Summary report on the 1973 French Frigate Shoals green turtle (Chelonia sp.) investigations*

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Background and objectives

During 1973 preliminary intensive investigations were conducted on green turtle populations at French Frigate Shoals (Figure 1), Northwestern Hawaiian Islands, in order to collect data on the little understood Hawaiian green turtle colony. Because French Frigate Shoals is the last major breeding and nesting site in the archipelago, information obtained at this location will be of direct benefit in formulating sound long range programs of protection and perpetuation for the entire colony.

Although green turtles have been tagged, measured and weighed at various times and locations in the Northwestern Hawaiian Islands, no intensive studies have been conducted during periods of reproduction. Nesting studies of this nature are essential to understanding the structure and dynamics of a marine turtle colony. The objectives of this investigation therefore were:

1. To conduct an intensive census-tagging study at East Island, French Frigate Shoals, during the peak of the nesting season.
2. To obtain information on length-width frequencies, renesting intervals and locations, fecundity, and the interrelationships of nesting and basking populations utilizing East Island.
3. To make periodic surveys of five other islands (Tern, Trig,

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* Manuscript for scientific publication in preparation.

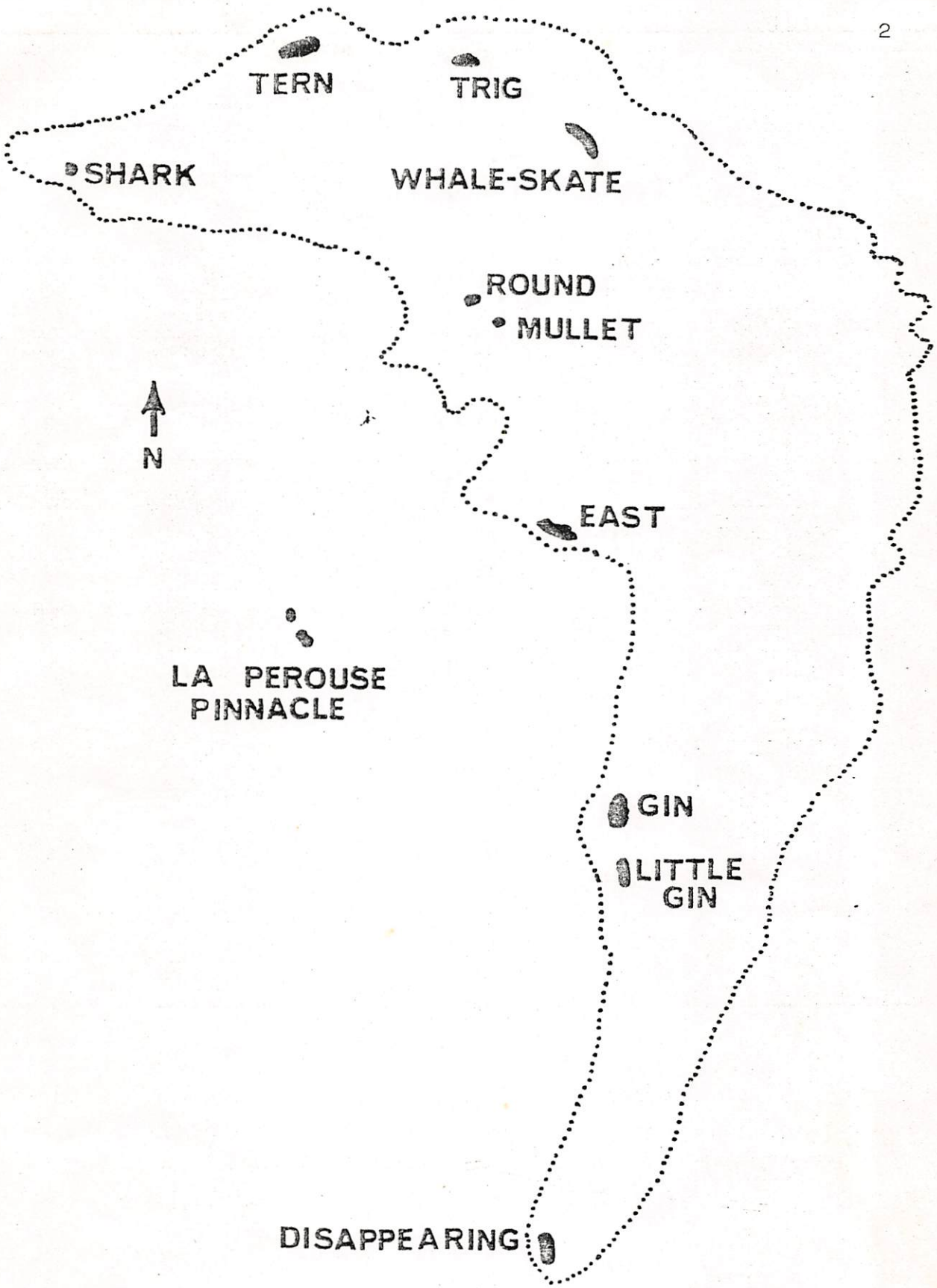


Figure 1. French Frigate Shoals (23°45'N 166°10'W), Northwestern Hawaiian Islands. 1 inch = approx. 1.6 miles.

Whale-Skate, Gin, Little Gin) within the atoll in order to determine the number of green turtles nesting and basking at these locations.

4. To collect preliminary data on egg fertility, embryo mortality and hatchling survival within nests.

June 2 - July 16 Investigation

Synopsis of activities

Seventeen areas, each approximately 50 meters in length, were established on East Island (Figure 2) for identification purposes. Specific areas were not designated for the non-vegetated sand, shell and coral point which comprises the west end of the island. Nesting activity was monitored nightly over the entire island at two hour intervals for the duration of the study. Individuals were identified by spray painting consecutive numbers on each carapace. These numbers (referred to as TC numbers) were visible from a distance, remained legible for approximately five to ten days, and were repainted when possible. Observations were made on the number of successful and unsuccessful nesting pits as well as nesting and renesting areas for each individual.

"Nesting pit" within the context of this investigation referred to the depression in the ground resultant from turtle nesting activity. As numerous pits were formed before actual egg deposition, the presence of eggs in a pit was difficult to determine unless careful monitoring of nesting progress was conducted. The alternatives, both of which were unacceptable in terms of ensuring maximum embryo survival, would have been ground probing with a pointed instrument or excavation of the area.

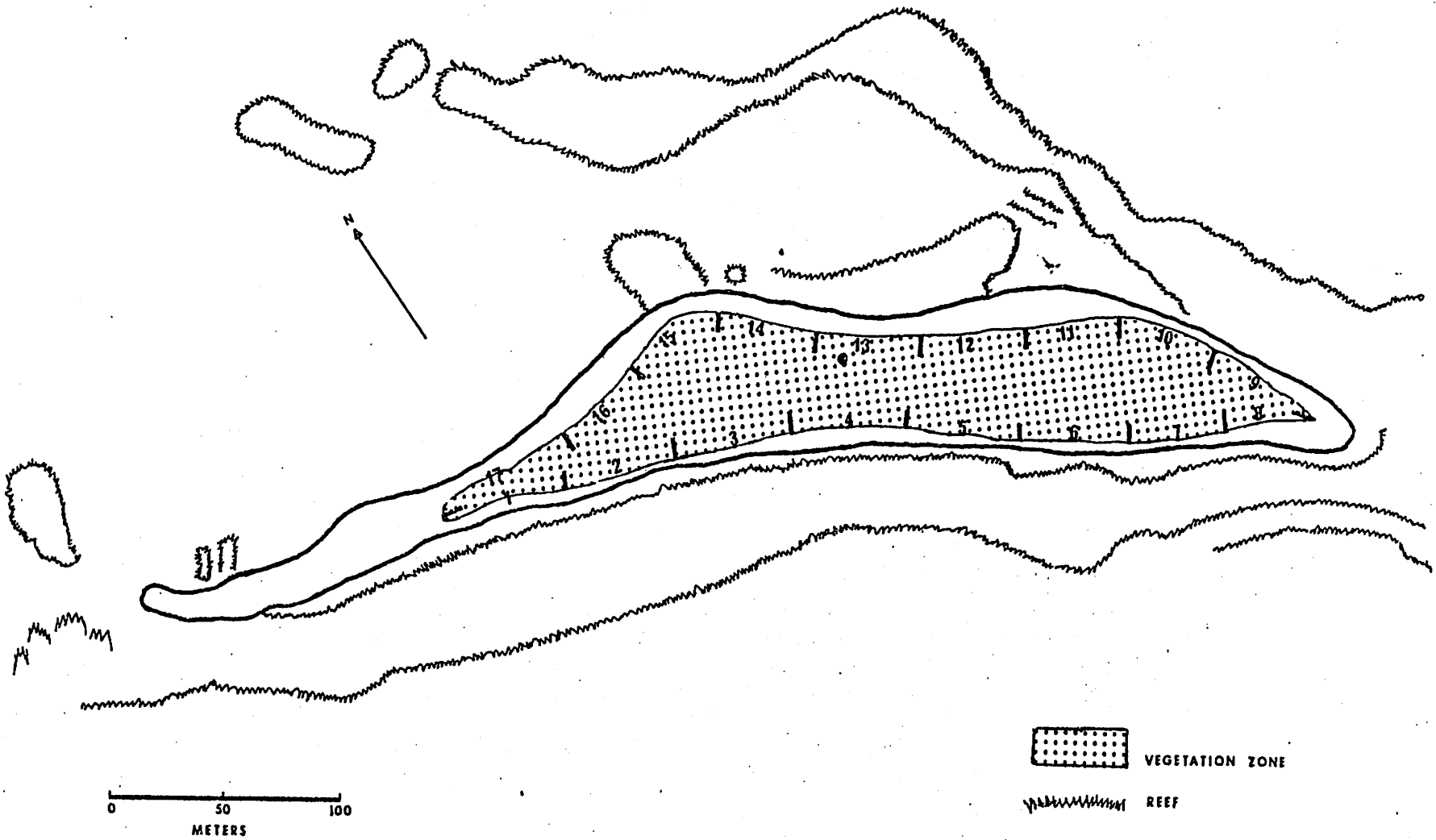


Figure 2. East Island, French Frigate Shoals. Numbers in vegetation zone represent designated areas.

During the latter cover-up stages of each nesting, or as conditions warranted, straight line and curved carapace measurements were taken and permanent numbered identification tags bearing a return address were attached to the front limbs. Egg counts were made during oviposition on a sampling of animals.

An afternoon census of basking and offshore turtles was conducted daily or as conditions permitted. Census surveys of nesting pits, baskers and offshore turtles were also periodically carried out on Tern, Trig and Whale-Skate Island, and twice on Gin and Little Gin. New pits located during each survey were marked with colored tags for subsequent recognition.

In order to evaluate the effects of the researchers' presence on the monk seal (Monachus schauinslandi), census data were also collected on this species.

Findings

East Island

During the period under investigation a total of 67 female green turtles emerged at East for nesting purposes. Fifty-one of these animals were measured and 42 were permanently tagged. Differences between the number of animals identified and those measured and tagged reflects the degree of data collecting activity that, in the investigator's opinion, could be carried out on each animal without interfering with normal behavioral patterns. All due caution was therefore taken to keep disturbances to a minimum. TC numbers, permanent tag numbers, date of tagging and measurement data are presented in Table 1. Table 2 presents the results of egg counts.

Table 1. TC number, tag number, date of tagging and carapace measurements for East Island female green turtles

TC number[a]	Permanent tag number HIMB[b]	USFW[c]	Date tagged	Carapace measurements (inches) Straight Length	Straight Width	Curved Length	Curved Width
1	632	T302	6-5-73	39¼ 99.70	29¼ 74.30	-	-
3	-	-	-	35¼ 89.54	24½ 62.23	36½ 92.71	31½ 80.01
4	630	T303	6-5	34½ 87.63	26 1/8 66.36	-	-
5	650	-	6-19	37½ 95.25	30 3/4 78.11	40 101.60	37 3/4 95.89
6	631	T301	6-5	39 3/4 100.97	29½ 74.93	41¼ 104.78	36½ 92.71
7	633,634	T304	6-5	37¼ 94.62	29 3/4 75.57	39 99.06	37 93.98
8	635	T305	6-5	35¼ 89.54	27 1/8 68.90	37¼ 94.62	35¼ 89.54
9	670	T277	7-5	35¼ 89.54	27 3/4 70.49	37½ 95.25	34½ 87.63
10	636	T253[d]	6-8	35 1/8 89.22	26 3/4 67.95	-	-
11	638	T308	6-8	37¼ 94.62	26 3/4 67.95	-	-
12	644	T310	6-11	36¼ 92.08	26 3/4 67.95	38 96.52	35¼ 89.54
13	639	T307	6-9	36 7/8 93.66	28¼ 71.76	-	-
14	640	T306	6-9	35 3/4 90.81	26½ 67.31	38 96.52	35 3/4 90.81
16	641	372[d]	6-10	35½ 90.17	27 5/8 70.17	36 3/4 93.35	33½ 85.09
17	642	699[d]	6-10	37½ 95.25	28 3/4 73.03	39¼ 99.70	34 3/4 88.27
18	645	-	6-12	37 93.98	28 5/8 72.71	39 99.06	37¼ 94.62
19	646	212[d]	6-12	34½ 87.63	28½ 72.39	36½ 92.71	35½ 90.17
20	660	T317	6-24	35 88.9	26 3/4 67.95	-	-
21	647	T309	6-12	38 96.52	26 3/4 67.95	40¼ 102.24	35¼ 89.54
22	657	T319	6-20	34 86.36	27¼ 69.22	35 3/4 90.81	33 83.82
23	649	T254[d]	6-14	36 91.44	27 3/4 70.49	38 96.52	35½ 90.17
24	652	T315	6-16	34¼ 87.00	26 3/4 67.95	36 91.44	34¼ 87.00

Table 1 (Continued)

TC number[a]	Permanent tag number HIMB[b]	USFW[c]	Date tagged	Carapace measurements (inches) Straight Length	Straight Width	Curved Length	Curved Width
29	-	-	-	37¼ 94.62	29 73.66	39¼ 99.70	35¼ 89.54
33	648	362[d]	6-17	37½ 95.25	29 73.66	39½ 100.33	36 91.44
36	-	-	-	36 3/4 93.35	29 73.66	38 3/4 98.43	37¼ 94.62
37	651	-	6-18	34½ 87.63	28 71.12	36 91.44	36 91.44
38	-	-	-	39½ 100.33	31 78.74	42 106.68	37½ 95.25
39	-	-	-	33¼ 84.46	27 3/4 70.49	35½ 90.17	35 89.00
40	656	-	6-19	37 93.98	29 3/4 75.57	39 99.06	37 93.98
41	-	-	-	32 3/4 83.19	27 68.58	35 88.9	34½ 87.63
42	-	-	-	37 93.98	30¼ 76.84	38½ 97.79	36 91.44
44	655	-	6-20	39¼ 99.70	30¼ 76.84	40½ 102.87	37 93.98
45	665	T276	7-2	33 83.82	26 3/4 67.95	35 89.00	34 86.36
46	658	T279	6-20	40 3/4 103.51	34 86.36	42½ 107.95	40¼ 102.24
48	654	T314	6-20	37 93.98	28½ 72.39	38¼ 97.16	36 91.44
49	-	-	-	38¼ 97.16	29½ 74.93	40½ 102.87	37 3/4 95.89
50	659	T324	6-23	36 3/4 93.35	28½ 72.39	-	-
51	661	T322	6-26	35¼ 89.54	27 3/4 70.49	37 93.98	35¼ 89.54
53	663	-	6-28	35½ 90.17	30½ 77.47	37½ 95.25	36½ 92.71
54	662	-	6-28	39½ 100.33	30½ 77.47	42 106.68	39 99.06

Table 1 (Continued)

TC number[a]	Permanent tag number HIMB[b]	Permanent tag number USFW[c]	Date tagged	Carapace measurements (inches) Straight Length	Straight Width	Curved Length	Curved Width
55	-	-	-	37½ 95.25	31 78.74	-	-
56	664,677	T323	7-1	37 3/4 95.89	29¼ 74.30	40½ 102.87	37 93.98
58	674	T325	7-2	35½ 90.17	30 76.20	37 3/4 95.89	37¼ 94.62
59	666	T316	7-4	33¼ 84.46	27¼ 69.22	35½ 90.17	35 88.90
60	667	T320	7-4	34¼ 87.00	26¼ 66.68	34 3/4 88.27	33 83.82
61	668	T312	7-4	34½ 87.63	25¼ 64.14	37 93.98	31 3/4 80.65
62	671	-	7-8	38¼ 97.16	29 3/4 75.57	40 101.60	36¼ 92.08
63	672	T278	7-9	39¼ 99.70	29½ 74.93	41 104.14	36½ 92.71
64	-	T280	7-11	35½ 90.17	27 3/4 70.49	37 3/4 95.89	36 91.44
65	676	T281	7-14	36¼ 92.08	28½ 72.39	38¼ 97.16	35½ 90.17
67	680	T282	7-14	38 96.52	29¼ 74.30	40½ 102.87	35½ 90.17
Mean, standard deviation and range				36 3/8 92.39 ± 1 7/8 4.76 (32 3/4 - 40 3/4) 83.19 - 103.51		38 3/8 97.47 ± 2 5.08 (34 3/4 88.27 - 42½) 107.95	35 3/4 90.81 ± 1 3/4 4.45 (31½ - 40¼) 80.01 - 102.24
				28 3/8 72.07 ± 1 3/4 4.45 (24½ 62.23 - 34) 86.36			

[a] no data for TC numbers 2, 15, 25-28, 30-32, 34, 35, 43, 47, 52, 57 and 66

[b] Hawaii Institute of Marine Biology, University of Hawaii

[c] United States Fish and Wildlife Service

[d] tag already present

Table 2. Fecundity of green turtles on East Island

TC number	Date	Observed successful nesting	Eggs deposited
8	6-6-73	1st	144
16	6-10-73	1st	110
17	7-11-73	2nd	110
18	7-10-73	3rd	119
33	7-12-73	2nd	85
63	7-12-73	1st	123
Mean, standard deviation			115 ± 19

Six turtles previously tagged by U. S. Fish and Wildlife personnel were identified as nesting on East Island. Data on these animals are given in Table 3. A comparison of carapace measurements for these animals (Tables 1 and 3) shows that little, if any, increase took place. As illustrated by TC 10 and 23 (which were originally measured in April, 1973) differences were due, in part, to technique and experimental error. TC 33 (HIMB 648, USFW 362) was subsequently reported to the principal investigator as having been captured on September 12, 1973 off the northeast coast of Oahu. This represented a minimum movement of 500 miles in 86 days or less.

A total of 340 nesting pits was formed on East during the study. Two individuals, TC 14 and 22, contributed 57 pits to this count (27 and 30 respectively) with only a single successful egg deposition by TC 14. This animal emerged for nesting purposes on 13 different nights, while TC 22 emerged on 12 nights. Normal nesting by both turtles was seriously impaired by the loss of portions of their hind limbs.

The number of successful nestings which took place in each of East's designated areas are displayed in Figure 3. Fewer occurred along the north coast (23) than along the south coast (28). Successful nesting was primarily a function of substrate quality. Although turtles regularly emerged at the non-vegetated west end, none who engaged in nesting were able to form a suitable pit due to sand slippage. Turtles often crossed this narrow end of the island from one side to the other with no hesitation or attempts at nesting.

It was common for an individual to emerge at several different areas during a single night. Rapid movement around the island in shallow waters

Table 3. Previously tagged green turtles observed nesting on East Island[a]

TC number	USFW tag number	Date originally tagged	Location	Status	Carapace measurements (inches) Straight Length	Straight Width	Curved Length	Curved Width
10	T253	4-26-73	East Island	basker	34 3/4 88.27	26½ 67.31	b	b
16	372	7-10-70	East Island	basker	35¼ 89.54	26 3/4 67.95	37 3/4 95.89	33 5/8 85.41
17	699	6-11-68	Whale-Skate Island	basker	37 3/8 94.93	29¼ 74.30	39 3/8 100.01	36 1/8 91.76
19	212	c	c	c	c	c	c	c
23	T254	4-26-73	East Island	basker	35 3/4 90.81	27 68.58	b	b
33	362, 648	7-10-70	East Island	basker	36¼ 92.08	27½ 69.85	39½ 100.33	35¼ 89.54

[a] data supplied by the U. S. Fish and Wildlife Service

[b] measurements not taken

[c] data not available

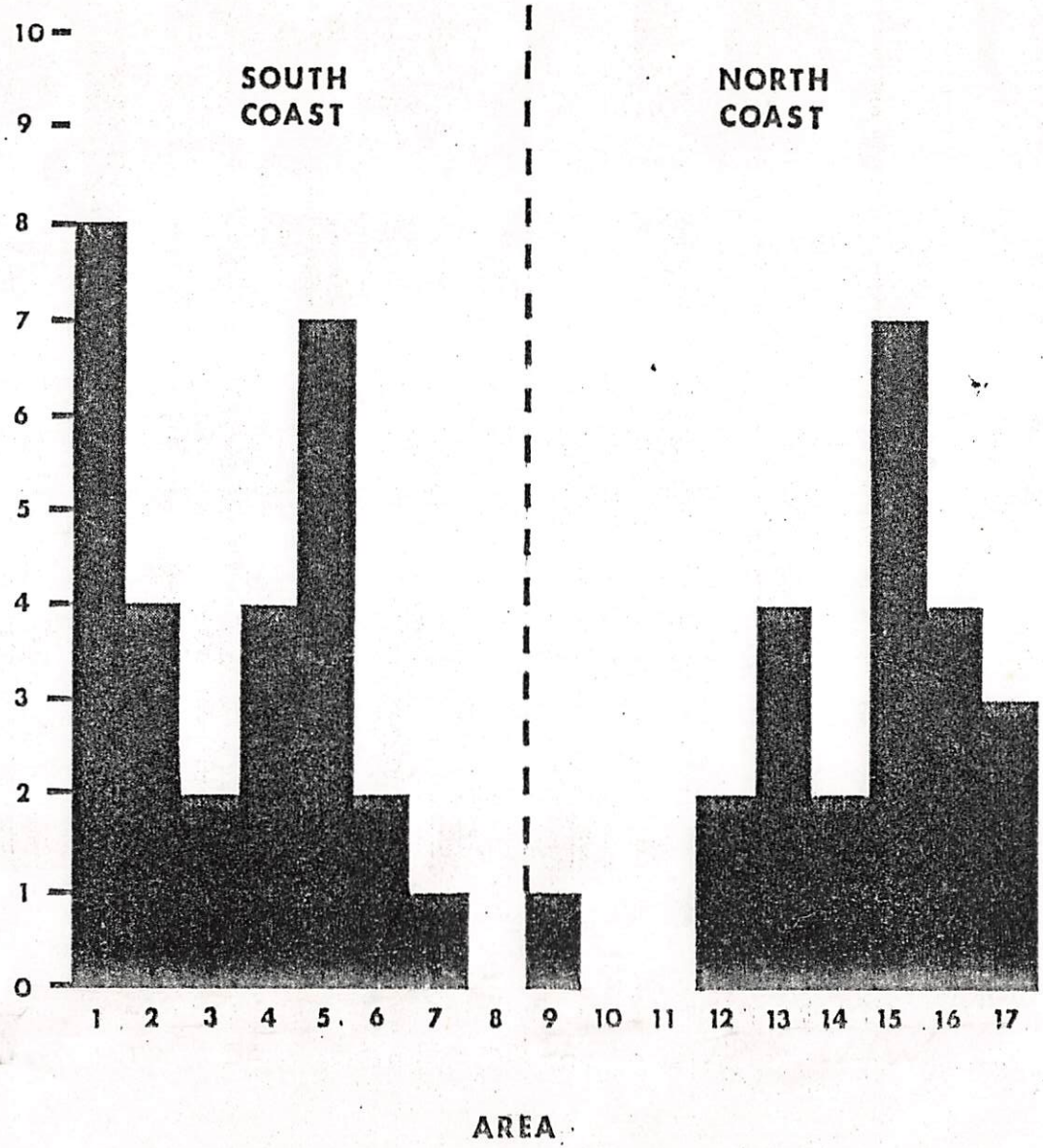


Figure 3. Number of successful nestings on East Island by area.

immediately offshore was observed to occur. Individuals also moved considerable distances once inside the vegetation zone with nesting activity taking place in two or more different areas. Return to the water after nesting was usually made along the same coast as emergence, however, movement by several animals into areas 5 and 6 was followed by a return to the water at areas 11 and 12.

Reoccurrence of successful nesting on East by the same individual averaged 18 days (range 12- 32). Four animals were observed successfully nesting three times, while nine animals were successful twice and 21 only once after coming ashore on several different nights. Thirty-three animals engaged in nesting activity but were not observed to be successful. Further studies will be necessary to determine if individuals nest on different islands within the same season.

Table 4 shows the areas of successful renesting by the same individual. Only one turtle (TC 19) renested on the opposite coast from the initial nesting. A pattern of renesting in the same or adjacent area seems to have been exhibited by most of the animals.

Data on the incidence of basking are presented in Table 5 . Animals were described as displaying basking behavior if they had emerged from the water to a position of quiescence for an extended period. All basking took place a short distance above the water's edge, well before the vegetation zone. On 23 different nights basking animals were noted between 2100 and 0600 hours, often remaining for up to five hours. All were sexually mature males except for one female (TC 14) that was observed night basking on a single occasion. Basking sites of greatest preference (for both day and night) were located at the southeast end of the island

Table 4. Areas of successful renesting on East Island by the same individual

Animal	Nesting sequence					
	1st	2nd	3	1	2	3
	South coast areas			North coast areas		
TC 1	4	4				
7				15	16	
10		2	5			
11	6	6				
13				16	16	16
16				17	15	14
17	7	1				
18	1	1	2			
19		1	1	13		
33	3	1				
44	2	1				
54	4	5	5			
56				12	15	

Table 5. Green turtle basking on East Island by date, time of day, sex and TC number

	Late afternoon census					Mid-day census				
Date	Total	Male	Female	Sex not determined	TC numbers	Total	Male	Female	Sex not determined	TC numbers
6-3-73	6	2	4	0	a	b				
6-4	1	0	1	0	a	b				
6-5	4	0	4	0	a	b				
6-6	13	8	5	0	a	2	1	1	0	a
6-7	15	9	6	0	a	b				
6-8	15	8	7	0	1,12	b				
6-9	b					3	2	1	0	a
6-10	14	2	9	3	14	b				
6-12	12	2	10	0	1,8,14,18,19	1			1	a
6-13	4			4	a	17	5	9	3	1,5,16,17,18,20
6-15	10		3	7	12,19,20	b				
6-16	12	1	11	0	1,8,12,18,19,22	b				
6-17	5	0	5	0	12,19,20	b				
6-18	11	2	9	0	5,11,12,20,22	b				
6-19	9	1	8	0	11,19,20,22,30,42	b				
6-20	3	1	2	0	20,42	0				
6-22	2	2	0	0	a	b				

Table 5 (Continued)

Date	Late afternoon census					Mid-day census				
	Total	Male	Female	Sex not determined	TC numbers	Total	Male	Female	Sex not determined	TC numbers
6-24-73	6	2	3	1	16,20,43	b				
6-25	7	3	4	0	5,23	b				
6-27	0					6	1	5	0	20,43
6-28	3	0	3	0	20,46,48	b				
6-29	4	0	4	0	20,40,43,48	b				
6-30	6	0	6	0	11,18,40	b				
7-1	4	0	4	0	20,48	b				
7-2	5	0	5	0	11,20,48,54	b				
7-3	2	1	1	0	20	7		5	2	13,16,18,22,54
7-4	2		2	0	22,48	b				
7-5	5	1	4	0	10,22,43	b				
7-6	4	0	4	0	19,22,46,50	b				
7-7	6	1	5	0	5,11,20,22,43	b				
7-8	10	2	8	0	14,19,22,23,43,46,54	b				
7-9	8	1	7	0	14,22,43,48,54	7		6	1	13,20,23,25,43,46
7-10	4	0	4	0	18,43,48,64	b				
7-11	5	0	5	0	11,22,43,46	b				
7-12	4	0	4	0	14,48	b				
7-13	2	0	2	0	19,48	6	0	6	0	14,19,43,48
7-14	1	0	1	0	14	b				
7-15	5	0	5	0	19,22,43,56	b				

[a] none observable [b] survey not taken

adjacent to areas 8 and 9. Only 26 of the 67 females identified as engaging in nesting activity were subsequently seen basking on East Island. Only one (TC 30) of the 67 animals was observed at any other island (Whale-Skate) within the atoll. Although TC numbers permitted detection of East Island nesters at other locations, no means existed for identifying turtle movement from other islands to East.

Few adults were observable in the water from shore during each survey except adjacent to the preferred basking sites. Juveniles estimated to range from 10 to 40 lbs were frequently seen immediately offshore in shallow water. Except for one sighting on June 2, no mating activity was apparent. Throughout the entire study TC numbers were found to possess long narrow scratch marks indicative of copulation or contact with coral. A survey taken in surrounding waters revealed several TC animals along the coral ledges near the southeast end of the island.

Whale-Skate Island

Table 6 presents data on basking observations, turtles sighted in the water, and number of new nesting pits during each survey. Two hundred and twenty five pits were formed during the investigation, nearly all of which were located on the southwest side of the island. Basking occurred exclusively on the northeast shore. Only one animal with a TC number (30) was seen basking on Whale-Skate, and then only on a single occasion (June 23) for a short period of time. Several baskers possessed a permanent tag but no TC number. These animals were approached without disturbance by lying flat and moving slowly in their direction. If approached from a standing position, retreat to the water always occurred. The low body

Table 6. Observations on green turtle basking and incidence of nesting pits on Whale-Skate Island (mid-afternoon surveys)

Date	Baskers				In water	Nesting pits
	Total	Male	Female	Sex not determined		
As of 6-2-73						36
6-5	16			16	5	22
6-9	19	9	10	0	2	9
6-14	7	3	4	0	2	6
6-17	1	0	1	0	5	26
6-21	10			10	8	40
6-23	2	1	1(TC30)	0	5	6
6-24	0				0	3
6-26	8	2	6	0	0	15
6-28	7	0	7	0	0	16
7-2	6	0	6	0	5	18
7-5	10	3	7	0	1	12
7-7	9	3	6	0	8	7
7-10	a					17
7-12	5	1	4	0	0	12
7-14	5	1	4	0	1	8
7-16	12	4	8	0	2	8
					Total	225

[a] survey not taken

profile presented while crawling was apparently associated with the monk seal, therefore alarm behavior was not stimulated. Turtles and seals were frequently seen basking alongside one another. On close inspection, tags showed mild corrosion and were identified as USFW. Numbers could not be read without disturbance because of their ventral position on the limb. A special effort was made during the present investigation to apply tags with the numbered side located in a dorsal position. This will allow for the easy identification of baskers during subsequent studies.

More adult animals were apparent in adjacent waters than at East Island and several juveniles (10 - 20 lbs) were regularly sighted along the west shore in shallow water.

Trig, Tern, Gin and Little Gin Island

Table 7 presents data on basking and new nesting pits at Trig, Tern, Gin and Little Gin. A total of 47 pits was formed on the north side of Trig. No nesting or basking activity took place at any other location on this island. An occasional adult was noted in adjacent waters.

Twenty-seven pits were formed on Tern, and all were along the south coast. No basking was observed on this island, however a few adults and juveniles (20 - 40 lbs) were sighted in adjacent waters.

Only two surveys were made of Gin and Little Gin due to adverse weather conditions. As indicated in Table 7, little turtle activity was apparent. No baskers were seen on Little Gin.

Other islands (Shark, Round, Mullet and Disappearing)

Hazardous landing on Shark excluded this island from land surveys. Both offshore and aerial observations did not indicate turtle activity.

Table 7. Observations on green turtle basking and incidence of nesting pits on Trig, Tern, Gin and Little Gin Island (mid-afternoon surveys)

Date as of	Trig					Tern	Gin				Little Gin
		Baskers					Baskers				
	Total	Male	Female	Sex not determined	Nesting pits	Nesting pits	Total	Male	Female	Nesting pits	Nesting pits
6-2-73					3	14				a	a
6-4	a				5	a	4	2	2	as of 6-4 10	0
6-5	8			8	0	a	a			a	a
6-9	5	2	3	0	6	a	a			a	a
6-14	1	0	1	0	3	2	a			a	a
6-17	0				8	5	a			a	a
6-19	a				a	2	a			a	a
6-21	0				6	a	a			a	a
6-23	0				7	a	a			a	a
6-24	a				a	a	0			9	9
6-26	a				a	3	a			a	a
7-1	a				a	9	a			a	a
7-2	0				12	a	a			a	a
7-5	3	2	1	0	0	a	a			a	a
7-7	0				0	a	a			a	a
7-10	4	1	3	0	0	5	a			a	a
7-12	a				a	1	a			a	a
7-14	1	1	0	0	0	a	a			a	a
7-16	a				a	0	a			a	a

[a] survey not taken

Intermittent surveys made on Round and Mullet revealed no nesting or basking activity. After the second week of July no part of Mullet remained visible above the water's surface. No visits were made to Disappearing due to the excessive distance involved (16 miles from Tern). An aerial survey of this island did not reveal turtle activity, however several baskers were noted on the unnamed sand bars between East and Gin.

Nesting season and size estimates

Preliminary land surveys conducted at the end of April showed no nesting activity or pits, however a total of 54 baskers was counted on the five major islands with 25 (22 males and 3 females) present on Whale-Skate alone. The disproportionately high number of males may indicate that this sex enters the atoll first at the onset of the season.

A nesting pit survey conducted at the beginning of the investigation (June 2 and 4) gave the following counts: East - 37, Whale-Skate - 36, Trig - 3, Tern - 14, Gin - 10 and Little Gin - 0. These values suggest that very little nesting occurred during May. Table 8 presents data on the intensity of nesting on East Island during the investigation. In general, the number of new animals on any one night was low. Fewer new turtles were observed after July 1, indicating that an identification of all individuals using the island may have been close to accomplishment. Incidence of pits on Trig and Tern (Table 7) decreased after the first week of July while less decline was apparent on Whale-Skate (Table 6). Previous observations by U. S. Fish and Wildlife personnel have indicated that nesting activity is light during August. Available information to date suggests a relatively short nesting season which extends from the

Table 8. Intensity of green turtle nesting on East Island

Date	Total number of nesting animals	New animals	Date	Total number of nesting animals	New animals
		Successful			
6-3-73	4	4	6-25	3[b]	1
6-4	6	3	6-26	3	0
6-5	3	2	6-27	6[b]	3
6-6	0	0	6-28	2	1
6-7	3	3	6-29	4	0
6-8	2	2[b]	6-30	1	1
6-9	2	2	7-1	4[b]	2
6-10	3[b]	1	7-2	4	0
6-11	5[b]	4	7-3	7[c]	1
6-12	2[b]	0	7-4	9	2
6-13	2[b]	1	7-5	5	0
6-14	3	2[c]	7-6	6	0
6-15	5	4	7-7	5	1
6-16	7[bc]	5	7-8	5	1
6-17	6[c]	4	7-9	4[c]	1
6-18	10[bc]	6	7-10	4[c]	0
6-19	8[bc]	3	7-11	4	0
6-20	10[bc]	2	7-12	3	0
6-21	5[c]	0	7-13	3	1
6-22	5[c]	2	7-14	7[b]	2
6-23	5	0	7-15	4	0
6-24	2	0			

[a] represents animals observed from 1900 hours to 0800 hours of the following day

[b] includes animal TC 14

[c] includes animal TC 22

early part of May to the latter part of August with most nestings occurring during June. After the middle of July it is probable that a major portion of the activity consists of the same individuals renesting.

Estimates of the number of nesting turtles utilizing islands other than East during the investigation are presented in Table 9 . The mean number of pits formed by each animal using East was determined and used to estimate the number of animals representative of the pits on each of the other islands. Due to the atypical behavior of TC 14 and 22, pits formed by these animals were deleted from the total count (340 - 57 = 283). Sixty-five turtles using East were therefore responsible for 283 pits or a mean of 4.3 pits per animal. Pits formed on Whale-Skate were divided by 4.3 to arrive at an estimate of 52 animals. Similar calculations were made for each of the other islands.

A tentative estimate of the total number of nesting females using French Frigate Shoals can be made from these data if the following assumptions are made:

1. The June 2 to July 16 investigation censused 80% of the nesting animals using the atoll during the 1973 season (probably a conservative estimate in view of the available evidence).
2. The 1973 nesting population size is similar to other populations using the atoll but on different reproductive cycles.
3. Nesting populations using the atoll display, on the average, three year reproductive cycles.
4. Disappearing and Shark Island do not host an appreciable number of nesting animals (further investigations at these locations will be necessary).

Table 9. Nesting turtles using Whale-Skate, Trig, Tern, Gin and Little Gin Island

Island	Nesting pits	Approximate number of animals
Whale-Skate	225	52
Trig	47	11
Tern	27	6
Gin	18[a]	4
Little Gin	18[a]	4
Total		77

[a] number of new pits observed on 6-24 doubled to account for absence of subsequent surveys

Calculations would then be as follows:

Total for islands (East + Table 9) = 144 represents 80% of estimated total for 1973 season.

1973 season total (144 ÷ .80) = 180 represents 1/3 of nesting colony.

Total nesting colony (180 X 3) = 540.

Total breeding colony size (males and females) can be estimated by assuming an equal sex ratio (540 X 2 = 1080). Little data are available on sex ratios in green turtle colonies and the cyclic reproductive patterns of males, therefore, such an estimate must be regarded with caution.

It should be emphasized that all size estimates offered are only tentative and future investigations will be necessary to confirm or adjust these values.

Monk seal observations

Total numbers of monk seals (basking and offshore) present at East Island during the investigation were found to remain relatively stable. Thirty-three surveys produced a mean of 38 $\pm$ 6 animals (15 adults, 4 sub-adults and 19 pups). Fourteen surveys at Whale-Skate gave a mean of 55 $\pm$ 9 animals (31 adults, 11 sub-adults and 13 pups). Ten to fifteen more animals were noted on this island during the last week of the investigation. Only 13 $\pm$ 6 (N = 10) seals were present at Trig which included a single pup. An occasional adult and sub-adult were seen at Tern.

Non-sleeping seals on each island appeared to be aware of the researchers' presence when in the immediate vicinity, however no alarm behavior was exhibited unless close approach was attempted. The East

Island campsite continued to be an area of abundant seal activity throughout the investigation.

Additional data collected on French Frigate Shoals' seal populations are being further analyzed and compiled for future reference.

October 11 to 17 Investigation

Synopsis of Activities

Surveys were conducted on East, Whale-Skate, Trig, Tern, Gin and Little Gin in order to locate turtle nests in which hatching and emergence had occurred. Once located, each nest was carefully excavated and the contents examined for incidence of undeveloped eggs and embryo and hatchling mortality. In addition, nest depth and substrate composition were recorded.

Census surveys were made on basking and offshore turtles at each island visited.

Findings

Nest excavations

A total of 12 nests was examined during the investigation of which eight were on East, three on Whale-Skate and one on Little Gin. No nests were found on the other islands. Locating nest sites was complicated by wind and rain which acted to remove identifying emergence signs left in the ground. Location was also made difficult because hatchlings had already emerged from the greater number of nests at a date considerably earlier than the present investigation. In many cases nests were located only after extensive excavation of suspected areas.

The substrate where nests were found on East (areas 1, 3, 5, 6 and 15) was brown in color and consisted of coral sand mixed with organic matter

derived from sea birds and decaying vegetation. Intermixed coral and shell fragments one half to three inches in length as well as fine roots were also present. This sandy organic region extended for approximately 18 to 20 inches beneath the surface before meeting an underlying stratum composed chiefly of light colored one quarter inch coral chips. The bottoms of most of the nests, which were identified by the presence of egg shells, were located in the coral chips between 21 and 30 inches underground. Except for the reduced amount of organic matter, substrate examined on Whale-Skate (southwest coast) was similar to that of East.

Substrate on Little Gin consisted entirely of fine to medium coral sand with no organic matter. Five to ten inches beneath the surface the sand was found to be moist and compact.

Results of each nest excavation are presented in Table 10. Although emergence had taken place in each nest, some live animals remained in eight of the nests examined. Except for a portion of the animals in three nests (2, 3 and 12), it was doubtful that any would have successfully emerged if unaided. In nests 2, 3 and 12 a single group of vigorous hatchlings was found clustered together a few inches below the surface in preparation for emergence. Other live animals in the three nests, as well as those in the other five nests, were found either individually or in groups of three or four animals each at various depths extending to 30 inches beneath the surface. On East and Whale-Skate (nests 2 and 3) firm sandy soil and coral fragments severely restricted hatchling movement. On Little Gin (nest 12) moist packed coral sand hampered the progression of animals located deeper in the nest. In several instances whole eggs and dead hatchlings also prevented advancement to the surface. Although no

Table 10. Results of green turtle nest excavations (October 11 - 17)

Nest location	Depth (inches)	Condition				Observations
		Eggs not developed	Partially developed embryos - dead	Fully developed and hatched - dead	Live	
1 East - area 1	29	8	1	7	44	all weak, emaciated and buried deep at various locations - deformed albino embryo
2 East - area 3	30	2	0	0	24	group of 10 close to surface - remainder buried deep at various locations
3 East - area 6	28	6	0	9	53	group of 10 close to surface - remainder buried deep at various locations - large coral chunks
4 East - area 5	21	10	8	2	4	all at nest bottom
5 East - area 15	26	1	0	14	10	all buried deep - 5 died within 1 hour
6 East - area 6	30	2	0	35	0	-
7 East - area 1	28	2	0	17	0	-
8 East - area 5	29	21	1	14	0	-
9 Whale-Skate	28	9	0	0	0	-
10 Whale-Skate	28	7	4	15	0	-
11 Whale-Skate	22	3	3	5	14	all buried deep
12 Little Gin	28	29	14	0	42	group of 14 close to surface - remainder buried deep - 7 animals with abnormal laminae counts

means existed for determining how long these animals had been trapped, yolk sac nourishment probably permitted survival for an extended period. Dead animals found fully developed and hatched were often in an advanced state of decomposition.

A combination of factors involving poor substrate conditions and eggs that had hatched late were probably responsible for non-emergence and nest mortality. The combined efforts of each member of the group is necessary for successful emergence to take place. Those hatching late did not become members of the main complement and therefore were more susceptible to entrapment.

Live animals were held until late afternoon and released on the closest adjacent beach to hatching. No predation was observed by the numerous Frigate (Frigata sp.) birds present over East and Whale-Skate. At East released hatchlings were followed in the water by the investigator for a distance. No molestation by fishes was observed, however human presence may have acted to keep predators out of the area. Strong currents along the south shore carried the turtles past the west end of the island out into deeper water.

During the course of the investigation several dead and dehydrated hatchlings were found on the surface. Imbellical scars and eyes showed signs of predation. Turnstones (Arenaria sp.) and plovers (Pluvialis sp.) have been reported to attack hatchlings at French Frigate Shoals and therefore may have inflicted the observed injuries. Ghost crabs (Ocypode sp.) are numerous at sand beaches on each of the islands and a dead hatchling was excavated from a burrow on Whale-Skate. Further studies will be needed to ascertain predation rates by the several species (sea

birds, carnivorous fishes and ghost crabs) present within the atoll.

Egg shells present in each nest were decomposed and in many pieces, therefore the number of eggs originally deposited could not be determined. Natural mortality within the nest (non-developed eggs, dead embryos and fully developed but dead hatchlings) was estimated for nests 6 through 10 by using the mean value (115 from Table 2) for the number of eggs counted during the previous investigation. An estimate was made for the remaining nests by assuming that each live hatchling not in a group near the surface represented an eventual mortality. These data have been calculated and are presented in Table 11.

Nesting and basking observations

On October 14, four fresh nesting pits formed by the same turtle were found in area 8 on East Island. One of the pits may have represented a successful nesting. Adjacent tracks appeared to be that of the green turtle (four limbs moving simultaneously), however the possible presence of other species in the area should not be ruled out. Except for this single occurrence, all islands surveyed contained no disturbed soil, vegetation or any other signs indicative of recent nesting.

Observations on turtles basking and those present in offshore waters are given in Table 12. In several instances these data undoubtedly represent the same animal being resighted on subsequent days (e.g. adult males on Trig and sub-adults off East). Relatively few turtles were apparent during the investigation. The previously tagged adult male (USFW 747) identified at Trig was found to have been originally tagged on June 14, 1968 at East. Adult female USFW 464 observed at Whale-Skate was

Table 11. Estimated natural mortality in green turtle nests

Nest	Percent mortality
1	52.2
2	13.9
3	50.4
4	20.9
5	21.7
6[a]	32.7
7[a]	16.5
8[a]	31.3
9[a]	7.8
10[a]	22.6
11	21.7
12	61.7

	Mean, standard deviation
Nests 6 - 10	22.2 ± 10.4
Nests 1-5, 11 and 12	34.6 ± 19.3
Nests 1-12	29.5 ± 16.9
East (N = 8)	30.0 ± 14.7
Whale-Skate (N = 3)	17.4 ± 8.3

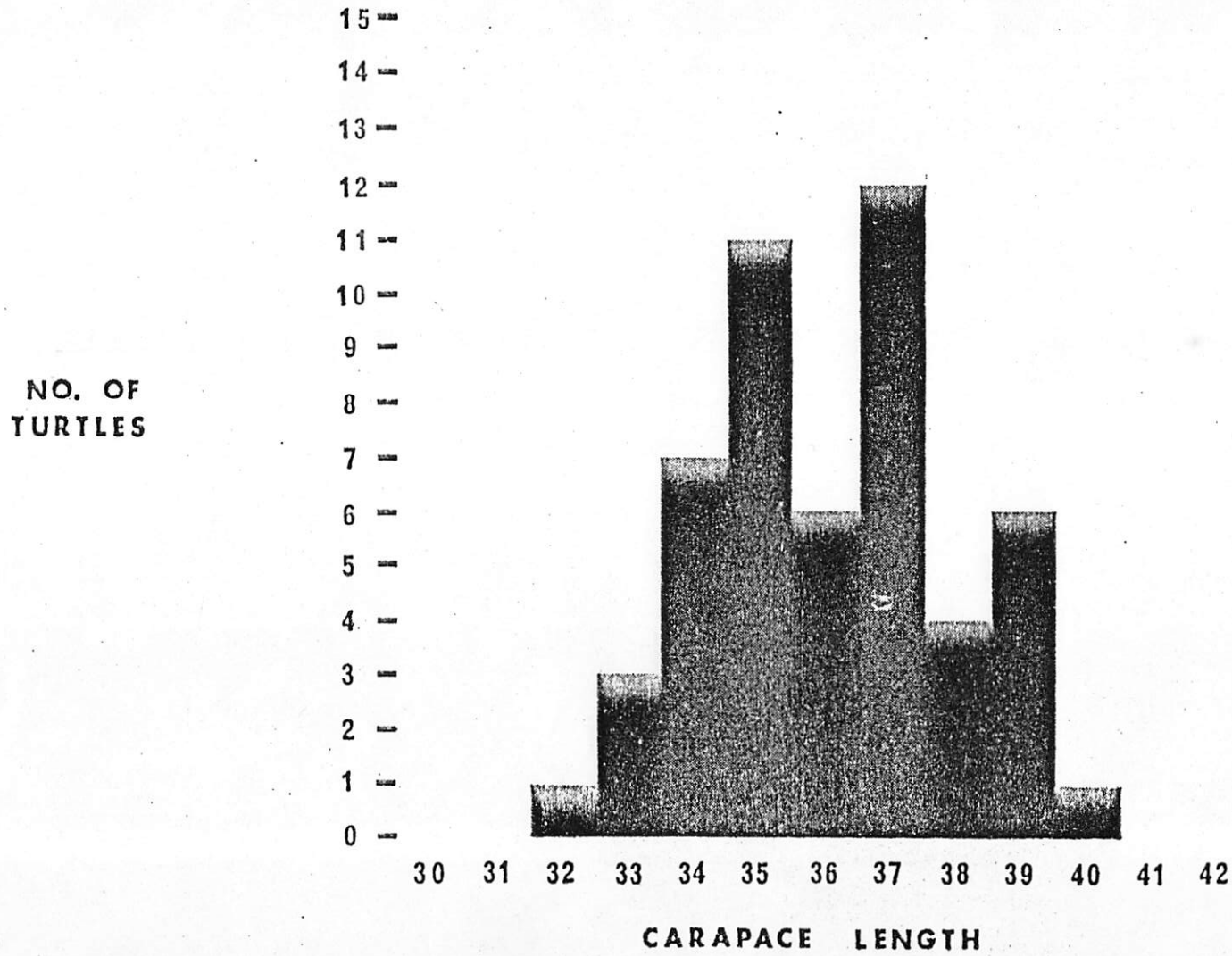
[a] no live hatchlings found in nest

Table 12. Observations on basking and offshore green turtles (October 11 - 17)

Basking - Date	Location	Stage, sex and condition	Permanent tag
10-12-73	Whale-Skate	adult male	none apparent
10-12	Trig	small female approx. 80-120 lbs.	none apparent
10-15	Whale-Skate	adult male - neoplasm on neck	none apparent
10-15	Trig	adult male	USFW 747
10-15	Trig	adult male - barnacles on carapace	none apparent
10-16	Whale-Skate	adult female	USFW 464
10-16	Trig	adult male - barnacles on carapace	none apparent
10-16	Trig	adult male	none apparent
10-16	Trig	adult male	none apparent
Offshore - Date			
10-13-73	East	2 sub-adults approx. 20 lbs.	none apparent
10-14	Gin	sub-adult approx. 10 lbs.	none apparent
10-14	East	2 sub-adults approx. 20 lbs.	none apparent
10-14	East	adult - sex unknown	none apparent
10-14	Whale-Skate	sub-adult approx. 20 lbs.	none apparent
10-15	Whale-Skate	adult - sex unknown	none apparent
10-15	Tern	sub-adult approx. 20 lbs.	none apparent
10-16	East	adult female	none apparent
10-16	East	2 sub-adults approx. 20 lbs.	none apparent

originally tagged on March 16, 1967 at Trig. Through photographic identification, an adult male which possessed a large neoplasm in the neck region was found to be the same individual seen basking on Whale-Skate several times during the June - July investigation.

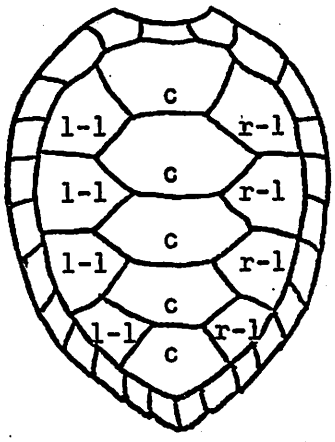
It is unknown to what extent green turtles of differing sizes reside within the atoll throughout the year. Further work will be needed to adequately define resident populations and establish migratory time schedules.



Appendix 1. Straight line carapace length distribution of nesting turtles measured on East Island.

Normal green turtle carapace laminae count:

centrals (c) - 5
left laterals (l-l) - 4
right laterals (r-l) - 4



Abnormal laminae counts (see table 10)

Hatchling no.	Centrals	Laterals	
		Left	Right
1	5	5	4
2	4	5	4
3	6	5	4
4	5	5	6
5	5	4	5
6	6	4	4
7	6	6	5

Appendix 2. Variations in laminae counts of seven hatchlings observed on Little Gin, October 14, 1973.