975, which is within the expected range ($P < 0.05$) for a total population of 1655, based on the assumption (see above) of no significant new recruitment. It therefore appears that there was no significant alteration of the marked portion of the population by immigration of new (unmarked) individuals between years. This fact, coupled with the other evidence presented, leads us to believe that we were sampling the total population in the marsh. The alternative explanation, that there is a significant part of the population which never enters the lower creek even though others move back and forth, seems to us less likely. In view of the fact that 26% of the individuals captured on the first sampling date in 1976 were marked during 1975, it is unlikely that the late season decline during 1975 represented a permanent exodus of terrapins from our study area. A trial sample was taken on 18 May 1977, which resulted in 17 marked individuals of 57 captured. This is also within the expected range ($P < 0.05$) for a population size of 1655.

That some individuals leave the marsh (temporarily, at least) is, however, substantiated by the fact that a few tags have been returned to us from outside the immediate vicinity. A tag from a large female was returned from a site some 8 km from the creek, where she was reportedly observed laying eggs.

Terrapins are known to hibernate in the submerged mud of tidal creeks (Coker 1920; Carr 1952), although Lawler and Musick (1972) found one individual hibernating in sand above the high tide level. It may be that terrapins hibernate preferentially in the mud at the bottom of the deeper water in the lower creek, since this area is less likely to freeze down to the mud than in the shallower channels upstream. They should thus be concentrated in this portion of the creek upon emergence the following spring, after which they might gradually disperse throughout the marsh. Alternatively, the observed seasonal variation in numbers may be related to changes in food availability, or to mating habits (as suggested by the disproportionate seasonal decrease in females).

One curious feature of the 1976 sampling effort is the disproportionate and significant decrease in smaller females relative to 1975. The reported minimum mid-plastron length for sexually mature females of this species is ≥ 130 mm (Barney 1922; Hildebrand 1932; Montevecchi and Burger 1975). The plastron length is 90% of the carapace length ($P < 0.05$), so that sexually mature females should have mid-carapace lengths of > 140 mm. Therefore, the size classes that have been decreased in relative frequency primarily represent nonbreeding individuals. We have formulated no satisfactory hypothesis for this phenomenon.

The graphs in Figs. 2 and 3 reveal a decline to the left of the mode in each case, indicating a lack of smaller (younger) individuals. In fact, only one individual less than 90 mm was ever found (Fig. 2b). An argument could be advanced that our sampling method excluded smaller individuals. However, this marsh has been extensively studied by others for many years, and neither we nor other investigators have seen more than a very few of these smaller terrapins anywhere in the marsh. Periodic seining, trapping, and various other sampling activities over the past several years throughout the marsh have yielded no smaller terrapins than those obtained with the otter trawl in the present study.

If the population is not declining over the years, each age class should, on the average, be equally abundant, assuming no mortality. Mortality will necessitate greater abundance in younger than in older turtles. The carapace length of hatchlings is generally under 30 mm for this species (Hildebrand 1932; Reid 1955). Therefore, one would expect individuals between 30 mm and 90 mm to be abundant, on a long-term basis.

We have as yet been unable to locate these smaller specimens anywhere in the marsh, although newly hatched specimens have frequently been observed near nesting sites in the vicinity of the marsh. It is unlikely that very young terrapins inhabit the main tidal creek, due to the strong currents. J. Burger (pers. commun. 1977) has suggested that juveniles may prefer near-shore marine vegetation in shallow areas outside of the marsh. As these areas are scarce and remote from our study area due to commercial development and dredging, the possibility exists that hatchlings can find little or no suitable habitat for survival near our study area. Thus, the missing size (age) classes may reflect a catastrophic and continuing source of mortality for young terrapins from our marsh population.

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