

Observations on Hawksbill Sea Turtles, Eretmochelys imbricata (L.),
in the Grenadine Islands, West Indies

by

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Abstract

Eggs of Eretmochelys imbricata were obtained from natural nests and oviducts of slaughtered female turtles for artificial incubation. Oviducal eggs hatched after approximately 90 days' incubation in contrast to nest eggs which hatched after approximately 60 days' incubation. The hatching success of nest eggs was 30%, while that of oviducal eggs was 70%. Hatchling turtles reared to an age of 20 months in captivity showed a rapid increase in body weight and carapace length. Growth in the latter portions of the study appears abnormally restricted, possibly due to confining conditions. Free hawksbill turtles were observed and tracked by SCUBA divers to obtain data on the habits of the animal in its natural environment. Observations were made of feeding habits, respiratory activity, and probable range. It is suggested that direct observation is a valuable tool for obtaining additional information on this species, and that establishment of preserve areas is a practical means for conservation of hawksbill turtles.

Introduction

Hawksbill sea turtles (*Eretmochelys imbricata* (L.)) are an endangered species (Honegger, 1968). Carr, Hirth, and Ogren (1966), Carr and Stancyk (1974), and Rebel (1974) have summarized present knowledge of hawksbill biology. Recent investigations concerned with the hawksbill have primarily dealt with nesting behavior or mariculture, but there is a paucity of data on the natural history of these animals; data which are required for effective conservation and management of this species. Since 1974, a variety of observations have been made in conjunction with an ongoing conservation program in the Grenadine Islands, W.I. These observations are the subject of this paper.

Materials and Methods

This study was undertaken on the island of Carriacou in the West Indies. Three principal activities were involved: (1) protected incubation of eggs from hawksbill nests and the oviducts of slaughtered female turtles; (2) rearing juvenile turtles in captivity to an age of 20 months; (3) observation of free hawksbill turtles in their natural environment.

Eggs from natural nests were transferred to shallow wooden boxes (10 cm x 45 cm x 30 cm) lined with plastic window screen (2 mm mesh width) and provided with drainage openings. Approximately 3 cm of sand from the nest site were placed in the box and the eggs were arranged as closely as possible into two layers. Care was taken not to rotate or jar the eggs during transfer. Once in the tray, the eggs were covered with 2 - 3 cm of sand, and transported to an enclosed incubation area. Trays were maintained at ambient air temperature (27 ± 2 C) and were sprinkled once weekly with 100 ml rainwater. Precautions were taken against infiltration by rats or ants. A similar procedure was followed when obtaining eggs from slaughtered female hawksbills. Shelled eggs were transferred directly from the oviducts to incubation trays. No attempt was made to incubate unshelled ("red") eggs which frequently numbered in excess of 700. Selected eggs from nest and oviducal clutches were opened at intervals during the incubation period for observations of embryonic development. Following examination of external features, these embryos were preserved for subsequent study of internal structures. The latter study is not yet complete, and will form the basis for a separate report. Hatchlings resulting from these incubation procedures were released within 24 hr of hatching onto a known nesting beach from which the turtles crawled into Hillsborough Bay and the Caribbean Sea.

Twelve juvenile hawksbill turtles were purchased from local turtle hunters. The first eight turtles were kept in two galvanized tanks (50 cm x 50 cm x 70 cm)

for eight months, after which they were transferred to a concrete tank (180 cm x 180 cm x 65 cm). Other juveniles were placed directly into the concrete tank at the time of purchase. Seawater in the holding tanks was replaced weekly. Six turtles died during fourteen months of captivity from wounds caused by other turtles (partitions were subsequently placed inside the tank to prevent fighting and to provide shelter). Each turtle was fed chopped fish to repletion once daily. In order to obtain more information on the normal dietary habits of sea turtles, four hawksbills were released into a natural salt water pond containing a variety of potential foodstuffs, and observed for periods up to 8 hours. At the age of 20 months all turtles were tagged with stainless steel fin tags and released onto a coral reef near Mopion, a sand cay 3.2 km north of Carriacou.

Direct observations of free hawksbill turtles were undertaken by volunteer divers over a period of 4 weeks. The primary purpose of this activity was to establish the feasibility of such observations for more detailed studies in the future. Turtles ranging in age from 2 to 5 years were followed by divers equipped with snorkelling equipment or SCUBA. A light tether of nylon seine twine was attached to some turtles during the training period for diver teams. Low power ultrasonic pingers ("Wet Beacon," Sound Wave Systems, Costa Mesa, CA) were also used as an aid in locating turtles when visual contact was lost.

Results and Discussion

Incubation of Eggs:

The average incubation period for nest eggs in this study (61 ± 2 da) agrees with data of Carr et al (1966) and Raj (1976) which indicate average incubation periods of 61 and 63 days respectively. Oviducal eggs required approximately 90 days to hatch, but with a much higher success rate than nest eggs. 40, of a total 129 nest eggs were opened for developmental study. Live embryos were found in 25 of the opened eggs; 6 contained embryos that had died at an early stage of development, and 9 showed no sign of development. A total of 11 nest eggs eventually hatched; if it is assumed that live embryos used in the developmental study would have hatched, a maximum success rate of 27.9% is indicated for this source. In contrast, of 21 oviducal eggs opened for study, 20 contained developing embryos and 63 of the 97 remaining eggs hatched with a maximum success rate of 70.3%.

The most likely reason for these differences in hatching success is a reduced sensitivity to motion in oviducal eggs relative to nest eggs. Raj (1976) reports that the average hatching success rate for 7 clutches of Pacific hawksbill nest eggs incubated in a laboratory was 91.4%. One clutch had a hatching success rate of 100%. These results are the highest reported success rates for incubation of marine turtle eggs. Raj suggests that the large variations in hatching success reported in the

literature may be attributed to basic differences in the collection, transportation, and incubation methods used in various investigations. He concludes that all turtle eggs may be moved over long distances at all stages of development, and incubated with greater success than in nature. Oviducal eggs are normally subjected to nearly continuous motion by the activities of the female turtle. Nest eggs, on the other hand, are normally motionless as well as being at a later stage of development and may therefore be more susceptible to damage caused by rough handling. We think it likely that a greater portion of the latter would have hatched if handled under the conditions specified by Raj.

The embryological development of nest eggs and oviducal eggs in this study differed in several respects. Oviducal eggs showed no signs of development during the first 6 days of incubation. Moreover, once development had commenced, the development of the embryos from oviducal eggs was slower than that of embryos from nest eggs as indicated in Table 1. This cannot be accounted for by the 6 day delay in initiation of development (i.e., a 24 day old nest embryo was comparable to a 34 day old oviducal embryo). There are several possible explanations for these differences. First, that a particular "triggering" mechanism initiates embryonic development in the hawksbill, and this mechanism is activated when eggs are laid. The absence of the nesting experience could therefore be responsible for the initial lag in the development of oviducal eggs, and the subsequent slow rate of development. An obvious trigger is a change in the physical environment associated with the laying

TABLE 1

process, such as the sudden absence of motion or temperature changes experienced when the egg leaves the body of the turtle. Second, although the turtles were caught in nets set in across known nesting beaches, capture may have occurred before the turtles were prepared to nest. The oviducal eggs, therefore, might have normally spent another week inside the turtle before being laid ("false nestings" and "trial runs" by turtles to nest sites have been reported by several authors). Finally, female turtles may possess a physiological mechanism for delaying embryonic development when subject to sudden stress. Such a mechanism might be activated by interrupted nesting or stress induced by capture. Normally, the inhibitory mechanism would become inoperative with the turtle's return to the water. This is not the fate of a slaughtered turtle, and the inhibitory mechanism may therefore remain operative for an unusually long period of time resulting in protracted embryonic development.

Table 1 indicates an increase in egg weight during the early stages of incubation, followed by a decrease in weight before hatching. This has also been reported by Bustard and Greenham (1968) in *Chelonia mydas* eggs. They attributed this weight increase to water uptake through the shell. Simkiss (1962) suggests that at least part of the initial weight gain is due to the uptake of minerals, specifically calcium, from outside the egg. He states that only 25% of the calcium necessary for the development of the embryo is present in the yolk, which is the main store of calcium in the egg contents. Assuming this to be true, mineral uptake from the sand surrounding the eggs must occur, since eggs in the present study were hatched

while being incubated in sand moistened only with distilled water (cf also Bustard and Greenham, 1968; Raj, 1976). The subsequent decrease in weight preceding hatching may be attributed to increased loss of metabolic products relative to water uptake during the latter stages of development.

One abnormal embryo was found in this study. The 38 day nest egg embryo possessed 7 vertebral (neural) scutes and 5 costal scutes on the right side rather than the normal complement of 5 and 4 respectively.

Captive Turtles:

The average carapace length of day-old hatchlings in this study was 39.5 mm. This is close to average carapace lengths of 42.3 mm and 42.4mm reported by Kaufman (1967) and Carr et al. (1966) respectively. Growth rates for hawksbill hatchlings in this study are compared with previously reported data in Table 2. As Caldwell (1962) points out, these data are "surprisingly consistent in indicating rapid growth." Caldwell has suggested that the scarcity of records of small turtles in nature compared with adult and sub-adult individuals may be due in part to much more rapid growth in young sea turtles than was once supposed. He also indicates that temperature may have been too low for optimum growth and normal feeding behavior in his Florida-based study, accounting for somewhat higher rates reported elsewhere. Data from captive turtles, however, may not be directly applicable to growth rates under natural conditions. Growth data from the present study are extrapolated and compared with previously reported information in

TABLE 2

Figures 1 through 4. The extrapolated length of 48 cm for a ten-year old FIGURES 1,2,3,4 hawksbill is far below the average carapace length of adult nesting females found around Carriacou (83.8 cm), as well as the average size of 83.1 cm reported by Carr et al (1966) for mature females and the maximum size of 91.4 cm suggested by Rebel (1974). This indicates that the growth of turtles in the present study was either abnormally restricted during the latter stages (despite high initial growth rates) or was reduced toward the end of the study due to seasonal fluctuations in carapace growth. Tubbs (1976) reports reduced mean growth rates in juvenile spiny lizards raised in crowded conditions. It is possible that the enclosures in which turtles were raised in our study were too confining for normal growth after the first 18 months, resulting in lower growth rates than have been observed in other turtles.

Daily food consumption by individual turtles and average weekly conversion efficiency figures were highly variable (Table 3). During the study TABLE 3 period, 3 turtles of the same age showed an average weekly food consumption of 290.6 g to 432.5 g with conversion efficiency values ranging from 0.248 to 0.304. These data are too variable to determine whether conversion efficiency of these animals changes with age. While Table 3 indicates a noticeable increase in food consumption as the turtles grow, Figure 1 shows only a very slight rise in the rate of weight increase, reflecting increased energy requirements to meet maintenance costs in larger animals.

Observations of Free Hawksbills:

Hawksbill turtles in the Grenadine Islands are found almost exclusively in the vicinity of coral reefs. Turtles released into shallow ponds or beds of turtle grass (Thalassia sp) appeared restless and swam during most of the observation period. In contrast, turtles released onto coral reefs tend to stay within the reef area. Turtles reared in captivity to an age of 20 months remained on the reef near their release point for at least 10 days. Turtles on submerged reefs would sometimes move off the edge of a shallow reef in the course of surfacing to breathe. Visual contact with the bottom was thus lost. In all cases, the behavior of the turtle changed at this point from langour to purposeful swimming, usually in a counterclockwise arc 3-5 m below the surface. The turtle would occasionally dive to a maximum depth of 20 m, but always returned to its previous depth in less than 60 sec. The overall impression was of an active search for shallow ground. When the bottom again became visible, the turtle would turn in the direction of shallow water and increase speed. The hawksbill then resumed its occupation of the reef surface.

In the course of investigating a variety of coral reefs in the Grenadines, we have frequently seen adult and juvenile turtles at depths ranging from 5 m to 20 m. These turtles appear to be a conservative feature: similar-sized individuals (we presume to be the same individuals) are seen in the same location with

intervals between observations as long as a year. The impression of a preference for corals reefs is reinforced by catch data obtained from local fishermen. Aside from turtles captured in nets during the nesting season, all hawksbill captures reported to us (more than 50 turtles) have been made in close proximity to coral reefs.

One explanation for this partiality may be the dietary habits of the hawksbill. It is generally acknowledged (Rebel, 1974; Carr and Stancyk, 1974) that hawksbill turtles are omnivorous. Four juvenile hawksbills released into shallow, naturally enclosed seawater ponds were observed to eat a variety of sponges, bark of mangrove roots, zooanthids, Cassiopea sp., Halimeda sp., and Chaetomorpha sp., although each turtle appeared to prefer a specific type of food which was not preferred by the others. Turtles released into reef areas, however, showed definite and consistent preferences for clionid sponges and colonial zooanthids. These results are similar to those reported by Carr and Stancyk (1974). In the latter study, the sponges Geodia and the ascidian Styela were dominant in the stomach contents of hawksbill turtles from Tortuguero. Substantial numbers of molluscs representing numerous shelled species were also reported. We have observed no consumption of molluscs in the Grenadine hawksbills, but have seen captive turtles eat coarse sand and coral rubble. Clionid sponges are frequently found in the skeletal material of reef corals (especially branched Porites species); most of the feeding by free hawksbills in the Grenadines

involved consumption of calcareous coral material along with adherent sponge. Coral rubble may therefore be a replacement for the mollusc shells consumed by Tortuguero turtles in the diet of Grenadine hawksbills. The role of such material (whether of mechanical benefit in macerating food or of direct nutritive value) is unknown.

Carr and Stancyk (1974) tabulate recoveries of hawksbill turtles tagged at Tortuguero, but found that the data were inadequate to decide whether long distance migration occurs. Nietschmann (Ms) reports a female hawksbill tagged while feeding which was subsequently recovered at a nesting beach 310 miles away. Our observations have dealt primarily with sub-adult turtles, all of which appear to have a range of less than 300 km². A single tagged hawksbill turtle, approximately 7 years old, has been recovered in the Grenadines. The turtle was captured in a net 6 months after tagging at a location 5 km from the site of initial release. Carr, Hirth and Ogren (1966) suggest that distant tag recoveries and the occasional occurrence of hawksbills far from their normal range may be the result of casual wandering rather than purposeful migration. This suggestion is supported by the behavior of hawksbills in deep water described above. These observations do little, however, to resolve the question of the fate of hatchling hawksbills during their first year. Chance dispersal by surface currents or rafting are conceptually sound ideas, but are inconsistent with the behavior of older juveniles reported here. The fact that hatchlings are seldom (if ever) seen may be indicative of

nocturnal activity or preference for areas not frequented by investigators, rather than departure of the hatchlings from the vicinity of the hatching site. We suggest that the most suitable means for solving this puzzle is direct observation and tracking by divers.

In addition to food and habitat preferences described above, data were collected on the respiratory activity of free turtles. The maximum interval between breaths (by "breath" is meant a single expiratory-inspiratory cycle) in any turtle was 20 min. During this interval, the turtle descended to a depth of 20 m, returned almost at once to the reef flat at 8 m, and foraged sporadically among partially dead stands of Porites coral. While turtles were over the reef, the usual interval between breaths was 5 - 10 min, and appeared to have little relationship to activity. This interval is shorter than the 10 - 56 min intervals reported by Parrish (1958) for resting turtles, probably because of increased metabolic activity due to higher ambient temperature. When swimming in deep water, turtles surfaced at least once per minute, usually taking a single breath before diving again to a depth of 3 - 4 m. These observations suggest that the adaptations to prolonged diving reported by Berkson (1966) for green turtles either do not occur in hawksbills or only occur under circumstances which were not realized in the course of the present observations. Number of breaths seemed to have little relation to the length of preceeding dive, nor was there any discernable pattern in the sequence of breaths. These data do not agree with those of Parrish (1958) or McCutcheon (1943) who

report distinct patterns in periods of breathing and apnea. This discrepancy emphasizes the probability of variation between observations of free turtles and those made in aquaria or the laboratory.

Carr and Stancyk (1974) point out that the hawksbill "has declined to endangered status before its ecology has been adequately investigated." Evaluation of adequate conservation measures and of the effects of mariculture projects depends upon more complete natural history information on hawksbill turtles of all ages. In the Grenadine Islands, the range of these turtles appears to be relatively small. This circumstance aids the acquisition of natural history information by direct diver observation, and suggests that establishment of local preserve areas for hawksbills may be of benefit in conserving this species. In the absence of data to the contrary, it seems probable that similar circumstances may occur in other areas where the hawksbill is found.

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Table 1
Comparative Development of Nest and Oviducal Eggs of E. imbricata

Age	Egg Mass		Egg Diameter		Carapace Length		Notes
	N	O	N	O	N	O	
18 hr	---	---	---	---	----	----	eye visible (N)
1 da	29.4 g	32.6 g	3.78 cm	3.96 cm	----	----	
2 da	---	31.0 g	---	3.86 cm	----	----	carapace visible (N)
6 da	29.1 g	---	3.79 cm	---	----	----	
9 da	---	29.6 g	---	3.78 cm	----	----	
13 da	29.4 g	31.8 g	3.86 cm	3.82 cm	----	----	eye visible (O)
18 da	31.4 g	31.8 g	3.81 cm	3.84 cm	11 mm	----	shell pigment (N) carapace visible (O)
21 da	---	37.0 g	---	3.92 cm	----	----	
27 da	27.1 g	---	3.46 cm	---	----	----	
32 da	---	---	---	---	27 mm	12 mm	
33 da	33.3 g	---	3.95 cm	---	28 mm	----	
37 da	30.0 g	34.7 g	3.84 cm	3.80 cm	33 mm	----	shell pigment (O)
40 da	29.2 g	---	3.65 cm	---	35 mm	20 mm	
55 da	26.9 g	---	3.67 cm	---	----	----	

N = nest eggs; O = oviducal eggs

Table 2

Initial Size and Growth in Hatchlings of E. imbricata

	1-da Hatchling		5-mo Hatchling		Average Increase	
	Length	Weight	Length	Weight	Length	Weight
	(cm)	(g)	(cm)	(g)	(cm/mo)	(g/mo)
Present Study	39.5	13.8	120.5	270	1.16 *	51.2 *
Kaufman (1967)	42.3	15.4	112	201.6	1.39	37.2
Schmidt (1916)	40	----	---	---	1.14 *	----
Caldwell (1962)	50	----	---	---	0.83 **	13.3 **
Rebel (1974)	----	----	---	---	0.4-0.97	7.69-31.2
Deraniyagala	----	----	---	---	2.06	----
(cited in Rebel, 1974)						

* -- for 6-7 month-old turtles

** -- averaged over the first year of growth

Table 3

Food Consumption and Weight Gain in Juvenile E. imbricata

Turtle Age (mo)	Start Weight	End Weight	Food Consumption	Conversion Efficiency	
	(g)	(g)	(average g/wk)	Average	Range
6 - 7	391	670	156.2	0.360	0.597
19 - 20	1162	1426	290.6	0.248	0.562
4 - 5	183	246	65.6	0.163	0.320
19 - 20	1437	1941	432.5	0.304	0.460
15 - 16	657	1191	316.2	0.423	0.360
19 - 20	985	1442	342.2	0.282	0.271

List of Figures and Figure Legends

Figure 1 -- Weight gain in Eretmochelys imbricata 2 - 20 months of age. Solid line represents best-fit power curve generated by given function.

Figure 2 -- Carapace length increase in Eretmochelys imbricata 2 - 20 months of age. Solid line represents best-fit power curve generated by given function.

Figure 3 -- Data of Figure 2 projected to an age of 10 years and compared with results of other workers.

Figure 4 -- Data of Figure 1 projected to an age of 10 years and compared with results of other workers.



