Factors influencing emergences and nesting sites of hawksbill turtles (*Eretmochelys imbricata*) on Cousine Island, Seychelles, 1995-1999

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Abstract: Nesting hawksbill turtles were studied on Cousine Island, Seychelles from 1995 – 1999. Emergences were highest during November and December, and most (91.0%) took place between October and January when the beaches were most stable and the general wind speeds were at a minimum, with 99.4% emergences occurring during daylight. There was no correlation between emergences and tidal conditions, lunar cycles, daily wind, rainfall, and eroding or depositing beaches. Most nesting took place on or beyond the upper third of beaches. There did not appear to be any special selection for sunlit or shaded conditions, or for vegetation presence or absence. Ultimately choice of a nest site appears to be related to high-tide level and sand moisture level.

Key words: Reptilia, Testudines, Cheloniidae, marine turtles, population size

Introduction

Although the occasional green turtle (*Chelonia mydas*) is found nesting on the granitic island of Cousine, Seychelles Republic, hawksbill turtles (*Eretmochelys imbricata*) form the bulk of the breeding population on the island, and any further reference to turtles is of this species. Little previous information has been published on marine turtles on Cousine Island except for an estimate of numbers of hawksbills believed to nest there (Frazier 1984), a brief general description of numbers and breeding (Bourquin & Hitchins 1998). Some turtle monitoring started during December 1991 when beachings, tracks, nestings and turtles seen were recorded. No turtles were tagged until the 1993/1994 nesting season, and initially only nesting turtles were tagged. Tagging of non-nesting turtles was started during the 1995/96 nesting season. Collection of more detailed information on nesting began intensively during the 1995/1996 nesting season and continued until the 1998/1999 season.

The Republic of Seychelles comprises of some 51 islands and islets. Forty of these, the inner islands, are formed of Pre-Cambrian granite. The granitic islands lie between 4-5^{o} latitude south and 55-56^{o} longitude east. Geologically they are part of the Seychelles bank, a shoal area of some 31,000 square km with water depths of less than 60m, surrounded by ocean 4 to 5 km deep. Cousine Island, at 4^{o}20'41''S and 55^{o}38'44''E, is just over 1 km long and 400m wide at its widest point, and is 25.7ha in extent (Stoddart 1988).

All the granitic islands of the Seychelles group experience a humid tropical climate. The relative humidity varies little from 75% to 80%. Mean monthly temperature ranges are between 25.7 and 27.8^{o}C with average diurnal ranges being 3-4.2^{o}C. Known temperature extremes are 19.3^{o}C and 32.8^{o}C. The coolest months are July and August and the hottest are April and May. Annual rainfall and length of dry/wet seasons vary considerably from island to island, and seasonally on each island.

South-east Trade winds (Trades) occur from May to October; lighter and more variable north-west Monsoon winds (Monsoons) occur from December to March. Winds are variable with frequent calms during the transition months of April and November. Highest mean wind speeds occur from June to September (13.9-17.1km per hour - south-east winds), and for the rest of the year mean wind speeds range from 5.9-10.4km per hour. Tropical cyclones have not been recorded for the granitic Seychelles, although strong winds frequently occur for short periods, especially during storms (Stoddart1988).

Cousine's landscape is strongly influenced by rock formations, dominated by the ancient granite. The highest point rises to just under 77m. A sand beach lies on a section of the east to north facing shoreline, and is about 900 m long. The vegetation of Cousine has been described (Bourquin 1996). The sea within a kilometer of Cousine's shore is up to 30 m deep, and the underwater visibility is generally very good, with exceptionally clear water during calm periods. During the Trades the sea's surface temperatures in the Seychelles are 23-27^{o}C and of intermediate salinity (34.3-35.2 %o), with even warmer waters (28-31^{o}C) occurring during the Monsoons. Average ocean salinities are about 35%o and ocean surface water salinities can change depending on rainfall and evaporation (Stoddart 1988).

The main oceanic current in the Seychelles region is the south equatorial current moving from east to west, with its main flow between 8^{o} and 14^{o}S. The granitic Seychelles lies on the northern edge of this current. The tidal range in the Seychelles is 1 to 2 m between successive high and low spring tides, and as a result the oceanic tidal currents are weak except where a narrowing constriction in land-masses occur.

The main factors influencing water movement and wave action around Cousine are the wind speed, direction and water depth. Patterns of wave refraction, current and eddy formation strongly affect the near shore benthic communities (Kelly 1996).

Methods

Climate - Rainfall, cloud cover, wind speed and direction on Cousine were recorded daily. *Location marking* - The dune crest of Cousine's beach was marked at 30m intervals, starting at the end of the beach in the south, with numbered markers which were used as reference points for all emerging turtles and their beach activities (Fig. 1).

Fig. 1. Beaches of Cousine

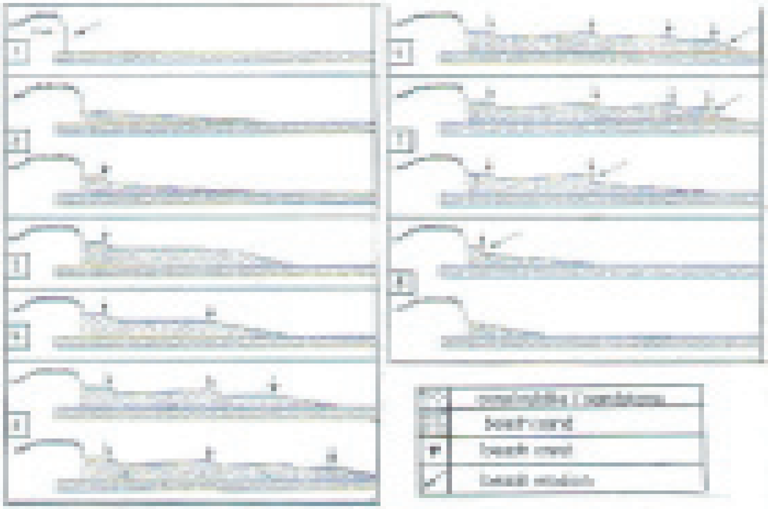

Fig. 2 Beach profiles on Cousine

Patrols - Patrols were undertaken daily from August to April at 1-1.5h intervals whenever possible, normally between 06:00-18:30h, sometimes earlier and later during nesting peaks.
Soil / sand characteristics - Ten soil samples were taken from 300-450mm below ground level on 3 May 1999 from the upper beach, dunes and behind the dunes – all areas to which hawksbills have access for nesting. These were analysed by the Seychelles Bureau of Standards. Soil textural classes were determined using the chart of Loxton (1961). Definitions were based on van der Eyk *et al*. (1969).
Beach and dune characteristics - The beach was divided into three sections for comparative purposes, the east section, the north-east section and the north section - each being about 300m long (Fig. 1). Beach widths were recorded and mapped monthly at spring tides from each dune crest marker beacon, at right-angles to the sea. Mean beach sand depths were estimated, and approximate beach sand volumes were calculated. Beach profile characteristics were classified into eight categories (Fig. 2). Dune characteristics and vegetation cover were obtained by observation and following plant identifications and descriptions in Bourquin (1996).
Emergences - A female turtle crawling on to dry land was considered to do so with the intention of nesting, whether she was successful or not, and we therefore considered any emergences as part of the nesting season. All turtle emergences were recorded, indicating points of emergence in relation to the dune crest markers, subsequent activity and, where possible, the times spent by the turtles on land. First seasonal emergences were considered as being the beginning of the breeding season, and last emergence as the end.

Results
Climate - Although rainfall was measured on Cousine island for a short time only (1992-1999), there were notable monthly fluctuations and extended dry periods. The longest continuous dry period known for Cousine was 61 days during June to August 1993, while periods of 30-40 days were not uncommon during any dry season. A dry period (rainfall under 100mm per month) varied from year to year but usually fell between June and December, with a consist-

ently wet month (September) sandwiched in between. This did not hold true for September 1997, which was dry, and for August 1997 (usually a dry month) during which 579mm of rain fell in 6 days. The most consistent rainfall months were September, December and February, the least consistent being June, July and October (Tables 1 & 2).

Beach characteristics.- The north and part of the north-east beaches were most stable from near the end of the Trades (October) to after the beginning of the Monsoons (January). During the Trades sand from the eastern beach was removed and transported away, while there was accumulation of sand and widening of the north beach. The process was reversed during the Monsoons. Because of erosion and deposition beach widths could vary from 123m wide to being completely washed away. Estimated beach sand volumes ranged from a total of 70,980 cu. m at the end of the Trades to 108,720 cu. m at the end of the Monsoons (Fig. 3).

Indications were that sand was not simply redistributed on the beaches from one part to another, but was also being brought ashore from marine deposits during the Monsoons, and removed from the beach to the sea during the Trades. The greatest volume of sand at the end of the Monsoons was on the east beach, while during the Trades the largest volume was on the north beach.

The changing of sand volumes by erosion and deposition changed the beach widths and profiles. While most dunes remained stable, the beach crest and the beach could change considerably, often very quickly. Stability of the dunes was indicated by the presence of vegetation, especially large trees (*Casuarina equisetifolia*), which gave an idea of how long the system had remained stable. For one of Cousine's dunes, this was for 30-40 years until dune erosion by tidal action during 1998 caused the collapse of some of the older trees on the dune crest. The beach crests could vary in height from being almost indistinguishable to 2m high. The dunes could be less than 0.5m high to over 4m high. Beach crests and dunes had faces varying from gently sloping to vertical (Table 3).

Table 1 Annual rainfall (mm), Cousine Island, Seychelles

Period	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00
1 July-31 Dec	423.5	351	1182	646.3	650.2	1805.3	505.4	816.4
1 Jan-31 June	1115	1014	828.2	1104	936.6	1025.5	828.9	868.5
Total	1538.5	1365	2010.2	1750.3	1586.8	2830.8	1334.3	1684.9

Table 2 Rainfall during turtle breeding seasons, 1992/93 - 1999/2000, Cousine Island.

			Rainfall in mm.					
Years	Aug	Sept	Oct	Nov	Dec	Jan	Feb	Mar
1992/93	46.0	125.0	18.0	44.0	177.0	444.0	317.0	42.0
1993/94	40.5	156.0	69.0	14.0	68.0	383.0	268.0	54.0
1994/95	284.0	209.0	115.0	197.0	192.0	208.0	162.5	89.0
1995/96	27.9	164.7	176.5	64.0	169.8	240.0	288.2	283.5
1996/97	47.3	175.0	41.9	200.8	146.4	159.6	92.8	226.6
1997/98	603.7	245.0	429.4	262.7	249.0	349.3	147.1	149.5
1998/99	16.0	152.0	8.2	168.3	127.5	330.9	232.8	125.2
1999/00	138.0	113.6	44.1	342.0	157.2	120.8	324.8	277.6
Mean	150.4	167.5	112.8	156.1	160.9	279.3	229.2	155.9
SD	190.5	40.1	130.3	113.4	48.8	106.9	80.3	90.1

Soil and sand characteristics: All samples were classified as sand, with over 90% of the mass containing particles over 20 microns in diameter. The nature of the beach sand was variable due to periodic erosion and deposition cycles. High or low organic content resulted from deposition of debris, especially *Sargassum* seaweed and "needles" (branchlets) of *Casuarina equisetifolia* trees. On the dunes themselves, and behind them, the presence of up to 5% organic matter was determined by the presence of vegetation, and the drainage of rain-water.

Day-length and emergences - Day length in Seychelles range from 11:50-12:24h. Turtle emergences can start on Cousine with day-length at about 11:57h (August) and can end during April (day-length of just over 12h). The greatest number of emergences occur during daylight hours exceeding 12:05h, peaking between 12:15-12:24h. With the beginning of daylight hour decrease (beginning of January), the number of emergences decreases rapidly. Since numbers of nests closely parallel emergences, nesting follows the same pattern (Fig 4).

Table 3 General characteristics of the Cousine Island beach.

Character	**East** **Zone 0 – 10**	**North-east** **Z one 10 – 20**	**North** **Zone 20 - 30**
Dune height in m (mean, range)	1.93(0.9–4.1)	0.98(0.3–1.7)	0.61(0.2-1.7)
Dune face slope very steep to moderately steep (%)	100	50	0
Dune face slope moderate to gentle (%)	0	50	90
Barrier of rocks on beach (%)	0	0	10
Dune ridge and base shaded (%)	0	18	65
Ground cover accessible to turtle (%)	0	50	100

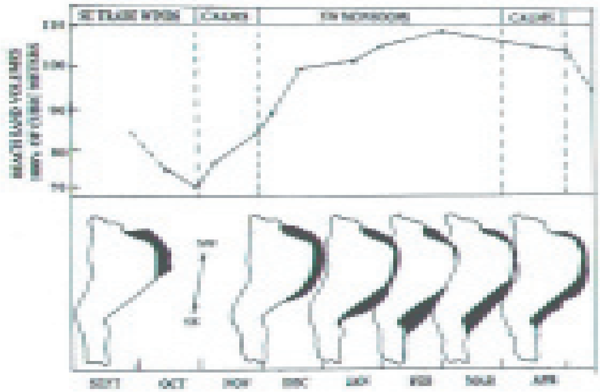

Fig. 3 Beach movement patterns on Cousine

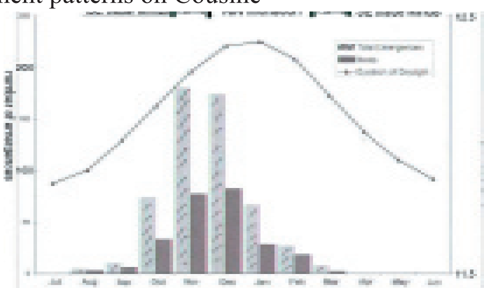

Fig. 4 Seasonal patterns of nesting on Cousine

Times of emergence - Times of turtle emergences for the 1995/96 to 1998/99 nesting seasons are given in Table 5.

First emergences were fairly evenly spread from 07:00-16:00h, with a peak from 1600-19:00h, while very few turtles (0.55%) emerge before 05:00h and after 1900h. Turtles emerging more than once on the same day, after not nesting on their first emergence, generally do so after midday. The distribution of hawksbill nesting emergences given by Mortimer and Bresson (1999) do not take second or more emergences into account, but used all emergences. Their results indicate a lower mean annual nesting emergence for the period 18:00-07:59h (13.8% compared to 18.3% on Cousine), and a higher mean for the period 14:00-15:59h (20.1% compared to 15.4% on Cousine). The remaining mean percentages of the emergences are within 2% of each other. Diamond (1976) found that nearly half the nesting attempts over two seasons on Cousin were made between 1500-1800 h, during this study 34.1% of all emergences were made during this period, which included nesting attempts as well as emergences not leading to nesting attempts.

Time of emergence related to tides - During the years 1995 to 1999, there was no significant favoured beaching time related to daily outgoing or incoming tide (χ^2=4.03, df=3, P>0.25) (Table 6). This supports Diamond (1976) who reported no significant correlation between emergences and tidal state at Cousin Island, although Garnett (1979) indicated that there was a strong tendency for hawksbills to beach close to the time of high tide on Cousin Island, but only a slight tendency towards this was found on Cousine.

Emergences related to lunar cycle - Emergences related to tidal changes of the lunar cycles are shown in Table 7. The turtles show no predeliction for emerging at any particular phase of the moon during their first emergences (χ^2=4.12, df=7, P>0.75), or for all emergences (χ^2=11.41, df=7, P>0.12). Garnett (1979) found hawksbills nesting more during neap tides than during spring tides on Cousin.

Table 5 Times and numbers of emergences (n=366 1st emergences, n=42 2nd or more on same day) during day and night, Cousine Island, 1995-1999, tagged turtles only. * indicates separations between divisions on which percentages are based.

	Time in hours (00's)														
Emerg. night	**5-6**	**6-7***	**7-8**	**8-9**	**9-10***	**10-11**	**11-12**	**12-13***	**13-14**	**14-15**	**15-16***	**16-17**	**17-18**	**18-19***		**19-20**
1st	8	11	28	21	28	34	20	20	27	23	27	54	39	24	1	1
%	5.2		21.0			20.2			21.0			32.0			0.6	
2nd	0	0	0	2	1	2	0	4	3	9	4	9	6	2	0	0
%	0.0		7.1			14.3			38.1			40.5			0.0	
Total	**19**		**80**			**80**			**93**			**134**			**2**	
%	**4.7**		**19.6**			**19.6**			**22.8**			**32.8**			**0.5**	

Table 6 Effect of daily tide changes on emergences (n=539), 1995-99, only first emergence on any day for any individual included. H = high, M = mid, L = low, n = number of emergences.

	Outgoing tide		**Incoming tide**		**Combined tides**	
	H to M	**M to L**	**L to M**	**M to H**	**M to H**	**M to L**
N	153	128	122	136	309	250
%	28.4	23.7	22.6	25.2	55.3	44.7

Effect of calms and winds on emergences - Emergences were compared with wind speed and direction for a 90 day period between 1st October and 23 December 1995, and 21-26 January 1996 (Table 8). There were no significant differences between the frequency of emergences and the frequency of the wind conditions (χ^2=6.52, df=8, P>0.58).

Most of the emergences occur during November and December, when there was a general period of variable winds and calm periods (November) and the beginning of the NW monsoons, which are lighter and more variable than the trade winds (Fig. 3). During this period the beaches are relatively stable (Fig. 3) therefore providing more stable nesting sites

Effect of rainfall on emergences - The correlation between rainfall and emergences is shown in Table 9. There is no particular rainfall period chosen by turtles in which to emerge as the frequency of the days in each category is not significantly different from the frequency of the turtle emergences for each of the categories (χ^2=9.82, df=4, P=0.044).

Table 7 Turtle emergences related to lunar cycles, 1995/6-1998/9.

*1 = new moon + one day either side; 2 = 4-5 day period before neap tide during the rising moon; 3 = neap tide and one day either side; 4 = 4-5 days before full moon; 5 = full moon + one day either side; 6 = 4-5 day period before neap tide during the waning moon; 7 = neap tides + one day either side; 8 = 4-5 day period before new moon. ** 1st emergences of any tagged turtle for any one day, or 1st emergence of a series of consecutive emergences over several days by any tagged turtle. *** All untagged emergences

Lunar condition*	1	2	3	4	5	6	7	8
Emergences n**	31	45	23	49	32	43	23	48
% of total n (294)	10.5	15.3	7.8	16.7	10.9	14.6	7.8	16.3
Emergences n***	28	31	18	34	26	23	17	21
% of total n (198)	14.1	15.7	9.1	17.2	13.1	11.6	8.6	10.6
All emergences	59	76	41	83	58	66	40	69
% of total (492)	12.0	15.5	8.3	16.9	11.8	13.4	8.1	14.0
Days per lunar condition (n=711)	69	104	70	108	68	114	69	109
% of total	9.7	14.6	9.8	15.2	9.6	16.0	9.7	15

Table 8 Effect of wind on turtle emergences. L – light; M – moderate; S - strong

Wind direction	**SE**			**SW**	**NW**		**NE**	**N**	**Calm**	**Totals**
Wind speed	**L**	**M**	**S**	**L**	**L**	**S**	**L**	**L**		
Number of days	39	8	3	2	18	2	2	1	15	90
% of total period	43.3	8.9	3.3	2.2	20.0	2.2	2.2	1.1	16.7	100
Emergences	29	4	0	2	11	2	3	2	13	66
% of total	44.0	6.1	0	3.0	16.7	3.0	4.5	3.0	19.7	100

Table 9 Correlation between selected rainfall conditions and turtle emergences

1 = rain (at least 5mm) on day of emergence; **2** = rain 1 day before ; **3** = rain 2-3 days before ; **4** = rain 4-5 days before ; **5** = rain 6 or more days before.

	Selected rainfall conditions				
	1	**2**	**3**	**4**	**5**
Days (n=751) with selected conditions, and % of total	173 (23.0%)	105 (14.0%)	134 (17.8%)	85 (11.3%)	254 (33.8%)
Emergences (n =290) % of total	73 (25.2%)	39 (13.4%)	33 (11.4%)	41 (14.1%)	104 (35.9%)

Emergence, nesting and beach localities - Emergences were highest on the north beach and lowest on the east beach, the greatest number of emergences occurring at point 29 and the lowest at point 7 (Fig 5, Table 10). The differences were significant both for emergences (χ^2=105, df=2, P<0.0001) and for nests (χ^2=131.04, df=2, P<0.0001).

Nesting and beach width **-** The greatest number of emergences and nesting incidences were on wide beaches, while the least number took place on narrow beaches (Table 11). The differences in the incidences of nests were significant (χ^2=218.6, df=2, P<0.0001)
Nesting and beach condition - There was no significant difference between numbers of nests on eroding or depositing beaches (χ^2=0.32, df=1, P>0.5) (Table 12).

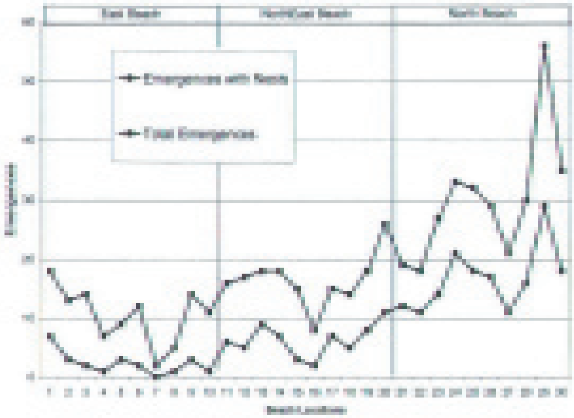

Fig. 5. Distribution of emergences on Cousine

Table 10 Emergences, nesting and beach localities

Emergence result	Beach			
	East	North-east	North	Total
Nest 23	63	167	253	
No nest	82	102	133	317
Total emergences	105	165	300	570
Emergences/total	18.4%	29.0%	52.6%	100%
Nests/ emergences	21.9%	38.2%	55.7%	44.4%

Table 11 Turtle emergences related to beach width.

Emergence result	Beach width			
	< 25m	25-50m	>50m	Total
Nests	11	49	193	253
No nests	73	53	191	317
Total emergences	84	102	384	670

Table 12 Emergences and nests related to eroding or depositing beaches.

Emergence result	Beach condition		
	Eroding	Depositing	Totals
Nests	131	122	253
No nests	142	175	317
Total emergences	273	297	570

Table 13 Emergences and nesting success related to beach profile types.

Beach Type	Total emergences	Number of nests	Nests / emergences
1	1	0	0%
2	67	18	26.9%
3	6	4	66.7%
4	166	85	51.2%
5	119	50	42.0%
6	20	5	25.0%
7	142	77	54.2%
8	49	14	28.6%
Total	570	253	44.4%

Table 14 Nesting positions on beach, A = zones 0-15, B = zones 15-30. * Indicates a significant difference between A and B in 3 different zones (χ^2, P<0.01).

	Position on beach			
	Dune and behind	Upper third	Middle third	lower third
A. Nest sites (n=46)	9 (19.6%)	33(71.7%)	1 (2.2%)	3 (6.5%)
B. Nest sites (n=180)	46 (25.5%)	97(53.9%)*	21 (11.7%)*	16(8.9%)*

Table 15 Exposure of nests to the sun, A = zones 0-15, B = zones 15-30. * Indicates that significantly more (χ^2, P<0.01) turtles nested in the full sun between zones 0-15.

	Degree of exposure to sun	
	Full sun	Shade (partial + full)
A. Nest sites (n=46)	35 (76.1%)*	11 (23.9%)
B. Nest sites (n = 180)	96 (53.3%)	84 (46.7%)

Nesting and beach profile **-** Of eight beach profile types (Fig.5), most emergences were on types 4 and 7 (54% of total emergences). The beach types with the highest nesting success rates were 3, 4 and 7 (Table 13). Although there were no significant differences between the ratio of nests to emergences on the beach profile types (χ^2=15.19, df=7, P=0.026), there were significant differences in the emergence choices for beach profiles made by the turtles (χ^2= 401, df=7, P<0.0001).

Nest localities - Nest sites were mainly in the upper third of the beach or on the dune crest (Table 14), that is, above high tide mark, and almost equally in full sun or shade (Table 15) in the area between zone markers 15 and 30, but favouring open areas between zones 0 and 15. Although there is also a significant difference between nest site position for the dune and behind, it is not included in Table 14. This is because it is very difficult for turtles to access this position between zones 0-14 (15 is accessible) due to a steep to vertical dune crest face. The results in the table clearly indicate that turtles appear to prefer nesting in the upper third of the beach and the dune, when the latter is accessible.

The area between zones 15 and 30 had all the options of shade and beach positions available to turtles wishing to nest. For the most part the other beach sections did not (see Table 3), and it was with some difficulty that the turtles were able to climb to the dune crest to nest in most of this section. Grigg (1993) said that turtles generally chose open areas in which to nest on Aride Island (Seychelles), in contrast to observations by Garnett (1978) and Frazier (1984), for Cousin island. We think that the presence or absence of vegetation is not a direct factor influencing nesting site choice, and certainly on Cousine the number of turtles nesting in or out of shade were about equal where a choice was available. We believe that nest site choice ultimately depends on the ability of the turtle to dig a nest-hole, and the characteristics of the beach. If the sand is too dry the nest-hole sides will collapse, and therefore it is likely to be soil moisture which is directly affecting nest site choice. Areas under shade or near vegetation are more likely to retain moisture than sand on open beaches, and this together with the choice of nest sites above high tide marks would explain the locations of the nest sites on Cousine. Where restricted nest site choices occur, the turtles will either not nest, or will nest in what may turn out to be marginal or poor sites.

In a few cases turtles appeared to be under stress to complete nesting, in extreme cases travelling very short distances (15m) to complete nesting and return to the sea. Such nests are subject to flooding at the next high tide, especially with a degrading beach. If there is physical stress involved (leading to an urgent need to lay eggs), then the norms of turtle nesting behaviour are likely to be disrupted.

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