PRELIMINARY STUDIES ON THE EARLY LIFE HISTORY OF THE QUEEN CONCH *Strombus gigas* IN THE EXUMA CAYS, BAHAMAS

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ABSTRACT

The Caribbean Marine Research Center has initiated a study on the life history of the queen conch Strombus gigas in the Exuma Cays, Bahamas. Nursery grounds of S. gigas in the southern Exumas are described. Surveys of a major nursery area conducted from October through November 1984 resulted in a count of 570,000 juvenile 0+ and 1+-year-class conch within a total area of 386,000 m2. Average density of the conch within the area was 1.48/m2. Average density within grass beds and adjacent sand shoals was 1.72/m2 and 0.76/m2, respectively.

Modes of length-frequency curves were 8.0 cm for May 1985 and 11.0 cm for February 1986.

Seasonal distribution and behavior of deepwater adults are also described.

INTRODUCTION

The queen conch (Strombus gigas) is one of the most important marine species in the Caribbean region. It has been second only to finfish as a harvested resource for the past century (Brownell and Stevely, 1981). Its popularity as a food source, however, has resulted in depletion of the species in southern Florida, the Bahamas and most of the Caribbean and Bermuda. The species has been so depleted in Florida that the State has closed the fishery completely. In the Exuma Cays, Bahamas, adult queen conch are no longer found in shallow waters where they were once abundant (Richard Ellis, pers. comm.). Most adult conch in this area are located in relatively deep channels (>6 m) and offshore, out of reach of most breath-hold divers.

A paucity of data concerning the life history of the queen conch existed until recently (Berg, 1976; Brownell et al., 1976; Hesse, 1979; Jory, 1982; Ballantine and Appeldoorn, 1983; Wood and Olson, 1983; Appeldorn, 1985; Iversen et al., 1986; Iversen et al., 1987). The recent development of hatchery techniques has

provided a better understanding of the early life stages of S. gigas (Brownell et al., 1976; Iversen, 1983; Siddall, 1983; Appeldoorn and Sanders, 1984).

Randall (1964) made some early observations concerning predation on juvenile and adult queen conch and their migration. Recent studies suggest predation to be the most important factor in juvenile queen conch mortality (Jory, 1982; Iversen et al., 1986).

Relatively little is known, however, about the factors controlling recruitment, habitat selection, density dependency and survival during the first months of settlement.

In this paper we present preliminary biological information on the life history of S. gigas from the southern Exuma Cays, Bahamas, during 1984, 1985 and 1986.

Study Site

The southern Exuma Cays lie on the southwestern edge of Exuma Sound on the Great Bahama Bank, 110 miles southeast of Nassau, Bahamas (Figure 1). The overall study area is in the vicinity of Lee Stocking Island (23°45'N, 76°10'W), site of the Caribbean Marine Research Center (CMRC). Most of the study sites on the western side of the Cays have strong tidal currents, particularly between islands, resulting in shifting sand banks. Temperatures range from about 21° C in February to 30° C in August and September. Salinity ranges from 36 ppt to an occasional 40 ppt. The bottom is characterized by stable subtidal sand and seagrass flats, comprised primarily of turtlegrass (Thalassia testudium) and high concentrations of the calcareous algae Rhipocephalus, Penicillus and Halimeda species. Mounds produced by the shrimp Callianassa are common in the same area.

The bottom is stabilized by an organic mat consisting primarily of algae, diatoms and the rhizomes of T. testudium. The stabilized grassflats contain ooids, pellets, grapestones and fine-grain carbonates (Kendall and Dill, 1987).

The eastern side of the Cays is characterized by a typically open ocean profile (2 m - >30 m), coral reefs, sand flats and smooth rising relic coral reef mounds.

Norman's Pond Cay (Figure 2, Site A) is characterized by an old salt production pond (about 80 acres) with an effluent channel on the western side of the Cay. Sand and beachrock lie north and south of the channel entrance. A partial dike at the entrance to the channel maintains water level in the pond about two feet above the surrounding sea during the ebbing and low tides, resulting in a outward flow most of the day. For a short period during high tide, when the level of the sea is above the dike, the flow is into the pond.

The site of the Children's Bay Cay S. gigas nursery area

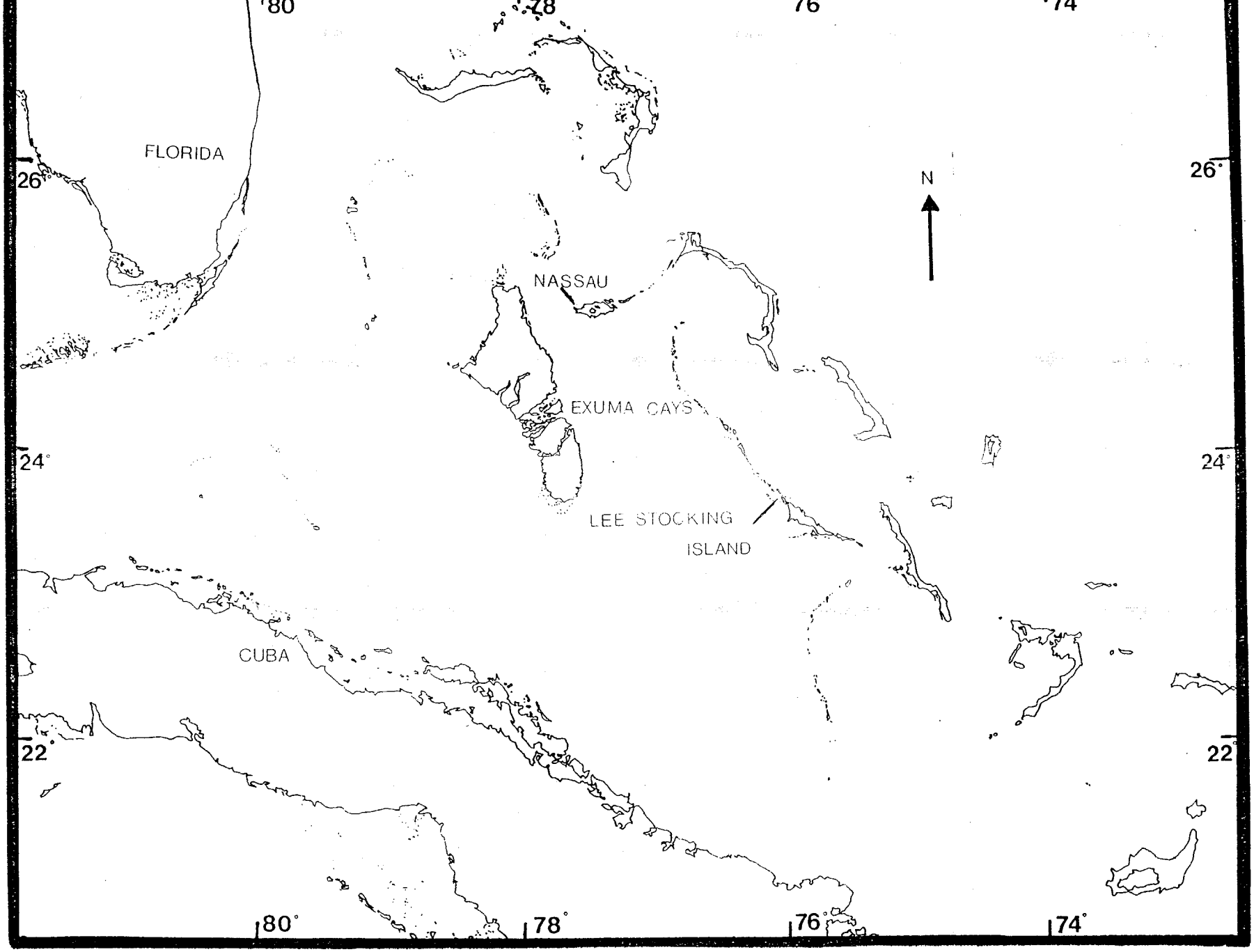

FIGURE 1. LEE STOCKING ISLAND

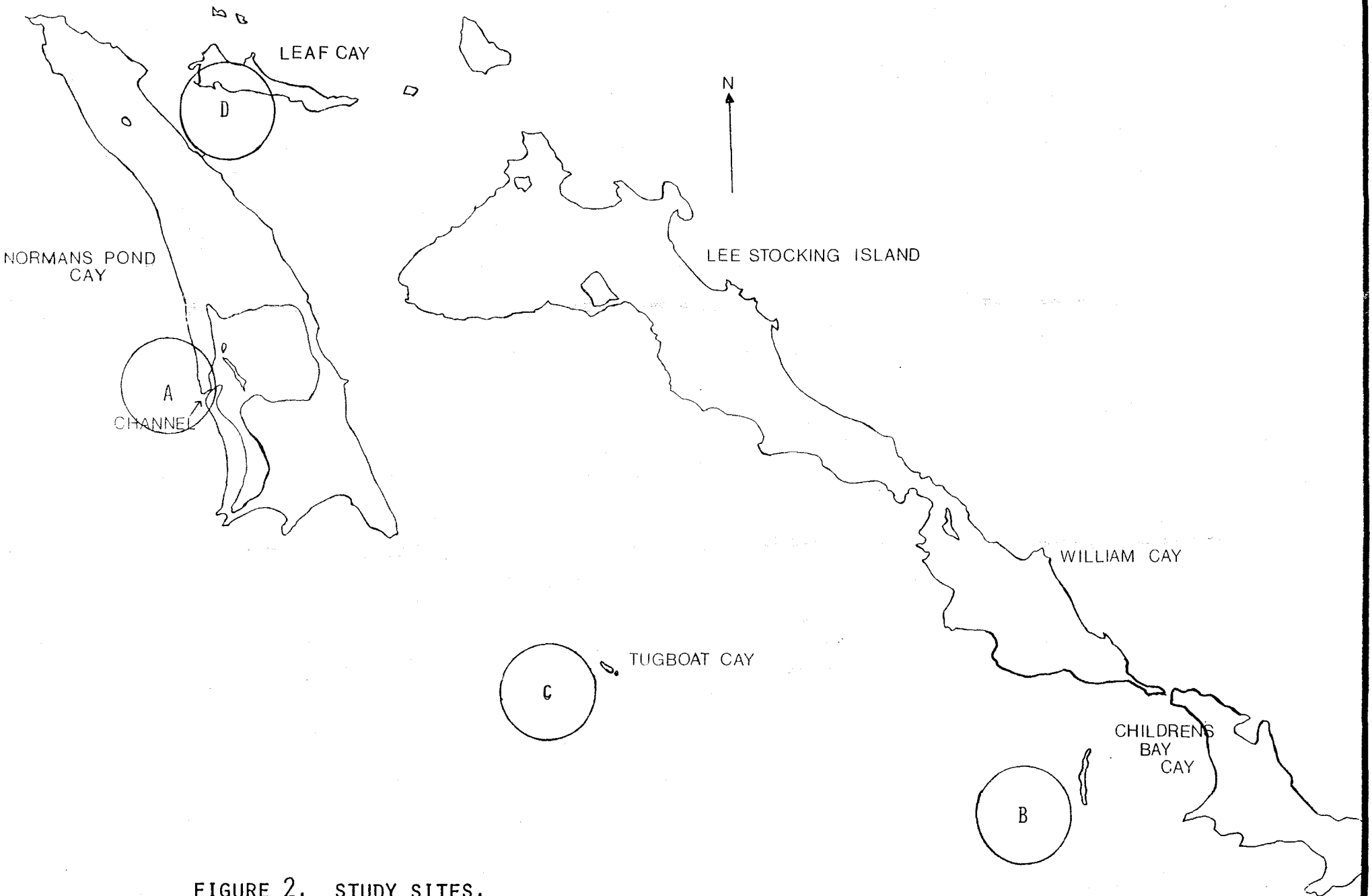

FIGURE 2. STUDY SITES.

(Figure 2, Site B) is characterized by a large bed of T. testudium adjacent to an unstable ooid shoal to the west and a moderately deep channel (>7 m) to the east. The nursery ground is primarily in a grass bed at a depth of 3 - 5 m which extends onto a shallow sand shoal (1 - 2 m).

The Tugboat Cay site (Figure 2, Site C) extends from the Cay to about 1/2 mile northwest onto a sand shoal and 1 mile west. Its major bottom characteristic is sporadic patches of T.testudium and coarse sand pebbles with a mean depth of about 4 m. Tidal currents reach about 1 knot.

The Leaf Cay site (Figure 2, Site D) is a small patch of T. testudium on the southwest side of the Cay in 4 m surrounded by deeper water. This is a minor nursery lying to the west of a major inlet.

METHODS

Standard scuba diving techniques were used to observe and measure juvenile conch. Plastic spaghetti tags were cut and tied around the spires of the conch shell.

Conch were measured along the anterior-posterior axis of the shell. Population density estimates of juvenile conch at the Children's Bay Cay site were obtained by: (1) measuring distances and direction between buoys set on the outer perimeters of the bed with a rangefinder instrument, (2) estimating area of the bed geometrically, and (3) counting and measuring conch within 20 circles each measuring 31.9 m2. Fifteen of the samples were taken on grass beds and five on the adjacent sand shoal.

Surveys of a shallow-water population of S. gigas at Norman's Pond Cay were conducted by counting all conch in blocks, each measuring 39 m north and south alongshore and 2 m east and west seaward (Figure 3).

RESULTS AND DISCUSSION

Juvenile Queen Conch

Norman's Pond Cay.

Distribution of juvenile conch (0+ and 1+ year class) at Norman's Pond Cay in July 1984 appeared to be related to the effluent from the salt pond which flows from the channel either north or south alongshore most of the day. Ambient water temperature was about 30°C and effluent temperature was about 2°C above ambient during the afternoon.

Approximately 2500 conch counted on July 18-28, 1984, were centered at the entrance to the channel and spread directly seaward about 22 m from the entrance and along the shoreline

NORTH

CHANNEL ENTRANCE

SOUTH

	A	B	C	D	E	F	G	H	I	J	K	L
1	16	13	18	32	47	38						
2	24	5	11	19	9	5						
3	28	12	28	15	12	11						
4	62	61	40	23	8	4	0					
5	7	36	9	9	2	2	0					
6	103	81	88	47	51	45	45	53	59	37	21	0
7	24	26	21	27	44	15	7					
8	42	50	36	24	29	8	2					
9	72	68	38	7	32	7	12					
10	86	56	47	23	17	9	2					
11	39	64	28	37	6	3	2					
12	47	51	34	12	1							
13	26	38	13	6	3							
14	50	27	11	1	1							
15	7	1	2	0	0							

FIGURE 3. DISTRIBUTION AND NUMBER OF JUVENILE S. GIGAS SURVEYED AT THE ENTRANCE CHANNEL TO THE OLD SALT POND LOCATED AT NORMAN'S POND CAY, BAHAMAS, 18 - 24 JULY 1984.

north and south (Figure 3). The conch were often exposed along the beach at low tide. This behavior has also been reported by Iversen et al. (1987).

By August 18th the conch started moving away from the channel entrance to the north and south. On September 9th only two conch were observed at the channel entrance, but heavy concentrations were found along the shallow shore on both sides. Ambient water temperature was 31.6°C, shoreline temperature was 31.6° C, and effluent temperature was 33.3° C.

On October 7th most conch were concentrated in two large clusters on the south side of the inlet. Waterflow from the channel at this time was northward alongshore. Ambient temperature was 26°C; effluent temperature reached 27°C by noon. This was the last observation of the Norman's Pond Cay population of conch due to an almost complete harvest by local fishermen soon after October 7th.

We presume that the association of juvenile S. gigas with the salt pond effluent was related to higher temperature and possibly higher nutrient content of effluent water (which was normally a murky green color), particularly during the late spring to early fall months. However, in July 1984 we observed that during the ebbing tide, when the channel water flows seaward, the conch moved away from the entrance as illustrated in Table I.

Table 1. Number of Conch at Norman's Pond Cay Channel Entrance and Adjacent Sites at High and Low Tide - July 1984.

	High Tide	Low Tide
North	29	95
Entrance	184	95
South	50	110

We believe this movement of conch away from the channel during the outgoing tide was due to either the strong current coming from the channel or abnormally high temperatures of effluent water occasionally found at midday.

During late summer, when temperatures of the pond effluent reached 33.3°C, the conch moved away from the channel completely but remained along the shoreline.

In October 1984 westerly storms and winds brought relatively high wave action onto Norman's Pond Cay. Following this we observed that for one week many of the young S. gigas were partially buried or gathered around small coral heads. Presumably this behavior was in response to the high energy waves in shallow water that could wash the conch onto the beach. Only

a few dead conch were found on the beach strand after the storm. Appeldoorn (1985) reported that burial of S. gigas and S. costatus was greater during periods of turbulence in Puerto Rican waters.

Children's Bay Cay.

Our pilot studies were centered around a large S. gigas nursery area adjacent to Children's Bay Cay just south of Lee Stocking Island during 1985 and 1986. This nursery area is characterized by Thalassia grass, coral rubble, stabilized sand and adjacent shifting ooid shoals. Depth ranges between 3 and 5 m and tidal currents move west and east at about 1 knot at the peak of flow.

Over a 3-year period this area remained populated with juveniles rarely exceeding 120 mm, although an occasional lipped adult was found in the nursery area. As of May 1985 no individuals measured under 60 mm. This is consistent with reports that juvenile S. gigas under 80 mm bury and are out of sight during the day (Randall, 1964; Appeldoorn and Ballantine, 1982).

Density of juvenile S. gigas in the Children's Bay Cay nursery area appeared fairly constant throughout the year. During October 29 through November 4, 1985, we counted 570,000 juvenile S. gigas in an area of 386,000 m2.

Mean density was 1.48/m2 (N=946). Density within the two distinct habitats of the nursery area was 1.72/m2 (N=824) for the Thalassia grassbeds and 0.76/m2 (N=122) on the adjacent ooid sand shoal. Comparative density measurements in the Berry Islands, Bahamas, ranged from 1.5/10m2 at Little Cockroach Cay to 19.6/10m2 at Bird Cay Channel (Iversen et al., 1987).

With the exception of Bird Cay Channel, the densities of juvenile S. gigas in the Children's Bay area of the Exuma Cays are among the highest reported anywhere. Densities of 0.001/m2 and 0.9/m2 have been reported for S. gigas populations in the Virgin Islands (Woods and Olsen, 1983) and in the Turks and Caicos (Hesse, 1979), respectively.

The size distribution of juvenile S. gigas in the Children's Bay Cay nursery area ranged from 6.0 - 12.5 cm in May 1985 to 7.0 - 15.0 cm in January 1986. The modes of the length-frequency curves were 8.0 cm for May 1985 and 11.0 cm for February 1986. Iversen's (1987) estimates of average length by ages suggest that the main population we measured at Children's Bay Cay was 1 year old. This agrees with age-size estimates in Puerto Rico (Berg, 1976) and Venezuela (Brownell, 1977), but is under Von Bertalonffy growth curve analyses of populations in the Virgin Islands (Berg, 1976; Brownell et al., 1976) and Cuba (Alcolado, 1976).

One hundred and fifty-two juvenile conch were tagged at the Children's Bay Cay site with 48 returns including 8 captured

twice. Most of the recaptures were made within 1 - 2 months of the initial tagging and all within a short distance of the site. Mean growth rate calculated from all of the returned tags was 0.12 mm/day and 0.37 cm/month. Iversen et al. (1987) reported growth rates from the Berry Islands as 0.44 - 1.63 cm/month for the summer and 0.18 - 0.30 cm/month for the rest of the year. Table 2 summarizes the tagging returns for this site.

We believe that the Children's Bay Cay site is important to the recruitment of conch into the southern Exuma Cays. Our observations indicated that the numbers of 1-year-old juvenile S. gigas remain relatively stable suggesting that new conch recruit into the area each year. The conditions that allow conch to thrive here are not understood. Obviously, food availability, good water quality, bottom sediment suitable to allow the youngest conch to bury and avoid predation, and currents that carry the pelagic veligers to nursery areas are all important to the success and survival of the juveniles. The Children's Bay Cay site offers rich Thalassia grassbeds that provide food for the conch and strong tidal currents that move water in and out of Exuma Sound.

Leaf Cay.

A small population of juvenile S. gigas was found adjacent to Leaf Cay just north of Lee Stocking Island. This group was fairly isolated and warrants only a brief mention here. Measurements made from July 1985 to January 1986 showed a size distribution ranging from 8.0 - 13.5 cm, similar to that of the Children's Bay Cay population. Modes of the length-frequency curves ranged from 10.0 cm in July 1985 to 11.5 cm in January 1986.

On June 4 and 10, 1985, 97 juvenile S. gigas were tagged at the Leaf Cay site. Fifty-nine were recaptured in the same area, including 14 captured twice. Mean growth rates calculated from tagging data were 0.14 mm/day and 0.41 cm/month. Tagging returns and growths from Leaf Cay are summarized in Table 3.

Tugboat Cay.

One of the largest juvenile conch populations in the vicinity of Lee Stocking Island was found west of Tugboat Cay. Although we do not have density figures for this area, it was generally observed that densities were not as high as in the Children's Bay Cay population, the Tugboat Cay nursery area being larger and the range of sizes and ages much wider. In August 1985 sizes at Tugboat Cay (N = 78) ranged from 8.4 - 14.7 cm (Figure 5). During the same month, sizes at Children's Bay Cay (N=100) ranged from 8.0 - 12.5 cm (Figure 4). A bimodal size distribution curve of juvenile S. gigas was evident at various times from July 1985 - January 1986 (Figure 5) due to occasional sampling of a population of smaller conch toward the eastern end of the Tugboat area. At the Tugboat Cay site conch ranged from 1 year to adult, the dominating ages being 1 and 2 years old with

Table 2. Summary of Tag Returns

Children's Bay Cay Site

Tagging Date	Size (cm)	Recovery Date	Size (cm)	Recovery Date	Size (cm)	Growth mm/day
5-02-85	9.5	6-12-85	10.0			0.12
	8.5	7-10-85	9.0			0.007
	9.5	7-10-85	10.2	8-22-85	10.7	0.01/0.11
	9.5	6-12-85	9.5			0.00
	9.5	6-11-85	10.5			0.25
	8.5	6-12-85	9.0			0.12
	9.0	6-18-85	9.0			0.00
	9.5	6-11-85	9.5			0.00
	5.5	7-10-85	6.5			0.14
	9.5	6-12-85	10.5			0.24
	8.0	6-12-85	Dead			----
	10.0	8-22-85	Dead			----
5-13-85	9.5	6-12-85	9.5	7-10-85	10.0	0/0.18
	9.0	6-11-85	9.5			0.17
	10.0	10-21-85	Dead			----
	9.5	6-12-85	10.0			0.16
	9.5	7-10-85	10.0			0.08
	8.5	6-11-85	8.5	7-10-85	9.0	0/0.17
	9.5	7-10-85	10.0			0.08
	8.0	6-12-85	8.5			0.16
	9.5	8-22-85	10.5			0.09
	9.0	6-11-85	9.0			0.00
	8.0	6-12-85	8.5			0.16
	8.5	6-12-85	9.0			0.16
5-15-85	8.5	6-11-85	9.0			0.18
	9.0	10-21-85	11.0			0.13
	6.5	10-14-85	Dead			----
	8.5	6-12-85	9.0			0.17
	8.5	6-11-85	9.0			0.17
	9.0	6-12-85	9.5	8-12-85	10.5	0.17/0.16
	9.5	6-11-85	9.5	7-10-85	10.0	0/0.17
	8.0	6-11-85	9.0			0.37
	9.5	6-11-85	9.5			0.00
	9.0	6-11-85	10.0	10-21-85	10.5	0.37/0.04
	8.5	7-10-85	9.5	8-8-85	10.0	0.18/0.17
	8.0	6-11-85	8.5			0.18
	8.5	6-12-85	9.0			0.18
	8.5	6-11-85	9.0	7-10-85	9.5	0.18/0.17
	10.5	6-11-85	10.5			0.00
	8.5	9-26-85	Dead			----

Mean growth rate = 0.12 mm/day

Table 3. Summary of Tag Returns

Leaf Cay Site

Tagging Date	Size (cm)	Recovery Date	Size (cm)	Recovery Date	Size (cm)	Growth mm/day
6-04-85	10.5	7-08-85	10.5			0.00
	9.5	7-08-85	10.0			0.15
	9.5	7-08-85	10.0			0.15
	11.5	8-09-85	12.2			0.09
	9.7	7-08-85	10.0			0.09
	9.7	7-08-85	9.8			0.03
	8.5	7-08-85	9.2	12-13-85	11.0	0.20/0.11
	10.0	7-08-85	10.3	8-09-85	10.7	0.09/0.12
	8.5	7-08-85	9.2			0.20
	10.0	7-08-85	10.7			0.20
	9.5	7-08-85	10.5			0.29
	10.0	7-08-85	10.7			0.20
6-10-85	11.2	7-09-85	11.2	8-15-85	11.3	0/0.02
	10.5	7-08-85	11.0			0.17
	10.0	7-08-85	10.5			0.17
	8.5	7-08-85	9.0	8-09-85	9.2	0.17/0.06
	9.5	7-08-85	10.0	8-09-85	10.2	0.17/0.06
	10.0	7-08-85	10.5			0.17
	8.5	7-08-85	9.5			0.35
	9.5	7-09-85	10.0			0.17
	10.5	7-09-85	10.5			0.00
	9.0	7-08-85	9.5			0.18
	9.5	7-08-85	10.1	8-15-85	10.1	0.21/0
	10.0	7-08-85	10.5			0.17
	10.0	7-08-85	10.5			0.17
	10.5	7-08-85	11.0	8-09-85	11.3	0.17/0.09
	10.5	7-08-85	10.5			0.00
	10.0	7-08-85	10.5			0.17
	10.0	7-08-85	10.5	8-09-85	10.8	0.17/0.09
	10.0	7-09-85	10.5			0.17
	9.5	11-06-85	11.8			0.15
	11.0	7-08-85	11.3	8-15-85	12.3	0.10/0.26
	10.5	8-15-85	10.9			0.06
	9.5	7-08-85	10.0	12-13-85	Dead	0.17
	9.5	7-08-85	9.7			0.11
	11.0	7-08-85	11.6			0.21
	9.5	7-08-85	10.0			0.17
	9.5	7-01-85	10.0	7-08-85	10.0	0.24/0
	10.2	7-08-85	10.7			0.17
	9.2	7-09-85	9.8			0.20
	10.2	7-09-85	10.7			0.17
	9.5	7-08-85	Dead			----
	10.5	7-01-85	11.0	7-08-85	11.0	0.24/0
	9.3	7-09-85	9.5			0.17

Mean growth rate = 0.14 mm/day

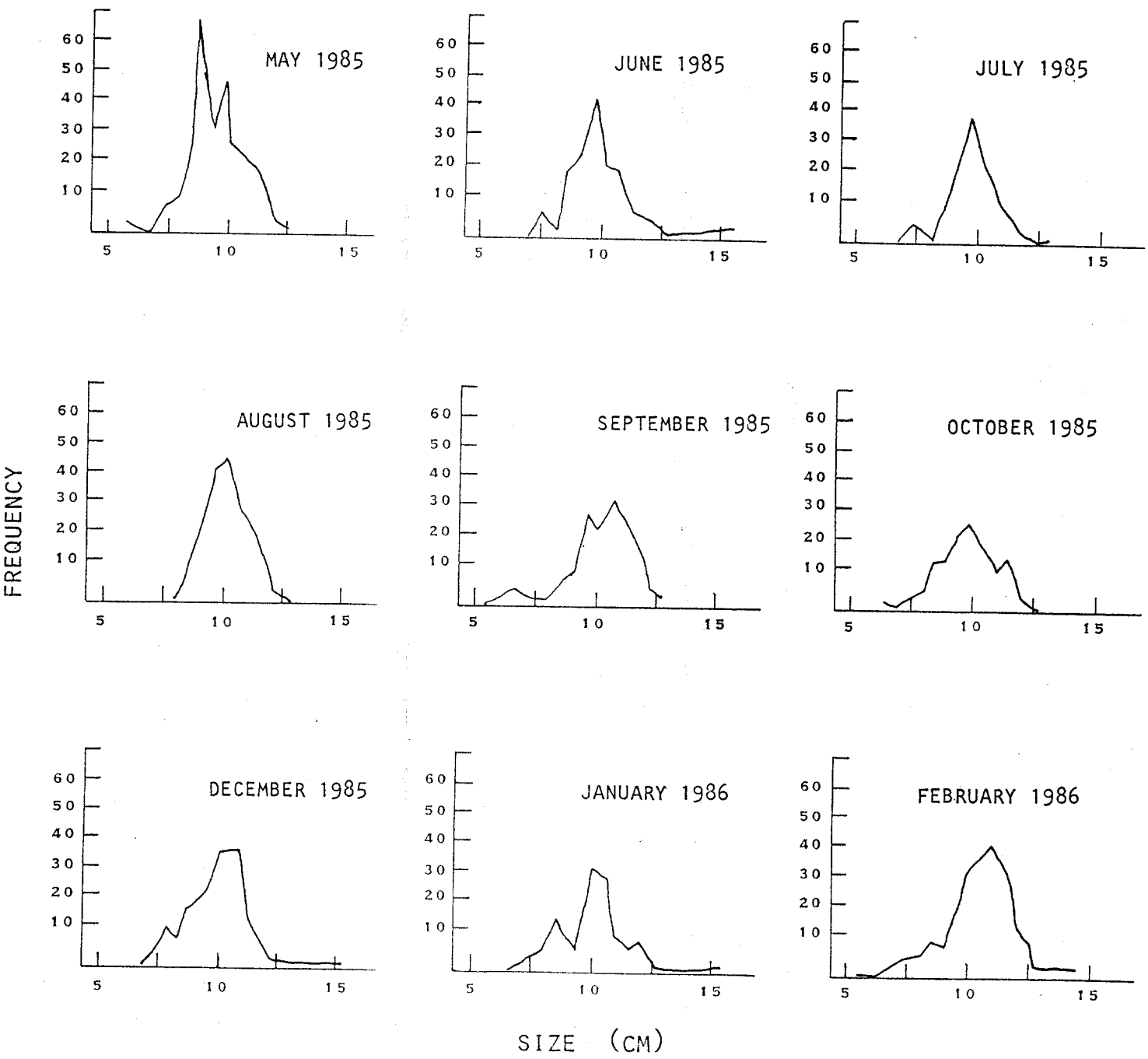

Figure 4. Size frequencies of juvenile Strombus gigas, Children's Bay Cay site, Exuma Cays, Bahamas -- 1985-86.

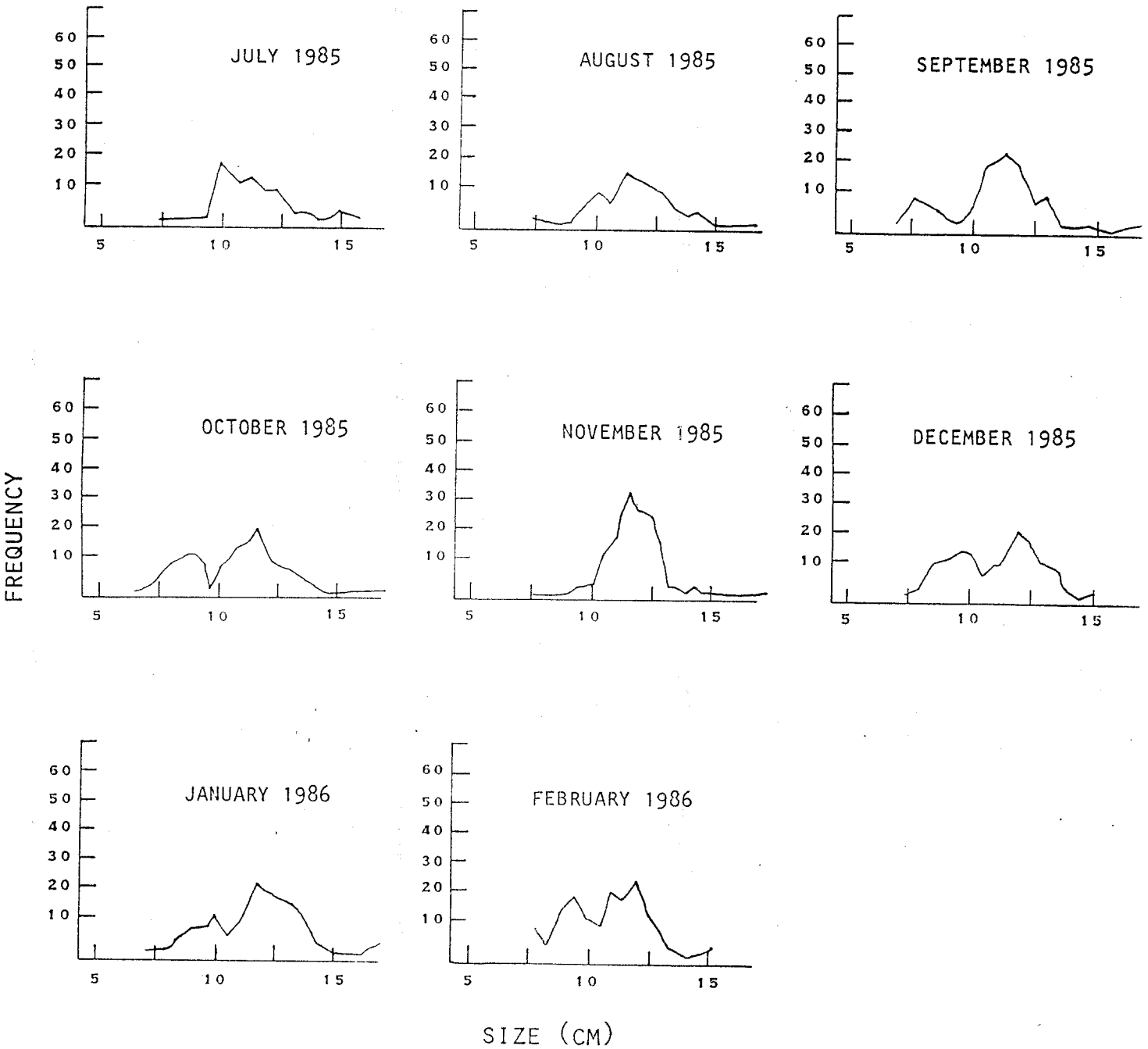

Figure 5. Size frequencies of tagged juvenile Strombus gigas, Tugboat Cay, Exuma Cays, Bahamas, 1985-1986.

significant numbers of 3+ also found. Nowhere else in the area between Leaf Cay and south of Children's Bay Cay have we found significant numbers of 2 - 3-year-old conch as were found at Tugboat Cay. Considering its close proximity, the Children's Bay Cay 1 - 2-year-old conch could migrate to the Tugboat Cay site.

Adult Queen Conch

Horseshoe Reef, Lee Stocking Island.

Adult queen conch in the Exuma Cays are now only found in relatively deep water (>6 m), generally in channels with high concentrations of Thalassia and offshore on sand and relic coral reef outcroppings.

The most significant adult population in the Lee Stocking Island area is an offshore spawning stock found at a depth of 15 - 23 m on the Exuma Sound side of the Island and ranging in size from 17.7 - 26.8 cm. They are found mainly during late spring through early fall on carbonate sand bottom partially covered by a thin algal mat adjacent to a deepwater reef (Horseshoe Reef) running parallel to, and about 1/2 mile from, the beach. This reef, with a steep vertical profile of about 5 m, is a barrier which prevents the conch from moving further inshore. During the winter months most of the offshore group have been observed on top of relic patch reefs. These large mounds have little living hard coral but are covered by algae and soft corals. The algae most likely provide food to the conch during the winter. During August 1987 some individuals remained on the offshore mounds (Allan Stoner, University of Puerto Rico, pers. comm.). We believe that a sizeable portion of the Children's Bay Cay, Tugboat Cay and other nursery conch populations in the area are recruited from the offshore spawning groups. The depth of the offshore conch population protects them from most fishing pressure allowing their numbers to remain constant and ensuring spawning success.

Studies of conch by other investigators indicate that their spawning season ranges from March to September (Randall, 1964; D'Asaro, 1965; Brownell, 1977) and that they migrate offshore in the winter (Randall, 1964; Hesse, 1979). We observed spawning behavior in this deepwater population on the sand bottom throughout spring and summer in 1985, 1986 and 1987. One small shallow water (<5 m) spawning group was also observed near the eastern shore of Norman's Pond Cay in July 1987.

In summary, the area around Lee Stocking Island is a major nursery ground for juvenile S. gigas and an excellent site for research on the species. We suggest that this site be the focus of future research concentrating on the following: 1) recruitment of young into the nursery areas, 2) description of factors necessary for the survival of the youngest conch, 3) predation, and 4) food availability.

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