Behavior of Hatchling Diamondback Terrapins (*Malaclemys terrapin*) in the Field

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Hatchling diamondback terrapins were studied in 1974 on Little Beach Island, New Jersey.

Thirty-six (36%) of the 100 nests studied were not destroyed by predators during the incubation period. Sixty-nine percent of the eggs in these nests hatched, and 76% of the hatchlings emerged successfully. Hatchlings in individual nests emerged over a one to eight day period, and most hatchlings emerged during the day.

Hatchlings emerging from nests on flat sand areas showed no compass orientation, while those emerging on sloping dunes moved downward. Results of tests on an incline apparatus were consistent with field observations.

Hatchlings emerging from nests on flat areas moved directly to the closest vegetation. Results of tests indicated a preference for the nearest grass clump. Hatchlings tested on an incline apparatus moved to the vegetation regardless of the direction of the slope.

FEW detailed studies have been made on the behavior of hatchling turtles from the initiation of hatching through the first day after emergence from the nest. Several factors affect orientation from the nest: geotaxis (Noble and Breslau, 1938; Parker, 1922), brightness pattern of the sky over water (Mrosovsky and Boycott, 1966; Ehrenfeld and Carr, 1967; Mrosovsky and Carr, 1967; Mrosovsky and Shettleworth, 1968; Mrosovsky 1972) and openness of the horizon (Parker, 1922; Anderson, 1958). These investigators were attempting to determine the mechanism whereby hatchlings found their way to the sea. However, hatchling turtles face a more immediate problem in emerging safely from the nest and avoiding an intense predation pressure at this time (Ehrenfeld, in press). The present study was designed to examine the predation pressures on hatchling diamondback terrapins (*Malaclemys terrapin*) and their behavior during, and upon, emergence. A hatchling in this instance refers to a turtle just emerging, or just below the sand surface ready to emerge. Such hatchlings have a carapace width equal to or greater than the plastron length.

Diamondback terrapins inhabit brackish water off the Atlantic Coast and nest on the adjacent sand dunes and barrier beaches. Little is known of their breeding biology in the wild (Carr, 1952).

Captive diamondback terrapins have provided information on clutch and egg size (Burns and Williams, 1972) growth, sex ratios and longevity (Hildebrand, 1932; Allen and Littleford, 1955) and other general life history information. Factors affecting nest site selection and general aspects of their reproductive biology are reported elsewhere (Burger and Montevecchi, 1975; Montevecchi and Burger, 1975). Factors affecting the survival and hatching in this species will be presented in another report.

STUDY AREA

Fieldwork was conducted from June through August, 1973 and June through 12 October, 1974 on Little Beach Island (39° 28′ N, 74° 21′ W), Brigantine National Wildlife Refuge, New Jersey. Little Beach is a barrier beach island containing sand dunes in all stages of succession on the ocean side. Salt marsh areas are located on the leeward side of the island. A more detailed description of the island can be found in Burger and Montevecchi (1975).

The study area was located on the edge of a leeward cove in a sand dune area primarily covered with beach grass (*Ammophilia breviligulata*), bayberry (*Myrica pennsylvanica*), and marsh elder (*Iva frutescens*). High dunes and low flat sand areas were present. The area used was 800 m long and 18 m wide.

METHODS

The study area was searched for turtle nests one to three times per day during June and July. Nests found were marked for future location and were checked every other day to de-

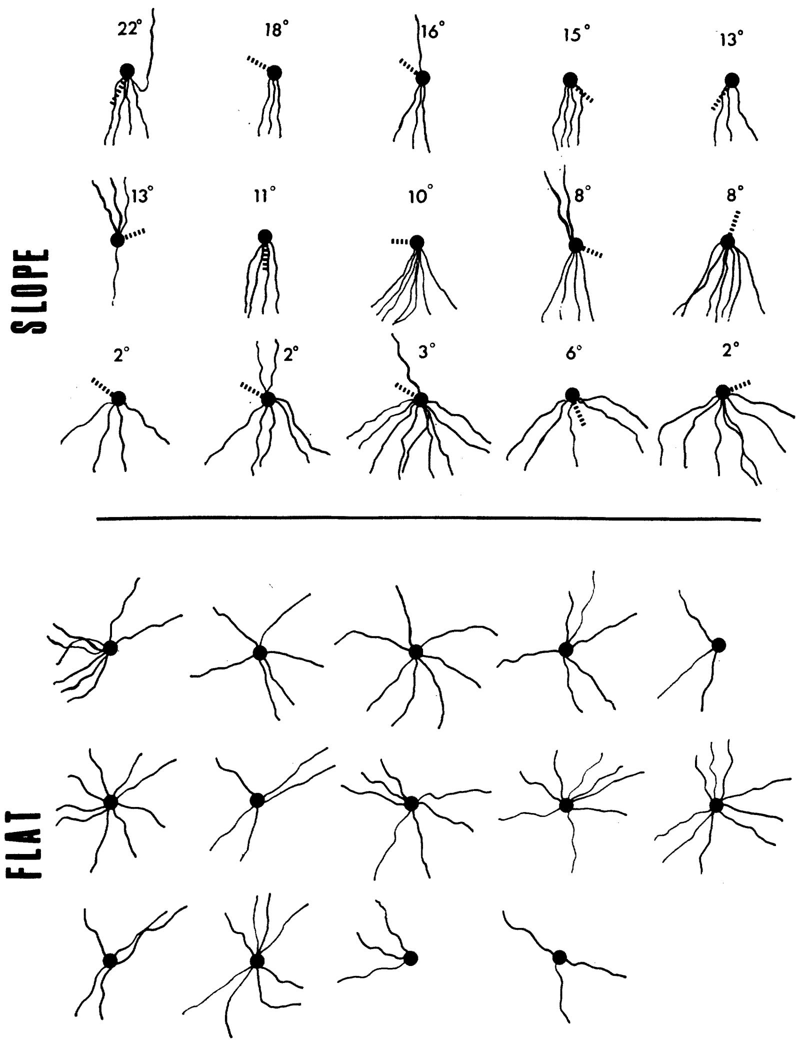

Fig. 1. Emergence patterns of diamondback terrapins from nests on slopes and from flat areas. Top of the page is high edge of slope direction. Degrees of slope are given for each pattern. The hatched line indicates north. Flat ground patterns are uniformly oriented so that north is at the top.

termine the rate of predation before and during hatching.

During late August and early September the study area was censused three to four times daily. Marked nests were examined for evidence of hatching and emerging. The entire area was searched for emergence patterns from nests not previously located, these nests being used to describe the natural emergence pattern since the digging up of nests may have influenced emergence pattern.

Experiments were carried out in the field and in the laboratory. Specific experimental procedures will be described in the appropriate sections.

Results

General information.—Two hundred and twenty nests were located during June and July and were followed until mid-October. By mid-September 100 nests were either destroyed by predators, the eggs had hatched, or were undeveloped. Sixty percent of the nests were disturbed by foxes and raccoons prior to hatching. An additional 4% failed to have any eggs develop. Thirty-six (36%) of the nests contained eggs that hatched. In these nests, 207 (69%) of the eggs hatched successfully, and 157 (76%) of the hatchlings emerged successfully. The time period of hatching in nests varied from one to four days ($\bar{x}$ =

TABLE 1. DIRECTION OF EMERGENCE OF DIAMONDBACK TERRAPINS FROM NESTS AS A FUNCTION OF SLOPE UNDER NATURAL CONDITIONS. N.S. = not significant.

	Flat	Sloped
Number of Turtles	88	84
Number of Nests	14	16
North	24	25
South	20	22
East	18	12
West	26	25
Chi Square	3.7	5.4
p	N.S.	N.S.
Up		16
Down		67
Right		1
Left		0
Chi Square		142
p		p < .001

TABLE 2. INCLINE EXPERIMENTS WITH DIAMONDBACK TERRAPIN HATCHLINGS IN THE FIELD AND IN THE LABORATORY.

	Field	Lab
A. *Response*		
Up	4	4
Down	30	18
Left	1	2
Right	1	0
# Turtles	36	24
Chi Square	74	33
p	< .001	< .001
B. *Latency of Response*		
x̄ (sec.)	9.8	37
S.D.	5.8	22
Range	2–25	5–90
N	24	24
t value	5.46	
p	< .001	

2.0 days). The top eggs in the flask-shaped nest always hatched first. Emergence from individual nests ranged from one to eight days ($\bar{x}$ = 2.5).

Fifteen (42%) of the 36 nests that had hatchlings were preyed upon sometime prior to emergence of the last hatchling. In two of these nests some unhatched eggs remained after predation and ultimately hatched successfully. I found 30 partially preyed upon nests in nearby areas with live eggs and hatchlings in the bottom.

Emergence pattern.—Hatchlings emerge from the nest one to nine days after hatching. In some nests hatchlings emerged the same day, in other nests hatchlings emerged as many as 11 days apart. Thus, the young may emerge together, in groups, or separately. Ninety-two (94%) of 98 hatchlings emerged between 0700 and 1900 h with most (N = 80) emerging between 1200 and 1700 h.

Emerging hatchlings leave a distinctive pattern of tracks visible in the sand. When the hatchlings emerge on the same day, their tracks remain and form a pattern. I searched the dunes for these patterns and plotted the patterns with observations on time of day, angle and azimuth of slope, angle and N-S direction of each turtle track.

Nests were located on both flat and sloped areas. Turtles emerging on flat areas radiated in all directions (Fig. 1). There was no significant difference in the direction of emergence for 14 nests (88 hatchlings) in flat areas devoid of vegetation over a radius of 2 m; movement from the nest site for the first 1 m was random (χ^2 = 3.7, d.f. = 3, N.S.; Table 1).

Emergence patterns for 16 nests (84 hatchlings) located on slopes were plotted (Fig. 1). Upon emergence most hatchlings walked down the slope (χ^2 = 142, N = 84, d.f. = 3, p < .001), although a few hatchlings went up. Virtually no hatchlings moved laterally with respect to the slope. Where the slope was greater than 10° the hatchlings did not radiate more than 30°. On slopes of less than 10° the trails radiated more than 75°.

Emigration of hatchlings from nests on sand dune slopes over 10° showed no significant compass directionality.

Incline experiments.—The following experiments tested hatchling preference for downward movement.

I built an apparatus of wood ⅓ meter square, with an incline of 20°. Sandpaper covered the wood surface so that hatchlings could move easily on the surface. During testing, the apparatus was placed 3 m from vegetation, and turtles were placed in the center facing to the right or left. I alternated the direction in which the turtles faced. All experiments were done from 1200 to 1500 h. Twenty hatchlings were field tested with the apparatus shifted so that it faced north, south, east and west on successive trials with each individual. No significant difference resulted in the response of the hatchling due to compass direction.

TABLE 3. DISTANCE TRAVELLED FOLLOWING INITIAL NATURAL EMERGENCE OF DIAMONDBACK TERRAPIN HATCHLINGS FROM NESTS WITH RESPECT TO VEGETATION. Measurements in m.

	Movements	Random Values
Number	80	
x̄ distance	5.47	16.21
S.E.	3.46	10.36
Range	.10–15.10	3.00–58.00
t value	10.4	
P	< .001	

Thirty-six hatchlings were incline tested in the field. Hatchlings usually walked down the incline ($\chi^2 = 74$, d.f. $= 3$, $p < .001$), although four moved upwards (Table 2). The mean time until hatchlings moved (latency of response) was 9.8 ± 5.8 sec. Hatchlings raised their head, looked around and immediately turned and walked off the apparatus.

To eliminate possible bias due to experimental conditions in the field, 24 hatchlings were brought into a laboratory and immediately tested with the same incline, where it was placed in an area surrounded by four white walls 1 m from the incline. The hatchlings still preferred to walk down the incline ($\chi^2 = 33$, d.f. $= 3$, $p < .001$); however, the latency of response (37 ± 22 sec) was significantly longer than in the field tested hatchlings ($t = 5.46$, $p < .001$).

Effect of vegetation.—Field observations of hatchling trails indicated that upon emergence they usually went to a nearby bush and subsequently moved to others. Emergence from 15 nests on flat sand were measured to determine the influence of vegetation. In each of the 15 nests, I measured the distance from the nest opening to the first vegetation encountered by the hatchling. An equal number of random distances were measured. The mean distance hatchlings went before encountering vegetation was 5.47 m, and random mean distance to vegetation was 18.21 m. Upon emergence the hatchlings went to the closest vegetation ($t = 10.4$, d.f. $= 80$, $p < .001$) (Table 3). Selection of vegetation was probably even higher because the density of vegetation varies and some turtles moved greater distances than others before reaching vegetation.

Forty hatchlings were tested for preference for close vegetation. I tested in a flat sand area containing two grass clumps 1 m apart. Hatchlings were placed ⅓ m from one of the clumps between the two clumps. Of those tested thirty-five moved to one of the two bushes. There was a significant choice of the nearest bush ($\chi^2 = 29$, d.f. $= 3$, $p < .001$) (Table 4).

Incline versus vegetation as a stimulus.—The above two sets of experiments indicate that the diamondback hatchlings observed at Little Beach Island show 1) no compass direction pref-

TABLE 4. EFFECT OF VEGETATION ON MOVEMENT OF DIAMONDBACK TERRAPIN UNDER EXPERIMENTAL CONDITIONS. See text for explanation.

A	*Flat Ground*		*Vegetation 3 m apart*	
	N		40	
	Close to bush		29	
	Far bush		6	
	Right		3	
	Left		2	
	Chi Square		29.25	
	p		< .001	
B	*Incline Apparatus*	High End	Low End	Side to
	Direction of movement:	Facing Bush	Facing Bush	Bush
	N	32	30	24
	Up	25	6	1
	Down	5	24	5
	Right	1	0	17
	Left	1	0	1
	Chi Square	49.5	113.5	28.7
	p	< .001	< .001	< .001

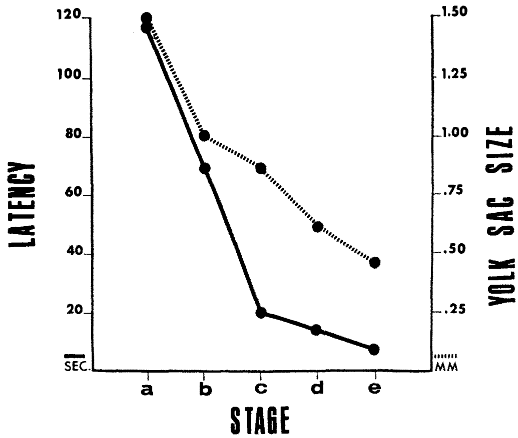

Fig. 2. Latency of righting response (solid line) of diamondback terrapins compared to yolk sac diameter (hatched line) for five stages of hatchlings (see text for explanation).

erence, 2) a preference for downward movement and 3) a preference for vegetation. The relative strengths of the latter two stimuli were tested by placing the incline apparatus next to a clump of grass such that it touched only the low end, the high end or the side of the apparatus. Turtles were placed facing away from the vegetation and their movement was recorded. Regardless of the position of the vegetation relative to the incline, the hatchlings walked toward and into the vegetation (Table 4); thus, turtles often turned completely around and walked upward or moved laterally to reach the vegetation.

Righting response.—As mentioned above, 15 of 36 nests containing hatchlings were preyed upon by raccoons that dug up nests during the night, ate the contents of the eggs, and left the shells nearby. Eggs and hatchlings were pulled from the nests and then eaten. Some young survived by moving rapidly from the opened nest. Because hatchlings are frequently inverted by removal, it is adaptive for hatchlings to have a well developed ability to right themselves upon exposure. Such a response is also adaptive as the hatchlings move from the nests to the sea, often falling down dunes and into crevices. They are especially vulnerable to thermal stress and predation at this time.

Hatchlings were grouped into five classes ranging from those just beginning to hatch to those ready to emerge. These stages were defined by the state of the hatchling, and by the quantity of unabsorbed yolk (Table 5). Twenty hatchlings were tested for latency of the righting response. All tests were performed between 1200 and 1500 h in the field. The latency period was lowest in young just beginning to hatch (Table 5, Fig. 2).

Discussion

Upon hatching, diamondback terrapins face two major problems: successful emergence from the nest and a safe journey to the nearby cove.

Emergence from the nest.—Twenty-five percent of the diamondback terrapins that hatch do not successfully emerge from their nests. Similar figures for most species of turtles are not available although several authors have stated that not all hatchlings emerge successfully (Hammer, 1969, 1972; Carr and Hirth, 1961; Hendrickson, 1958).

Most diamondback hatchlings that did not emerge successfully were eaten by raccoons. This high rate of predation suggests a possible strong selection for rapid emergence. However, in some nests 12 days elapsed between the hatching of the first egg and the emergence of the last turtle.

Table 5. Righting Response of Diamondback Terrapin Hatchlings as a Function of Development.

			Latency (sec.)			Yolk Sac (mm)		
Stage	Description	M	x̄	S.D.	Range	x̄	S.D.	Range
A	Small hole in shell	20	117.9	42.9	60–207	1.5	.15	1.3–1.8
B	Hole for head and front feet	20	70.2	21.6	38–120	1.1	.25	.8–1.8
C	Shell completely open	20	20.1	12.7	6–42	.8	.13	.6–1.1
D	Turtle just barely out of shell	20	16.0	13.1	2–45	.6	.08	.4– .7
E	Ready to emerge, turtle at surface or just below sand surface.	20	8.0	8.6	2–37	.4	.01	.4–6

Correlation = .97.
$p < .001$.

Several authors have suggested that social activity among nest mates affects emergence in *Chelonia mydas* (Hendrickson, 1958; Carr and Ogren, 1959; Carr and Hirth, 1961). Carr and Hirth (1961) found that the collective movements facilitate emergence from the nest and that in small (1–3) clutches, hatchlings are less successful than in large (74) ones. In the present study there was no significant difference in emergence success in nests with less than three hatchlings compared to those with more than three.

In many species of turtles a nest plug is made by the female at the entrance to the nest. This plug can become dry and hard, making emergence difficult; however, rainfall will moisten and soften the plug. Thus, moisture influences emergence of hatchlings in *Pseudemys scripta* (Cagle, 1950; Moll and Legler, 1971) *Chelonia mydas* (Carr, 1967) and *Batagur baska* (Loch, 1950). In the present study no nest plug was located in any of the nests. This was to be expected since nest plugs are usually formed in mud rather than in sand. The number of days between hatching and emergence did not seem to be modified by precipitation.

In diamondback terrapins in New Jersey, the time between hatching and emergence appears to be related to air temperatures. Mean air temperature on the day of hatching for hatchlings that emerged the same day was 25 ± 1 C. Mean air temperature during the days from hatching until emergence for those nests in which hatchlings did not emerge the first or second day was 19 ± 2.2 C ($t = 12.2$, d.f. $= 98$, $p < .00$). Of 26 nests hatching the last week of August, the mean number of days between first hatching in a nest and total emergence was 3.6. The average daily temperature during this week was 24 C. In the first week of September the mean daily temperature was 18 C, during which nine nests hatched. The mean number of days between hatching and emergence was six.

Journey to the sea.—Ninety-two of the 98 hatchlings whose exact times of emergence were known emerged during the day, a pattern contrary to sea turtles which emerge at night. Mrosovsky (1968) has shown that thermal inhibition of activity is a major factor in limiting the emergence of hatchling green sea turtles to night-time. This is also contrary to what one might expect in a species subjected to high predation by diurnal predators (Moll and Legler, 1971). Laughing Gulls (*Larus atricilla*) and Black-crowned Night Herons (*Nycticorax nycticorax*) eat hatchlings as they move over the sand. Diamondback terrapin hatchlings appear to counter this problem by rapidly moving to vegetation until nightfall. Few hatchlings were ever observed on the dunes during the day, and all observed tracks led to vegetation.

Emerging hatchlings in this study moved to the closest vegetation. Hatchlings placed experimentally between two grass clumps always moved to the closest vegetation. Hatchlings tested on an incline always moved to the closest vegetation regardless of the direction of the incline. When tested on an incline with no close vegetation, the hatchlings moved downward. Parker (1922) and Noble and Breslau (1938) have discussed the role of geotaxis in orientation. Three species of freshwater turtles showed a tendency to move uphill. This response may be related to the negative geotaxis required for emergence from the nest. Orientation has been shown by other authors to cease regardless of slope (Daniel and Smith, 1947; Caldwell and Caldwell, 1962; Ehrenfeld and Carr, 1967; Ehrenfeld, 1968).

There is evidence that in sea turtles orientation depends largely on light (Daniel and Smith, 1947; Carr and Ogren, 1960; Mrosovsky, 1972). Carr and Ogren (1960) have shown that it is possible to induce hatchling sea turtles out of the surf and up the shore by using a strong light. Mrosovsky and Carr (1967) further demonstrated a preference for blue light. Brightness, however, seems to be the main factor of light that attracts turtles (Ehrenfeld and Carr, 1967; Ehrenfeld, 1968).

Mrosovsky (1964) and Mrosovsky and Boycott (1966) working with *Pseudemys* in the laboratory found that some animals chose a water compartment surrounded by white walls and others chose a compartment surrounded with black walls. These findings are interesting when compared to the positive phototactic responses of sea turtles. Mrosovsky and Boycott (1966) suggest that the response to the black side may represent motivational differences in that these animals were frightened. Further, Anderson (1958) reported that hatchling turtles when placed close to water in the daytime, did not go to the water as they would at night but that they burrowed in the sand. In the present study diamondback terrapin hatchlings went immediately to vegetation. All of the above experiments suggest that some freshwater species show a negative phototaxis.

Negative phototaxis may be selected for because of high diurnal predation. Certainly *Pseudemys* (Moll and Legler, 1971) and diamondback terrapin suffer predation during daylight. I do not believe it is entirely a fear response as Mrosovsky and Boycott (1966) suggest, since diamondback terrapin hatchlings went to vegetation immediately upon emergence. Vision may play a more important role in orientation in freshwater turtles than it does in sea turtles since freshwater turtles vision on land is superior to that of sea turtles (Ehrenfeld, pers. comm.).

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