Observations of Breeding Aggregations of the Queen Conch, *Strombus gigas*, in Bermuda

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ABSTRACT

Using towed-diver surveys and strategic sampling, four breeding aggregations of *Strombus gigas* were identified for study on the Bermuda platform. These aggregations were located on the periphery of the platform, a factor which may minimize their contribution to local larval recruitment. Studies of water-current patterns over these sites were initiated.

In an attempt to optimize larval retention, a program relocating egg masses to a central location on the platform has been conducted over the past two years. Year-class-one animals were observed this year for the first time; this is an encouraging development. However, stock assessments, made using data obtained from towed-diver surveys, showed no significant increase in the total abundance of *S. gigas* over the past year.

Breeding aggregations are dominated by old animals. Analysis of variance of the age structure of four aggregations, based on shell length and shell-lip thickness, showed significant differences among sites. Despite their advanced age and thick shells, these sexually active conchs are mating and producing very large masses of viable eggs.

INTRODUCTION

This paper, which presents data on breeding aggregations of queen conch on the Bermuda platform, represents a continuation of our stock-assessment research (Berg *et al.*, 1992). To understand the dynamics of a population, especially an isolated self-sustaining population, one must know population size, annual larval production, larval retention, recruitment patterns, and growth and mortality rates. With estimates of standing stock size, effective breeding-stock size, and age-specific fecundity, one can model the annual production of larvae. Since 1988 we have been estimating total population size by using data collected during survey tows. Our recent efforts centered more on defining effective breeding-stock size, seasonal breeding activity, and the effects of hurricanes on breeding activity. In addition, egg masses were collected from conch in breeding aggregations at the periphery of the Bermuda platform and were moved to a site central on the platform.

METHODS

Aggregations of breeding conch were found by divers during survey tows and by using information from local fishermen and Bermuda Fisheries' personnel. Of five aggregations discovered, four were studied extensively. These were located near Castle Roads (CR), North Rock (NR), Hogfish Cut (HF), and Ledge Flats (LF) (Figure 1). A metal stake was used at each location to mark the center of the breeding aggregation. Surveys were conducted at irregular intervals in each area by divers who used a 30.5 m line as a radius (2922.5 m^2) to swim around a metal stake. Divers were stationed along the line, and each counted the number of egg masses, the number of animals, and noted the conchs' breeding activity (mating or laying) within their section. All conchs were tagged by drilling a hole through the edge of the shell and inserting stainless-steel seizing wire through the hole. A numbered plastic tube (Floy tag) was slipped over the wire, which was then twisted tightly around the edge of the shell. Total shell length and shell-lip thickness were measured to 0.1 cm using calipers before each conch was returned to its breeding area. Lip thickness was measured at a point approximately mid-way along the shell lip and one cm in from the edge. On subsequent surveys the tag number of each conch involved in breeding activities was noted, as was the total number of tagged conchs within the circle. Observations of breeding activity were begun at Castle Roads during the summer of 1988 and continued throughout that winter. Monitoring of the other sites began in the summer of 1989. Egg masses were collected in plastic bags during each circle survey and were transported, still in the bags, in a bucket of seawater to Shelly Bay (SB) (Figure 1), where they were released over a sand bottom with *Syringodium*.

A total of 31 stock-assessment survey tows were completed in a manner identical with those done in 1988 and reported in Berg *et al.* (1992). New starting positions for the transects were chosen using two random numbers, corresponding to grid x-by-y positions, obtained from the SFSC Statgraphics 2.6 program for uniformly distributed random numbers. The locations of these tows are illustrated in Figure 1.

Water-mass movement over North Rock, Castle Harbour, and Shelly Bay was measured by following the movement of a drogue made of a 3-m-long piece of polyvinyl chloride pipe 7.6 cm in diameter. The pipe floated in a vertical position; 2.4 m of the pipe was below the water line. Atop the pipe were two 5.1-cm-diameter by 62-cm-long cylindrical radar reflectors (Mobri, Inc.) joined end to end. Movement at Shelly Bay was measured by sighting landmarks over a four-hour period, at North Rock by using a ship's radar over a 5.5-hour period, and at Castle Harbour by sighting landmarks over a two-hour period.

RESULTS

Five breeding aggregations of *Strombus gigas* were located on the Bermuda

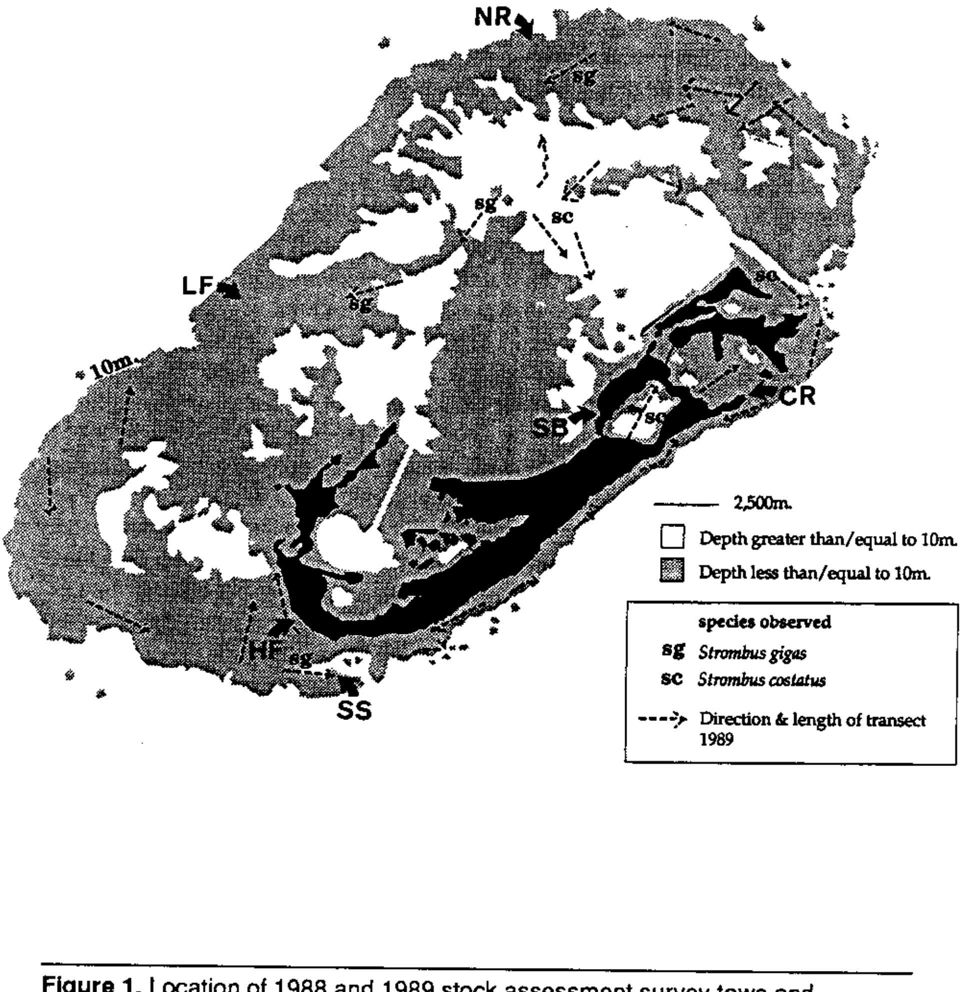

Figure 1. Location of 1988 and 1989 stock assessment survey tows and *Strombus gigas* breeding areas on the Bermuda platform. Breeding areas indicated as follows: CR = Castle Roads, HF = Hogfish Cut, LF = Ledge Flats, NR = North Rock, and SS = South Shore. Egg masses were released at Shelly Bay = SB.

platform in depths of < 10 m (Figure 1), although the South Shore site (SS) was not surveyed in detail. All of the aggregations were found at the periphery of the platform; two aggregations were found at the mouths of channels leading onto the platform (Castle Roads and Hogfish Cut). The bottom habitat at all of the sites where breeding aggregations were found consisted of coarse sediment and sparse beds of *Thalassia, Halodule,* and *Syringodium.* Water temperatures ranged from 27°C to 29°C during the observation period (July 13 to Oct. 6, 1989). Two hurricanes passed close to Bermuda during this period (Aug. 6 and Sept. 6), causing heavy seas that lowered water temperatures and moved large amounts of sand into breeding areas at Castle Roads and Hogfish Cut. Conchs were buried by this sand.

The length-frequency distribution for each breeding aggregation is given in Figure 2. For the first time in our surveys, first- and second-year-class animals were observed in Bermuda, at Ledge Flats and North Rock. Most animals were old adults, with rounded shells and thick shell lips. Shells were riddled with boring organisms and most had the coral *Siderastrea radians* encrusting them. Pairwise one-way ANOVA for mean length of adults showed significant differences ($P < 0.01$) for all but CR+HF ($P > 0.05$) (Table 1). Shell-lip thickness also appeared to differ among aggregations (Figure 3). One-way ANOVA for mean shell-lip thickness of adults without coral on the lip edge showed significant differences ($P < 0.01$) for all but CR+NR ($P > 0.05$). Two-way ANOVA (lip x length), with unequal but proportional subclasses, showed significant differences among all aggregations ($P < 0.01$).

In all aggregations, old conchs were actively mating and laying large egg masses (Figure 4), samples of which, when incubated in the Bermuda Fisheries' laboratory, released viable, actively swimming veligers. At Castle Roads, breeding activity was observed from May 8 to Aug. 14. At Hogfish Cut, no breeding activity was observed after August 11. At Ledge Flats and at North Rock, breeding activity continued from the time of first observations (July 15 and Aug. 2, respectively) to September 14. Breeding activity and egg masses were observed at all sites after the August 6 hurricane, but they were only observed at Ledge Flats and North Rock after the September 6 hurricane.

Approximately 260 egg masses were collected from the four breeding sites and released at Shelly Bay. Last year approximately 30 egg masses were translocated.

A total of 41.37 ha were surveyed, approximating 0.0575% of the total submerged platform. A total of 91 *S. gigas* were observed, for a mean density of 2.9 ± 9.3 conch/ha for the entire submerged platform (Table 2). No *S. gigas* were seen in inshore basins. Mean density for the reef platform alone was 3.3 ± 9.6 conch/ha. A total of 63 *S. costatus* were counted, for a mean density of 2.0 ± 10.41 conch/ha for the entire submerged platform. Highest densities were in the basins (29.9 ± 41.0), rather than in the reef platform area (0.19 ± 0.66 conch/ha).

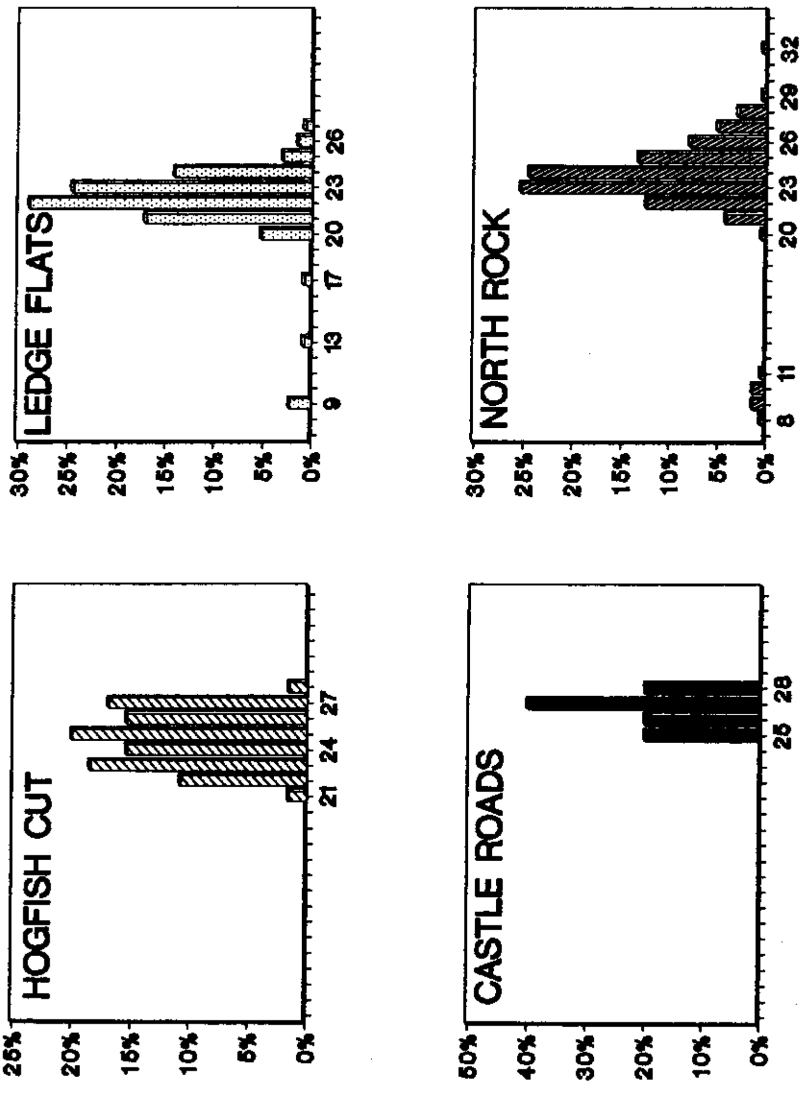

Figure 2. *Strombus gigas* shell length-frequency at four breeding areas on the Bermuda platform. Total shell length given in centimeters.

Table 1. Mean and standard deviation values for shell length (cm) and shell-lip thickness (cm) of adult *Strombus gigas* at four locations on the Bermuda platform. All values are significantly different from one another within that category at the P = .01 level, except those paired comparisons identified by footnotes a and b, where P > .05.

	SITE			
	CASTLE ROADS	HOGFISH CUT	LEDGE FLATS	NORTH ROCK
NUMBER	40	51	116	193
LENGTH				
$\bar{x}$	25.76[a]	25.48[a]	22.94	24.52
SD	1.70	1.64	1.34	1.76
THICKNESS				
$\bar{x}$	2.07[b]	1.43	2.57	2.22[b]
SD	.52	.27	.42	50

Water-mass movement, rather than wind-driven movement, was measured by the drogues at all sites. The drogue moved approximately 500 m/hr to 285° off Shelly Bay, 575 m/hr to 354° at Castle Roads, and 675 m/hr to 90° at North Rock.

DISCUSSION

All five aggregations of breeding conch that we observed were at the periphery of the Bermuda platform; two of these sites were in channels that drain the platform. The bottom habitat of breeding areas in Bermuda is similar to what has been reported from other areas (Alcolado, 1976; reviewed in Davis *et al.*, 1984); as are water temperatures that correlate with breeding activity (Hesse, 1976; Davis *et al.*, 1984; Weil and Laughlin, 1984).

Two hurricanes that occurred during summer caused a mixing of the water column and a slight lowering of temperatures for a few days. This did not terminate breeding activity (Figure 4), but heavy sand deposition at Castle Roads and Hogfish Cut buried conchs with as much as 1 m of sand. After the Sept. 6 hurricane, only 2 conchs were observed at Hogfish Cut, whereas 44 conchs were observed after the August hurricane. The North Rock and Ledge Flats sites did not appear to be affected by the September hurricane, whereas striking disruption of the seagrass bed at Castle Roads was noted. Poor visibility at Castle Roads precluded conducting a survey for several days. Hesse (1976) also noted burial of conchs by sand and the cessation of breeding activity after a September hurricane in the Turks and Caicos Islands. Davis *et al.* (1984)

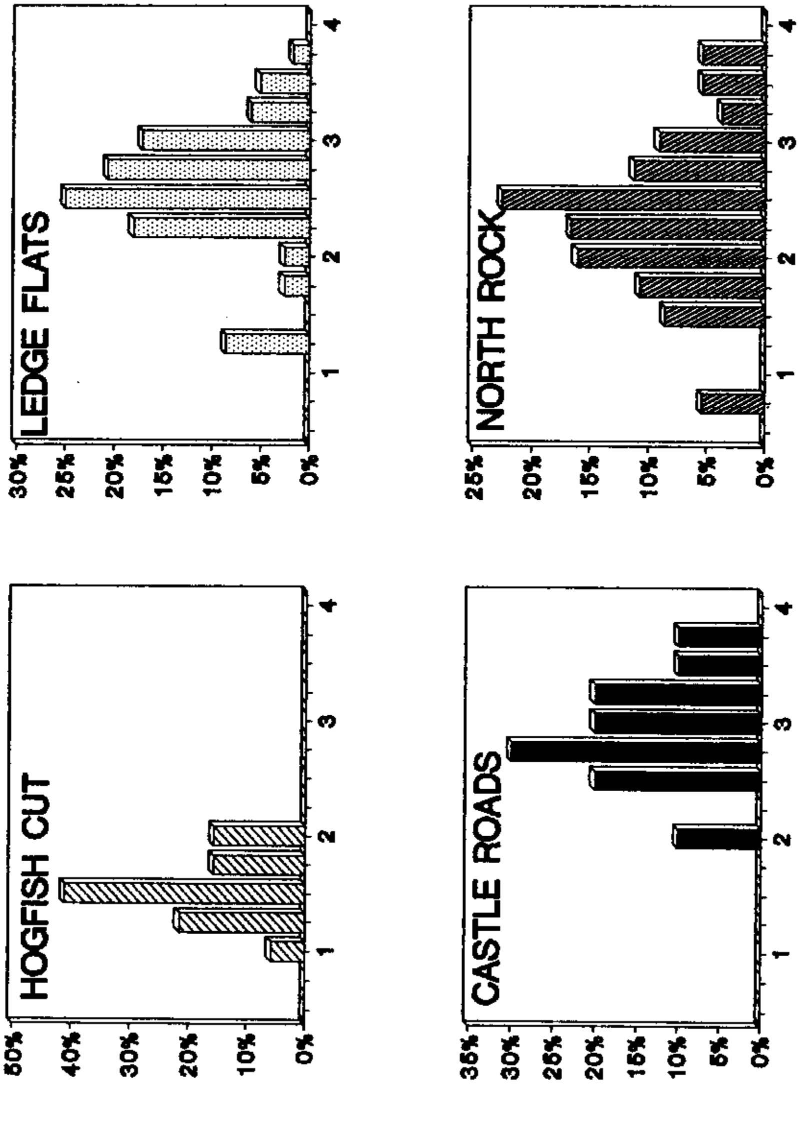

Figure 3. *Strombus gigas* shell-lip thickness frequency at four breeding areas on the Bermuda platform. Lip thickness given in millimeters.

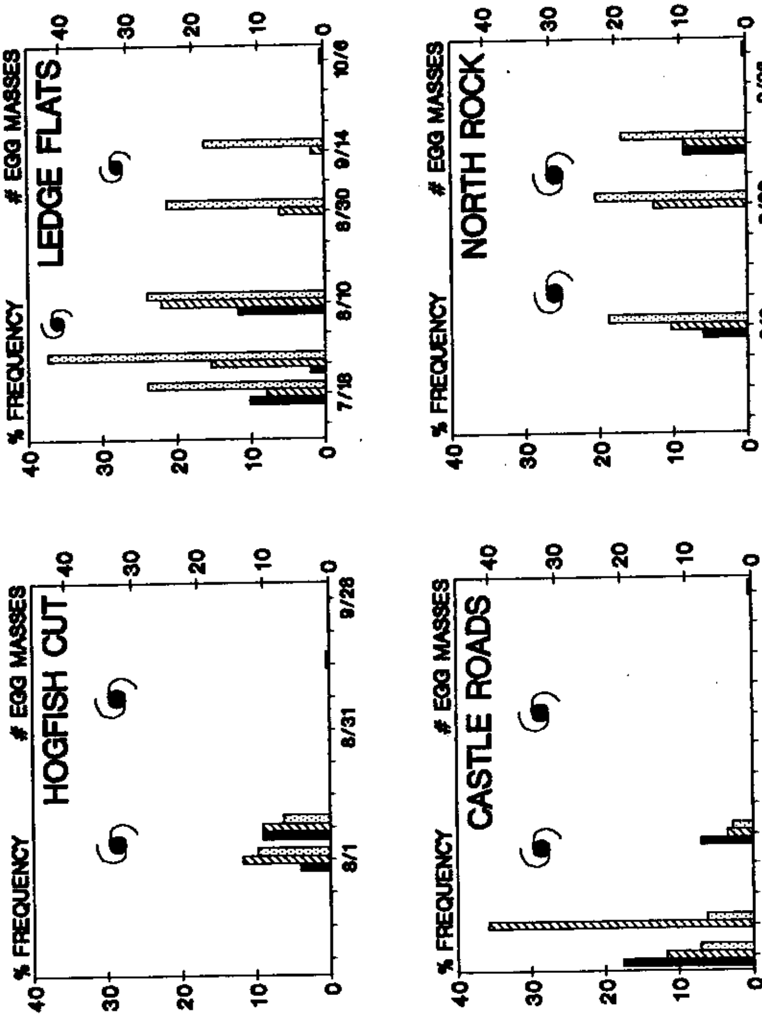

Figure 4. Breeding activity of *Strombus gigas* on the Bermuda platform in 1989. Black bars represent percentage of population performing mating behavior. Cross hatched bars represent percentage of population laying egg masses. Stippled bars indicate number of egg masses counted on that date. Hurricane symbols indicate approximate dates the hurricanes passed near Bermuda.

Table 2. Density of *Strombus gigas* and *S. costatus* in Bermuda waters during 1989. Total platform is the submerged portion only (total area minus island area). Values for density are mean ± one standard deviation; values for abundance are mean ± 95 confidence limits.

	Transects #	Total Area ha	Area ha	Surveyed %	*Strombus gigas* No. #	*Strombus gigas* Density conch/ha	*Strombus gigas* Abundance $x10^4$	*Strombus costatus* No. #	*Strombus costatus* Density conch/ha	*Strombus costatus* Abundance $x10^4$
BASINS	2	5430	2.7	0.0497	0	0	0	58	29.0 ± 41.01	11.8 ± 149.9
REEF FLAT	29	66540	38.67	0.0581	91	3.3179 ± 9.5608	15.6 ± 18.1	5	0.1924 ± 0.6584	0.9 ± 1.0
TOTAL PLATFORM	31	71970	41.37	0.0575	91	2.935 ± 9.27	15.8 ± 18.3	63	2.0323 ± 10.41	11.0 ±20.6

reported that egg-laying activity decreased during summer storms.

Adults from each aggregation appeared to be of different ages, based upon obvious differences in shell length and shell-lip thickness. These differences could occur because the conchs were recruited in different years; because source populations might be genetically different, even if they were recruited in the same year; or because of differences in food availability or habitat while the juvenile conchs were growing. Conchs collected at the North Rock site on June 29 and 30, 1983 (Berg, personal observation) were identical in mean shell length (23.89 ± 1.66 n = 50) to those collected there this summer (23.87 ± 3.17 n = 253).

At all of the sites conchs appear to be aged. Unfortunately, there is no objective way of reliably determining the age of an adult conch. We have begun an experiment to determine the age of coral growing on the shell lip, thereby estimating the age of the adult conch. Bermuda conch may be 30 to 40 years old, based on coral thickness and on conservative growth rates reported in the literature for *Siderastrea radians* (Huston, 1985; Lewis, 1989). Therefore, Bermuda's conch population consists almost entirely of geriatric animals, suggesting consistent failure of recruitment into the adult age class in recent years. Genetic analysis of Bermuda conch shows little gene flow from other populations (Mitton *et al.*, 1989), which suggests that the Bermuda conch is a relatively self-sustaining stock.

In order to increase larval recruitment, we have been moving conch egg masses to a centralized location on the Bermuda platform. The discovery of first-year-class animals gives us encouragement that this technique may be effective. A similar program was conducted in the Archipielago de Los Roques by Laughlin and Weil (1983), but they never reported the results of their work. A comparison of our stock-assessment data for 1988 and 1989 shows no statistically significant increase in stock density for either *S. gigas* or *S. costatus* during that period. Unfortunately, a large variance is inherent in mean values because of the non-uniform distribution of both species. They have been protected in Bermuda since 1978, but little recovery has been apparent for *S. gigas*. We hope that our efforts will, in fact, speed the recovery of these depleted stocks and give us a better understanding of the processes of larval dispersal and recruitment as they affect island fisheries.

ACKNOWLEDGMENTS

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