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An Analysis of Sand from Green Turtle Nesting Beaches on Ascension Island

S. E. STANCYK AND J. P. ROSS

Sand samples from most of the beaches on Ascension Island which are used by green turtles (*Chelonia mydas*) were collected and analyzed for organic, water and calcium carbonate content, pH, color and grain size distribution. Color, grain size distribution and water content varied to such an extent that Ascension beaches encompass the ranges of these parameters for green turtle nesting beaches surveyed in other parts of the world. A brief nesting survey and examination of nesting records kept by Mariculture, Ltd. suggested less frequent nesting on beaches near civilization, where human disturbance was high. There was no correlation between any other beach parameter and nesting frequency. We conclude that in the absence of disturbance or competition, green turtles have a wide tolerance of physical conditions on their nesting beaches.

GREEN turtles are known to nest on sandy beaches in tropical and subtemperate areas worldwide. The number of beaches currently in use is smaller than in the past, since turtle populations have been so reduced that several species are considered threatened or endangered (IUCN, 1970; Carr, 1972). However, turtles still nest on a wide variety of beach types, and Hendrickson and Balasingham (1966) feel that certain beach characteristics, particularly coarseness or slope, are important in nest site selection. There is little published information about the beaches. Most of the published descriptions of beach characteristics are analyses of grain size distribution or cursory statements about color and "fineness." Hirth and Carr (1970), Hirth (1971) and Hughes (1974) have published relatively complete quantitative sand analyses. One of the largest remaining nesting areas is Ascension Island, and there is a growing body of information on the turtle population nesting there (Carr, 1975). There is wide variation in sand type and particle size, ranging from coarse calcareous fragments to fine siliceous dust and even crystals of augite or olivine. This variation appears to encompass the complete range of reported nesting beach types. The purpose of the present paper is to report on some of the physical characteristics of beaches on the island in relation to observed nesting patterns.

Ascension Island is located in the South Atlantic, at longitude 14°25'W and latitude 7°45'S. It is about 2,000 kilometers from the adult feeding ground on the coast of Brazil (Carr and

Hirth, 1962). The island has a 40 km circumference and is of volcanic origin, with numerous beaches which vary greatly in size, appearance and accessibility from the sea (Fig. 1). Carr, Ross and Carr (1974) showed that green turtles commute between the various beaches, sometimes in a single night. Although Hirth and Carr (1970) published physical data on one of the beaches, we felt that a more detailed analysis of the nesting media at this important rookery was justified.

MATERIALS AND METHODS

Sand samples were collected on 11, 12 and 14 March 1974 from 16 of the beaches known to be used by turtles (Fig. 1). In the center of each beach, sand was taken from depths of 10, 30 and 50 cm in the turtle nest pits closest to the water line. These samples were placed in 25 ml plastic vials, which were then sealed. Samples were collected between 0800 and 1200 h. Similar samples were collected directly from the egg chambers excavated by turtles found on the beach at night. Since there was no difference between these and the other samples, they were pooled for several beaches and means and standard errors determined. The sealed vials were weighed to the nearest 0.01 g within two hours of the time of collection. To determine the water content of the sand, the samples were opened and dried at 105 C for 40 h in an oven. The loss of weight in the vial and sand after drying represents the water content. Five empty vials dried and weighed as a control showed no weight loss.

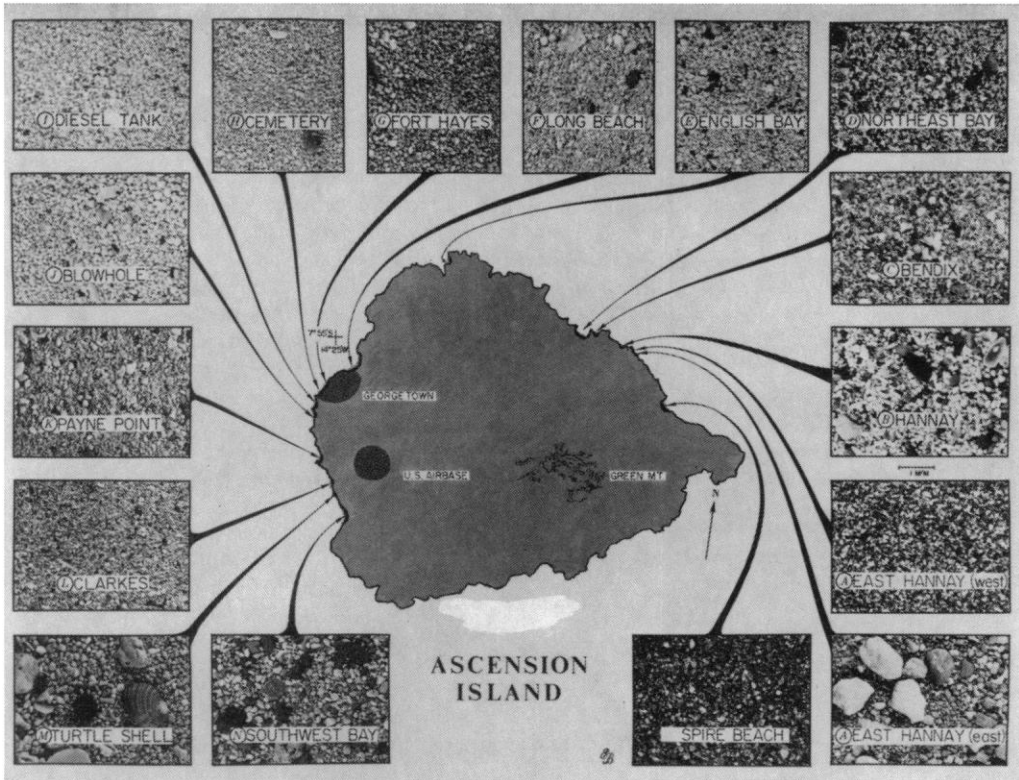


Fig. 1. Map of Ascension Island, showing location and color variety of nesting beaches.

Additional samples were obtained from the beaches by pooling several fractions of sand collected at 10 cm depth from the center of the beach. These samples, which weighed between 300 and 800 g, were used for the determination of particle size distribution, pH, organic content, calcium carbonate content and color.

Particle size was determined by passing 40 g of sand through a series of nested sieves (mesh sizes 2 mm, 1 mm, 0.5 mm, 0.25 mm, 0.125 mm, 0.088 mm) on a shaker for 15 min. The fraction of sand retained by each sieve was weighed and recorded as a percentage of the total sample.

The pH was determined by the method of Biilman and Jensen, in Jackson (1958). Ten grams of oven-dried sand was immersed in 10 ml of deionized water in plastic vials. The pH was determined with a Beckman Zeromatic II pH meter with temperature compensation at three times: immediately after immersion, and after standing for 2 and 24 h at 25 C.

Organic content was determined by combusting 2.0 g of dry sand in a muffle furnace at

500 C for 5 h. Weight loss of the sample due to combustion was recorded as a percentage of the total sample.

Calcium content was determined by the gravimetric method described in Black, 1965 (sec. 91-5). The method consists of converting CaCO_3 to CO_2 and CaCl_2 with 3N HCl and measuring the weight lost as CO_2 , from which the original CaCO_3 content can be calculated. Carbonates are expressed as percent by weight of each sample.

Color of both wet and dry sand samples was determined by use of Munsell Soil Color Charts, 1954 Edition, and recorded in the standard Munsell notation.

RESULTS

The sixteen beaches surveyed are shown in Fig. 1. Several of the beaches mentioned by Carr and Hirth (1962) have been subdivided by changes in beach topography, and four new beaches to the east of Northeast Bay have been added. There is great variation, at least in color,

TABLE 1. GRAIN SIZE ANALYSIS OF SEVERAL NESTING BEACHES ON ASCENSION ISLAND. Numbers are mean values plus or minus standard errors where calculable.

Beach	% Particle Size (mm) by Weight						Modal fraction
	>1.0	1.0-0.5	0.5-0.25	0.25-0.125	0.125-0.088	<0.088	
Southwest	16.3 ± 2.6	57.8 ± 1.2	25.3 ± 3.0	0.15 ± 0.03	0.07 ± 0.01	0.37 ± 0.13	1.0-0.5 mm
Blowhole (C & W)	84.6	15.3	0.0	0.0	0.0	0.0	>1.0 mm
Diesel Tank	38.7	60.7	0.3	0.3	0.0	0.0	1.0-0.5 mm
Cemetery	23.6	72.9	3.4	0.0	0.0	0.1	1.0-0.5 mm
Ft. Hayes (Pierhead)	24.2	69.2	3.3	0.4	0.2	2.7	1.0-0.5 mm
Long	22.5 ± 2.5	47.8 ± 2.0	25.1 ± 1.7	3.6 ± 0.3	0.2 ± 0.0	0.8 ± 0.2	1.0-0.5 mm
English Bay	26.6	67.9	5.5	0.1	0.0	0.0	1.0-0.5 mm
Northeast Bay	3.1 ± 0.7	14.8 ± 2.3	53.8 ± 1.0	26.8 ± 2.2	1.4 ± 0.2	0.2 ± 0.03	0.5-0.25 mm
Bendix	6.1	27.2	65.3	1.4	0.0	0.0	0.5-0.25 mm
Hannay	58.8	40.3	0.6	0.3	0.0	0.0	>1.0 mm
West East Hannay } East East Hannay }	23.3 ± 2.3	48.2 ± 6.2	22.9 ± 1.2	2.7 ± 1.4	0.57 ± 0.3	2.2 ± 1.1	1.0-0.5 mm
$\bar{x} + S_{\bar{x}}$	29.8 ± 7.1	47.7 ± 6.3	18.7 ± 6.9	3.3 ± 2.4	0.4 ± 0.3	0.6 ± 0.3	

between the beaches (Fig. 1, Table 2). The figure does not show the degree of accessibility of the beaches, but many (Turtle Shell, Blowhole, Diesel Tank, Cemetery, Bendix, Hannay, East Hannay, East East Hannay) have extensive rocky shelves stretching before them which are exposed, or nearly so, at low tide. Others, particularly Southwest, Ft. Hayes, Long Bay, English Bay and Northeast Bay face open water and appear to be quite accessible at all stages of the tide. During our five-day stay, we found a turtle stranded on the beach at Turtle Shell Beach and another caught in the rocks off Diesel Tank Beach. Such strandings are not uncommon (Kim Critchley, pers. comm.).

Tables 1-3 summarize the results of the analyses of all beaches. Most of the beaches could be classified as relatively coarse-grained in the sense of Hendrickson and Balasingham, 1966 (particles predominantly greater than 0.5 mm). On all beaches analyzed, over 90% of the sand is contained in two or three of the six size fractions. On all but four the modal grain size is either 0.5 mm or 1.0 mm; however, some of these tend toward coarseness (Blowhole, Diesel Tank, Ft. Hayes, English Bay, Hannay) while others approach fineness (Southwest Bay, Long Bay, East Hannay). The finest-grained beaches were Northeast Bay and the adjacent Bendix, and it should be noted that they also had relatively heavy nesting (5.0 and 4.0 turtles/100 m/

night, respectively; Table 3). Finally, the finest fraction (less than 0.088 mm) was never very abundant, ranging from 2.7% on Ft. Hayes beach to 0.0% on Blowhole, the coarsest beach.

Table 2 shows water content, pH, percent organic matter, calcium carbonate content and color of the beaches examined. The water content on all beaches was close to 30 mg/g, with a mean of 31.9 mg/g, except on Northeast Bay beach and Southwest Bay beach, where it was significantly lower ($P = 0.01$). Northeast Bay beach is thought by local people on Ascension to contain more fine particles than the other beaches (Marlin Simon, pers. comm.). This idea stems partly from the fact that Northeast Bay beach is drier and therefore dustier than the others, although it ranks third in percent of particles less than 0.125 mm. There was no significant difference in water content due to depth (F test).

The pH varied between 7.40 and 8.48 (no significant difference) and there was no discernible trend or gradient in pH among the beaches. Organic content was more variable, between 9.3% at English Bay and 0.5% at Turtle Shell, with a mean of 4.04 ± 0.84 (SE). It is difficult to detect trends but note that the three beaches with the highest organic content (Blowhole, Diesel Tank, English Bay) are all near civilization, the first two being beside Georgetown, and the third being near the island's power gener-

TABLE 2. ANALYSIS OF SEVERAL PHYSICAL CHARACTERISTICS OF BEACHES ON ASCENSION ISLAND.

Beach	Mg/g H ₂ O $\bar{x} \pm SD$	pH	% Organic Matter	% CaCO ₃	Color	
					Wet	Dry
Southwest Bay	22.1 \pm 5.0	8.48	1.3	96.0	10.0yr 7.5/6 pale tan	2.5y 7.5/5 pale yellow-tan
Turtle Shell	-	-	0.5	98.1	2.5y 8/6 pale yellow-tan	2.5y 8/4 pale yellow
Clarkes (Barge?)	-	-	6.5	93.2	2.5y 7.5/5 pale tan-yellow	2.5y 8/5 pale tan-yellow
Paynes Point	-	-	3.8	93.5	2.5y 8/3 white	10.0yr 8/2 white
Blowhole (C & W)	38.3	8.2	9.2	99.2	2.5y 8/2 white	2.5y 8/2 white
Diesel Tank	30.1	7.5	9.2	99.3	2.5y 8/3 white	2.5y 8/3 white
Cemetery	28.7	7.9	3.5	96.9	2.5y 8/4 pale yellow	2.5y 8/3 white
Ft. Hayes (Pierhead)	29.9	7.4	2.1	97.0	2.5y 7.5/2 white	2.5y 7.5/3 pale tan-white
Long	33.4 \pm 10.3	8.3	1.7	94.6	10.0yr 7.5/6 pale tan	10.0yr 7.5/6 pale tan
English Bay	39.9	7.5	9.2	95.6	2.5y 8/3 white	2.5y 8/2 white
Northeast Bay	18.1 \pm 5.9	8.0	0.9	20.8	10.0yr 3/3 dark olive	10.0yr 5/3 olive gray
Bendix	34.6	7.6	8.5	65.4	10.0yr 6/4 light tan	10.0yr 6/5 light tan
Hannay	39.6	8.0	4.3	69.5	2.5y 6/2 gray	2.5y 7.5/2 gray
East Hannay	36.0 \pm 19.6	8.2	1.2	2.7	10.0yr 2/2 dark gray-black	2.5y 4.5/2 olive gray
East East Hannay	-	-	2.5	27.7	10.0yr 2/2 dark gray-black	2.5y 4.5/2 olive gray
Spire	-	-	0.5	0.9	5.0y 2/2 dark olive-black	2.5y 3/2 dark olive
Mean \pm S _e	31.9 \pm 2.1	7.9 \pm 0.4	4.0 \pm 0.8	71.9 \pm 9.2		

ating plants. However, several of the other beaches are also near civilization and do not show increased amounts of organic matter, and we have no explanation for the wide variation in organic content on the Ascension beaches. Possibly the ashing technique used here is not as reliable or accurate as the potassium dichromate method used by Hirth and Carr (1970).

There appears to be a general relationship

between the amount of calcium carbonate in a beach and its color. Both entities vary greatly from one beach to another, ranging from 99.15% calcium carbonate on the whitest beach (Blowhole) to 0.91% calcium carbonate on the darkest (Spire). Thus, the major visible differences between Ascension beaches appear to be due to the mixture of biogenic and volcanic sands.

There is little available information on the

TABLE 3. USE OF ASCENSION ISLAND BEACHES BY GREEN TURTLES. Results of a three-night Survey 13–15 March 1974.

Beach	Length (m)	Turtles/100 m/night	Total turtles/night Mean \pm SD
Southwest Bay	475	2.5	12 \pm 2.5
Turtle Shell	350	2.6	29 \pm 6.0
Clarkes	300	2.3	7 \pm 1.5
Paynes Point	120	3.3	4 \pm 3.0
Blowhole	160	5.6	9 \pm 5.5
Diesel Tank	150	2.0	3 \pm 3.0
Cemetery	200	3.0	6 \pm 1.0
Ft. Hayes	150	0.7	1 \pm 1.0
Long	875	2.7	24 \pm 2.0
English Bay	175	3.4	6 \pm 1.5
Northeast Bay	358	5.0	18 \pm 6.5
Bendix	138	3.6	5 \pm 2.0
Hannay	100	5.0	5 \pm 2.5
East Hannay	63	3.2	2 \pm 2.0

use of Ascension beaches by turtles on a nightly basis, so we surveyed beaches for three nights. The results (Table 3, Fig. 2) show that there is an average of 3.2 turtles/100 m of beach/night, but this value ranges from 0.7 to 5.7 on different beaches. Comparison of beach use by turtles with particle size (Fig. 2) indicates that there is no close relationship between these two parameters. Beaches situated on the north and west parts of the island are used by a greater concentration of turtles, regardless of grain size distribution. Thus, Northeast Bay beach and Hannay beach vary greatly in grain size distribution (18% coarse vs. 99% coarse), but both had over 5 turtles/100 m/night nesting on them. It is difficult to detect any trends in a three-night survey, but note (Fig. 2) that the northeast beaches (Northeast Bay, Bendix, Hannay), which are also the most remote, tend to have the highest nesting use, while the least-used beaches (particularly Diesel Tank and Ft. Hayes) were near Georgetown or the U.S. military base, where turtles approaching shore may have been affected by light or people. Thus, there is a strong possibility that human interference is causing turtles to nest on less disturbed beaches. We have had an opportunity to examine data on beach use collected by Marlin Simon of Mariculture Ltd., from 9 February to 14 March 1974, and find that in general the trends we saw in our

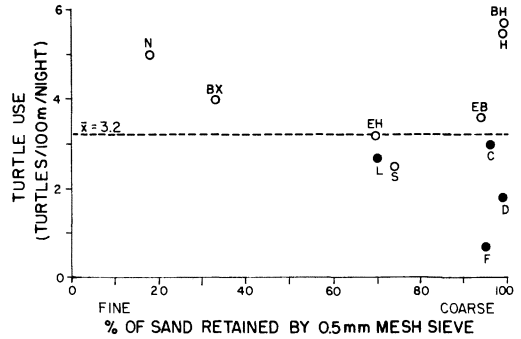


Fig. 2. Turtle use and particle size of some Ascension Island Beaches. Dark circles represent beaches with high human disturbance. BH = Blowhole, BX = Bendix, C = Cemetery, D = Diesel Tank, EB = English Bay, EH = East Hannay, F = Ft. Hayes, H = Hannay, L = Long, N = Northeast Bay, S = Southwest Bay.

3-day survey hold true for the longer period. However, it is possible that certain beaches were emphasized in the latter survey, biasing the count.

DISCUSSION

The question of whether grain size distribution on a beach influences the nesting preference of adult turtles has remained unresolved, although several recent studies (Hendrickson and Balasingham, 1966; Pritchard, 1966; Carr and Hirth, 1962; Hirth and Carr, 1970; Hughes, 1974) have commented on the particle size of nesting beaches. Hendrickson and Balasingham (1966) stated that "fine-grained" beaches (grain size predominantly less than 0.5 mm) were preferred by *Chelonia* along the coast of Malaya. Their interpretation, which is open to question, was based on the fact that *Dermochelys* nested almost exclusively in a zone of coarse beach, while *Chelonia* did not nest there at all. However, the coarse grain size of the "Dermochelys beach" was determined by other factors, particularly steep slope of the beach and a postulated onshore current. Either of these factors, as well as nearness of the beach to deep water, could have influenced the open-ocean dwelling *Dermochelys* as much as the coarse grain size of the beach. Assuming that the two species nest simultaneously, once leatherbacks began using a beach in the densities reported by Hendrickson and Balasingham (1,554 nests/km/year), any *Chelonia* nest on the same beach would stand a good chance of being excavated before hatching,

and green turtles would eventually be eliminated from this section of beach. Approximately 78% of the sand on the most heavily-used *Dermochelys* beach is greater than 0.5 mm (calculation based on data in Fig. 5 of Hendrickson and Balasingham, 1966). This value is equivalent to or lower than values for several green turtle nesting beaches in other parts of the world: Aldabra Atoll, Indian Ocean, 50.3%; Aves Island, Caribbean Sea, 73.7% (Hirth and Carr, 1970); Tromelin North Beach, Southeast Africa, 74% (Hughes, 1974); Ascension Island, 33–99% (Fig. 2). While *Dermochelys* is known to share several nesting beaches with *Chelonia*, both fine-grained (Tortuguero, Costa Rica; Carr, 1972) and coarse-grained (Shell Beach, Guiana; Pritchard, 1966), the density of *Dermochelys* in the Trengganu area of Malaya is greater than in these areas. Point Isère and Silébâche beaches in French Guiana have a greater density of *Dermochelys* than Trengganu, and few green or ridley turtles nest there (Pritchard, 1971; 1973). Our data (Table 3, Fig. 2) indicate that green turtles nest in relatively high density on both fine- and coarse-grained beaches on Ascension Island. We conclude that in the absence of disturbance or competitors green turtles have a wide tolerance for particle size on their nesting beaches.

Ascension beaches have a relatively constant pH and water content (except for Northeast Bay and Southwest Bay). On the other hand, our data show that Ascension turtles are using beaches which differ considerably in several characteristics other than particle size, such as organic content, color, accessibility from the sea and calcium carbonate content. The values found for these parameters encompass the complete range of values reported for nesting beaches in Yemen, Aldabra Atoll, Costa Rica and Aves Island by Hirth and Carr (1970).

The observed preference of green turtles for particular beaches is probably a result of pressure from several sources—most notably predation on the adults or on the nests and hatchlings. However, the physical characteristics of a particular beach may also have a profound effect on nesting success. Prange and Ackerman (1974) have shown that the oxygen demands of developing turtles are met by gases diffusing through the sand, and diffusion is likely to be affected by factors such as particle size and water content. In this context it is interesting that the turtles on Ascension, where predation on adults and nests is absent, undertake the

same extensive covering of the finished nest as turtles on beaches more susceptible to predation, such as Tortuguero. In addition to the obvious benefit of making the nest hard to find, covering behavior could enhance other aspects of nest success, perhaps by ensuring a proper density and depth of sand over the eggs.

Evidence that physical beach characteristics affect nesting success is lacking; however, there are reports that nesting is often clumped on single beaches with presumably constant physical characteristics and accessibility. While such clumping may be due to aggregated travel to the beach, it is noteworthy that “half-moons” or “prospecting trails” are a common feature of sections of the strand between sites of heavy nesting (Hirth and Carr, 1970). Perhaps beaches thought to be constant all along their length are not. Whether beaches with different physical characteristics provide similar environments for developing embryos, and whether beach type influences development time or hatching survival is unknown. These questions cannot be answered at present, but in light of current proposals to preserve particular beaches as permanent nesting sites for sea turtles, or to build beaches for use in turtle mariculture or conservation, careful quantitative examination of successful nesting beaches in order to determine what beach qualities are crucial to adult choice and embryo survival seems appropriate.

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The Non-Cost of Brooding in *Ambystoma opacum*

ROBERT H. KAPLAN AND MARTHA L. CRUMP

Ambystoma opacum is the only member of a primarily aquatic-breeding genus of salamanders that remains with its eggs after terrestrial deposition. In order to determine the energetic cost of this "parental investment," we compared dry weight, total calories, weight-specific caloric content and ash content in females that had just begun to brood with those near completion of brooding. Differences in these four variables between the two groups are not significant at $P \leq 0.05$. The argument that brooding females are at an energetic disadvantage because they are unable to forage is discarded because males collected from the area during the same period also had empty stomachs and intestines. We therefore suggest that there is no increase in energetic cost due to brooding in *A. opacum*.

BROODING behavior is present in all three orders of amphibians. Its distribution in salamanders suggests that the behavior has evolved independently several times. Brooding behavior in this order ranges from a weak bond between the parent and offspring (mere presence of parent at the egg deposition site) to active defense of the clutch and transporting of the eggs to a more favorable site (Salthe and Mecham, 1974).

The "complexity" and "constancy" (Williams, 1966a) of brooding behavior in those species displaying it suggest that it is an adaptation for attaining greater offspring survival and ultimately increased individual fitness in some environments. Several empirical studies have

shown how offspring survival might be enhanced by this behavior.

From the theoretical literature (Williams, 1966b; Trivers, 1972; Smith and Fretwell, 1974) we reason that brooding behavior would not evolve if the cost to the overall fitness of a parent exceeded the benefit. This cost is measured as a decrease in the future reproductive success of the individual. The cost would be generated by energy drains on a brooding parent due to the physical nature of the behavior itself and/or the relatively lower feeding rate which may be associated with the behavior. This could then result in reduced clutch sizes in the next breeding period (salamanders: Maiorana, 1976; fish: Bagenal, 1969; spiders: