Population Assessment of Queen Conch, *Strombus gigas*, in the St. Eustatius Marine Park, Netherlands Antilles

Prepared by: Julie E. Davis
Prepared for: St. Eustatius Marine Park

September 2003

Abstract

Queen conch, *Strombus gigas*, is a large, herbivorous, marine gastropod found primarily in the Western Atlantic Caribbean region. Adult conch range in length anywhere from 143-264 mm and are typically found in depths up to 25 meters, but are more often found between 10 – 18 meters. Due to its commercial importance and high market value, queen conch populations have dwindled to extremely low levels within its range. St. Eustatius Marine Park was established in 1996 and became actively managed in 1998 to conserve and protect the marine environment surrounding St. Eustatius up to and including the 30-meter (100 feet) depth contour and regulates the conch fishery on the island. Within the park, two no-take reserves are established on both the northern and southern ends of the island. The study revealed numerous sites that are ideal conch habitat from depths of 60-110 feet. Average density of conch was 0.043 conch/m^2. A total of 86 individuals were included in the survey. The average length of conch was 22.1 cm with average lip thickness was 1.0cm. Individuals were on average 170.4 cm apart and were uniformly distributed. Density of *Strombus gigas* in St. Eustatius is three times greater than densities reported for Turks and Caicos but drastically lower than densities reported for beds at similar depths in the Bahamas and Dominican Republic. The results of this survey suggest that Statia's conch population may be very unique because the shallowest bed is located at 60 feet and conchs have been observed in depths up to 110 feet. Conch may be aggregating in certain areas for nutritional, reproductive or protective benefits. Typical locomotory and reproductive behaviour were observed during the study. Most conch surveyed met regulation size, which is encouraging because it means that juveniles are being left and allowed to reach sexual maturity thereby replenishing the population. Because catches are not reported it is not known if most conchs being collected are greater than 19cm (siphonal length) and have a fully-grown lip, which may mean immature individuals may be being removed prior to reproducing. There are numerous opportunities for further study on the *S. gigas* population in the St. Eustatius Marine Park including larval, behavioural and migration studies as well as collection of basic oceanographic data, which would have widespread applicability.

List of Figures and Tables

Figure 1**:** Map of study area, St. Eustatius, Netherlands Antilles, West Indies. Extent of survey and site number indicated for each site.

Figure 2: Mean siphonal length of *Strombus gigas* at each of four sites in the St. Eustatius Marine Park, Spring 2003. Absence of transect within site indicates absence of conch within the transect. Site 1, n = 26; Site 2, n = 25; Site 3, n = 5; Site 6, n = 33.

Figure 3: Mean lip thickness of *Strombus gigas* at each of four sites in the St. Eustatius Marine Park, Spring 2003. Absence of transect within site indicates absence of conch within the transect. Site 1, n = 26; Site 2, n = 25; Site 3, n = 5; Site 6, n = 33.

Figure 4: Mean distance to nearest conspecific neighbour (next nearest *Strombus gigas*) at each of four sites in the St. Eustatius Marine Park, Spring 2003. Absence of transect within site indicates absence of conch within the transect. Only neighbours within 500 cm were measured. Site 1, n = 11; Site 2, n = 15; Site 3, n = 1; Site 6, n = 20.

Figure 5: Mean density of conch at each of four sites in St. Eustatius Marine Park, Spring 2003. . Absence of transect within site indicates absence of conch within the transect. Site 1, n = 26; Site 2, n = 25; Site 3, n = 5; Site 6, n = 33.

Table 1: Study site description

Table 2: Distribution of *S.gigas* at each site, according to the Standardized Morisita Index of Dispersion (n = 3; df = 2).

Introduction

Queen conch, *Strombus gigas*, is a large, herbivorous, marine gastropod found primarily in the Western Atlantic Caribbean region. It is an economically important species throughout this region, both for food and the use of its shell. Queen conch are typically found in or around seagrass beds (*Thallassia testudinum*) but also frequent bottom types ranging from algae covered to coral rubble and reef. Adult conch range in length anywhere from 143-264 mm and are typically found in depths up to 25 meters, but are more often found between 10 – 18 meters. Juvenile queen conch assemblages are often found in shallower waters where there are strong reversing tidal currents (Stoner *et al.*, 1995). The optimal temperature range of queen conch is 17-32°C, optimal salinity range is 30-40ppt (Davis, 2000). Queen conch display a seasonal migration; inshore during the spring and in offshore, deeper waters in the autumn (Brownell and Stevely, 1981).

S. gigas reach sexual maturity at 3-3.5 years of age, when their flared lip is fully formed and growth in shell length ceases (Davis *et al.*, 1984; Appeldoorn, 1984). Queen conch may enter the fishery as much as one year prior to reaching maturity (Appeldoorn, 1984). Breeding takes place between March and September, changes in temperature and weather trigger the onset of reproduction (Davis *et al.*, 1984). Egg masses are laid over a period of 24-36 hours following internal fertilization (Berg, 1975). Hatching occurs 3-5 days after the egg mass is laid (Davis *et al.*, 1984). *S. gigas* have a pelagic larval stage and settle when shell length reaches 1mm (Ray-Culp *et al*., 1997). Juveniles are rarely seen in the wild because they remain buried in the sand (up to 20cm deep) until they are approximately 1-1.5 years old or 5 cm long (Iversen *et al.*, 1986). This is thought to be a predation avoidance tactic, but despite these efforts up to 60% of juveniles succumb annually to predators such crabs, lobsters, filefish and shrimps (Ray-Culp *et al*., 1997). Once conchs have emerged from the sand they are preyed upon by numerous organisms ranging from other gastropods, to crustaceans, sea stars (particularly *Oreaster reticulatus*), rays, sharks, bonefish, and even the loggerhead sea turtle (*Caretta caretta)* (Iversen *et al.*, 1986). To avoid predation *S. gigas* find safety in numbers (Ray-Culp *et al*., 1997) with conchs in vegetated areas surviving longer than conchs in unvegetated areas (Ray *et al.*, 1995). Another survival technique of queen conchs is to remain buried in sand during storms; they may remain buried for up to two weeks after a storm (Davis *et al.*, 1984). Queen conch feed on several types of algae including *Dictyota cervicornis, Enteromorpha prolifera, Spyridia filamentosa,* and *Spirulina platensis* (Creswell, 1984). *Strombus gigas* grows very slowly, even where food sources appear unlimited because they expend large amounts of energy interacting with one another (Siddal, 1984). Lip thickness and the presence/absence of a flared lip is the primary indicator of conch maturity (Krause, 1997). Generally, if the lip is thicker than 4 mm the animal is mature, <4 mm and it is not (Krause, 1997). Female conchs are generally larger than males (Berg, 1975). Conchs most commonly exhibit a 'leaping' locomotion in the wild, whereas 'pedal suction' locomotion is most common in captivity (Hesse, 1980). Queen conch are most active at night and travel an average of 2.3 meters per day (Berg, 1975; Hesse, 1980). Due to the large amount of time and energy conch spend moving it is important to realize that any study on the distribution of conch is a representation of a temporary condition (Stoner *et al.*, 1995). Low tides, low wind speed, and lack of clouds can all contribute to the death of *Strombus gigas* (Iversen *et al.*, 1986).

Due to its commercial importance ($40 million in the greater Caribbean region (Appeldoorn, 1994)) and high market value, queen conch populations have dwindled to extremely low levels within its range. Marine fishery reserves have been established in coastal marine environments around the globe in an attempt to revive these conch populations, along with many other threatened marine resources. Queen conch has been fished in St. Eustatius for many decades. Current methods see fishermen using SCUBA equipment to fill baskets with conch that are then sent to the surface. Two fishermen harvest the majority of conchs in Statia. The fishery does not currently contribute significantly to the economy as conch are consumed locally and the catch is limited.

St. Eustatius Marine Park was established in 1996 and became actively managed in 1998 to conserve and protect the marine environment surrounding St. Eustatius up to and including the 30-meter (100 feet) depth contour. Within the park, two no-take reserves are established on both the northern and southern ends of the island. The Marine Environment Regulation Sint Eustatius 1996 NR. 3 states that harvesting of conch within the marine park is only permitted without the use of SCUBA or hookah equipment, where conch shell lengths exceed 19 cm and have a fully grown lip. The ordinance also states that "it is illegal to catch more than 20 conch per person per year" and that "the collecting of conch is only permitted for own use and consumption". Fishermen are obligated by the ordinance to report their catch to the marine park manager.

Materials and Methods

Survey of Traditional Ecological Knowledge:

Local fishermen were able to lead us to the major conch beds surrounding Statia. Fishermen provided information on the location, depth, and extensiveness of conch beds as well as bottom composition at the site. Size of conchs at various beds, historical information on fishing methods and effort on the island, and status of the Caribbean conch fishery was also discussed during interviews.

Site Selection/ Exploratory Phase:

This study was conducted between March and June 2003 in the St. Eustatius Marine Park, Netherlands Antilles. Fishermen identified sites 1, 2, 3, 4, 6, 7, and 8 as conch habitat. Sites 9, 10, and 5 were identified as possible conch habitat from aerial surveys and past marine park staff experience (Fig. 1; Table 1). Each site was visited and visually surveyed using diver propulsion vehicles (DPVs), which travelled at a constant speed of 4 km/h. This phase of the study would have been impossible without the use of DPVs as most conch beds were located at a depth of approximately 80 feet thereby limiting bottom time. Extensiveness of the bed was determined using an exploratory transect pattern. Approximately four, 300 meter transects in alternating north-south and east-west directions were completed at each site. Approximately 1350 linear meters were surveyed at each site with a single conch being identifiable from approximately 4.5meters to the left and right of each transect line. Thus a total area of approximately 10, 000m^2 was visually surveyed at each site. Transects began at the extremity of a bed and were oriented in a direction, relative to landmarks and dive sites, to cover the area identified by fishermen and aerial surveys as conch habitat.

An aerial survey was conducted June 2, 2003 in an attempt to identify new sites or sites not mentioned by fishermen. The plane flew at 99km/h at an altitude ≤ 600 meters and circled Statia three times.

Table 1: Study site description

Site Number	**Site Name**	**Extent of survey**	**Longitude**	**Latitude**	**Depth (ft.)**	**Bottom Composition**
1	Outer Statia Harbour	Detailed	17° 28.46'N	62° 59.81'W	80-90	Coral rubble
2	West of Barracuda Reef	Detailed	17° 27.34'N	62° 29.55'W	80-90	Coral rubble/sand
3	Zeelandia	Detailed	17° 30.99'N	62° 58.69'W	70-80	Sand/algal cover
4	Venus Bay	Exploratory	17° 31.13'N	62° 58.92'W	75-85	Sand/algal cover
5	STENAPA Reef	Exploratory	17° 29.08'N	62° 59.45'W	65-70	Sand/algal cover
6	Drop Off	Detailed	17° 27.67'N	62° 58.42'W	60-70	Sand/algal cover
7	Outer Jenkins Bay	Exploratory	17° 30.75'N	62° 29.82'W	90-110	Sand/algal cover
8	Botanical Garden	Exploratory	17° 27.95'N	62° 56.91'W	60-65	Reef/coral rubble/sand patches
9	Corre Corre	Exploratory	17° 28.68'N	62° 56.58'W	65-75	Reef/coral rubble/sand patches
10	English Quarters	Exploratory	17° 29.82'N	62° 57.37'W	75-80	Reef/coral rubble/sand patches

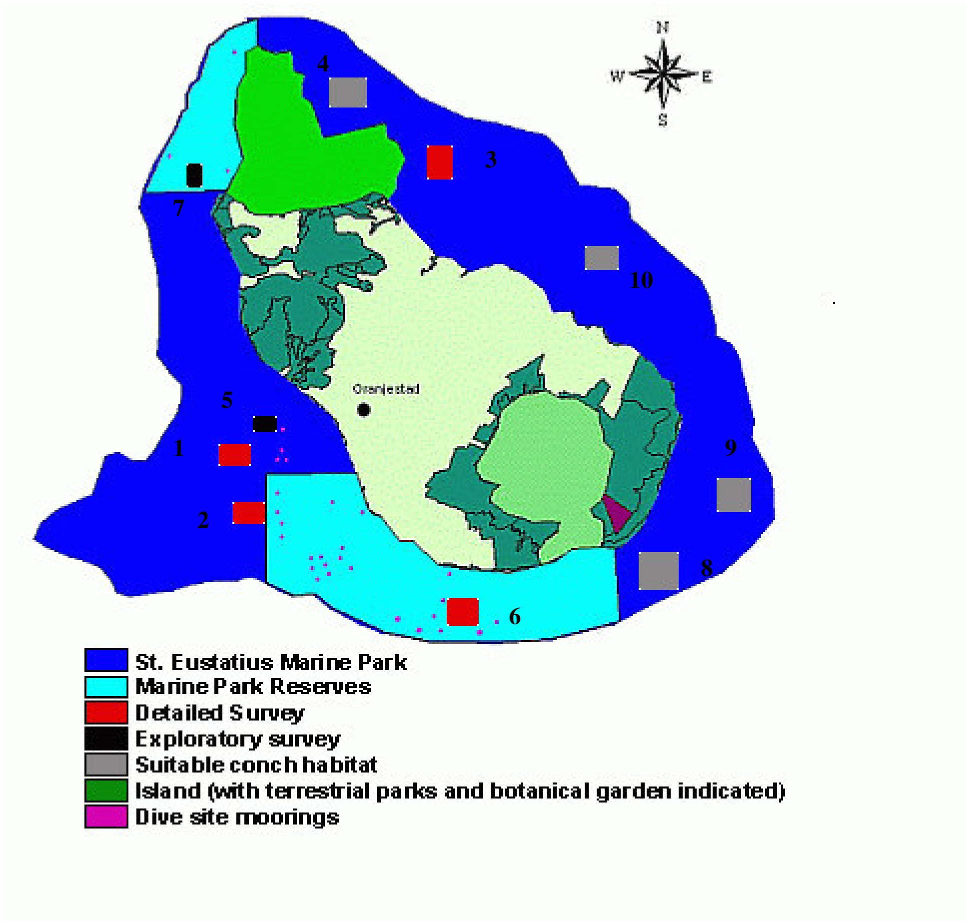

***Figure 1*:** Map of study area, St. Eustatius, Netherlands Antilles, West Indies. Extent of survey and site number indicated for each site (Table 1).

Detailed Survey Technique Used on Identified Beds:

Each site where live conchs were present during the exploratory phase was returned to during this phase of the study and surveyed in detail between April and July 2003. 3, 20 meter transects were surveyed at each site. The starting point of transects was determined by swimming a random number of kick cycles from the anchor line in a random compass bearing direction. This method ensured a maximum area of the bed was covered and that the sampling would be as representative as possible of the environment. Ten meters to each side of the 20 m transect line was surveyed resulting in a total of 1200 m^2 of seafloor being assessed at each site. The following measurements were noted for each live conch in the 20 m X 20 m area: siphonal length (from tip of the spire to the extremity of the opposite end of the shell), length of the lip, thickness of the lip, and distance to the next nearest conch within 500 cm. Video transects were recorded at most sites to allow park personnel to monitor changes in bottom composition over time. Conch behaviour was recorded and noted during this phase of the study.

Statistical Analysis:

One-way ANOVA was used to test for significant differences in siphonal length, lip thickness, and nearest neighbour distance between sites and between transects. Bonferroni post-hoc test was used to detect significant differences in siphonal length, lip thickness, and nearest neighbour distance between transects. Homogeneity of variances was examined using Levene's test, and heteroscedastic data were transformed using a natural log or square root transformation. A significance level of 0.05 was observed. All statistical analyses were done with SPSS Base 11.0 for Windows.

The Standardized Morisita Index of Dispersion was used to determine the distributional pattern of *Strombus gigas* at each site. This allowed us to determine if conch were distributed randomly, uniformly, or in clumps over the bed.

Standardized Morisita Index of Dispersion (Morisita, 1959), calculated as,

$$\mathbf{I_d = n\,[\sum x^2 - \sum x / (\sum x)^2 - \sum x]}$$

Then two critical values are calculated using the following formulas:

$$\textbf{Uniform index} = \mathbf{M_u = \chi^2_{0.975} - n + \sum x_i / (\sum x_i) - 1}$$

$$\textbf{Clumped index} = \mathbf{M_c = \chi^2_{0.025} - n + \sum x_i / (\sum x_i) - 1}$$

where $\chi^2_{0.975}$ or $\chi^2_{0.025}$ = value of chi-squared with n-1 degrees of freedom

n = sample size or number of transects
$\sum x$ = sum of the transect counts = $x_1 + x_2 + x_3 \ldots$
$\sum x^2$ = sum of the transect counts squared = $x_1^2 + x_2^2 + x_3^2 \ldots$

The standardized Morisita Index (I_p) can then be calculated depending on which of the following four cases is met:

when $I_d \geq M_c > 1.0$ then $I_p = 0.5 + 0.5\,(I_d - M_c / n - M_c)$

when $M_c > I_d \geq 1.0$ then $I_p = 0.5\,(I_d - 1 / M_u - 1)$

when $1.0 > I_d > M_u$ then $I_p = -0.5\,(I_d - 1 / M_u - 1)$

when $1.0 > M_u > I_d$ then $I_p = -0.5 + 0.5\,(I_d - M_u / M_u)$

Results

Exploratory Phase:

This phase of the study revealed numerous sites that are ideal conch habitat. Sites 4, 8, 9, 10 (Fig. 1) although very similar in composition to sites 1, 2, 3, and 6 (Table 1) did not have conch inhabiting them at the time of the study. Sites 4 and 8 were referred to by fishermen as prominent places to catch conch. Site 9 is in the general vicinity of an area previously illegally harvested by fishermen from a neighbouring island. Conchs were absent from all of these sites at the time of the study. These sites were visited approximately three times over a period of three months with each visit yielding zero conchs. Sites 5 and 7 are assigned a different classification than other exploratory sites because they are sites that have conchs but present other limitations. Site 7 was referred to as a conch bed at a depth of 80 feet. Upon exploration with diver propulsion vehicles conchs were not found until depths of approximately 107 feet. Due to decompression limits it was not feasible or particularly safe to conduct a detailed survey, that would have been comparable with other conch beds, at this site. Survey of Site 5 revealed numerous dead conchs (<10). The absence of a hole in their shell for removal of the meat would suggest these animals may have died of other causes or that the shells were dumped overboard from a passing vessel. Due to lack of certainty of where the shells may have originated a detailed survey was not conducted at this site.

<u>Detailed Survey</u>:

Average density of conch was 0.043 conch/m^2 (min. = 0, max = 0.061) (Fig. 5). Conchs were most abundant at Site 6 and Site 1. A total of 86 individuals were included in the survey. The average length of conch was 22.1 cm (min. 16.0 cm, max. 24.6 cm). Average lip thickness was 1.0cm (min. 0.18 cm, max 1.9 cm). There was a significant ($f = 4.782$; $p = 0.004$) difference in the siphonal length of *Strombus gigas* between each of the four sites (Fig. 2). A significant ($f = 2.464$; $p = 0.02$) difference in siphonal length also existed between transects at each of the sites. The greatest difference in siphonal length was detected between conchs at sites 3 and 6 and sites 1 and 2. That is, Zeelandia and Drop-Off conchs displayed similar siphonal lengths. Outer Statia Harbour and West of Barracuda Reef conchs also displayed similar siphonal lengths. But these two classes differed significantly from one another ($p = 0.221$-0.719). These same classes of conchs also displayed significant ($f = 5.539$; $p = 0.002$) difference from each other with regard to lip thickness (Fig. 3). Unlike siphonal length, which was relatively uniform across transects, lip thickness varied greatly even between transects conducted at the same site ($f = 7.733$; $p = 0.001$). With lip thickness as an indicator of age we found that 8% of all conchs surveyed were not fully mature.

Individuals were on average 170.4 cm apart (min. 24 cm, max. 330 cm). No significant ($f = 1.124$; $p = 0.350$) difference was detected in the distance to the next nearest conch (nearest conspecific) between sites (Fig. 4). However, when transects were compared a significant ($f = 3.773$; $p = 0.002$) difference was detected. Conchs were particularly close together on one transect at Site 6 (Drop Off) which resulted in a significant ($p = 0.036$) difference between this transect and all others in the study.

The Standardized Morisita Index of dispersion revealed that *Strombus gigas* was uniformly distributed at all sites with the exception of Site 2 (West of Barracuda Reef), where there was 95% confidence that *S. gigas* was distributed in a clumped pattern (Table 2).

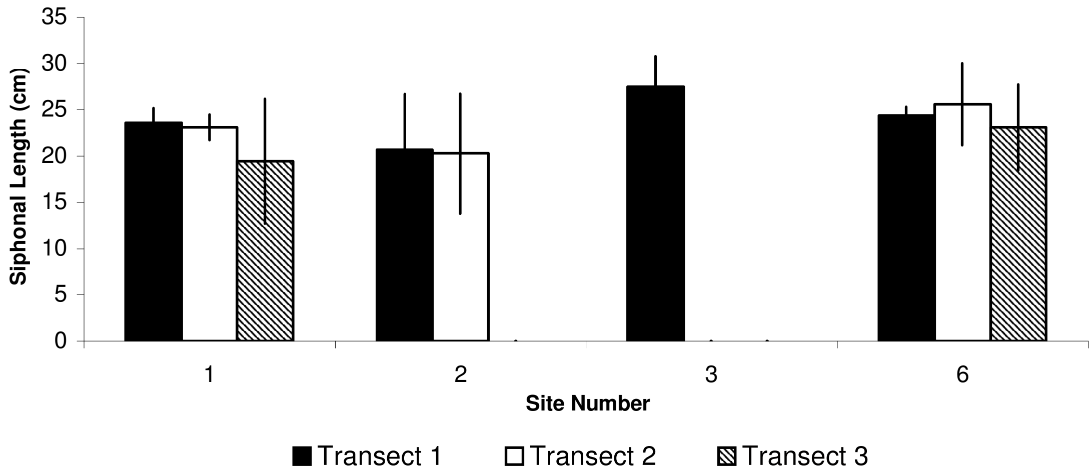

Figure 2: Mean siphonal length of *Strombus gigas* at each of four sites in the St. Eustatius Marine Park, Spring 2003. Absence of transect within site indicates absence of conch within the transect. Site 1, n = 26; Site 2, n = 25; Site 3, n = 5; Site 6, n = 33.

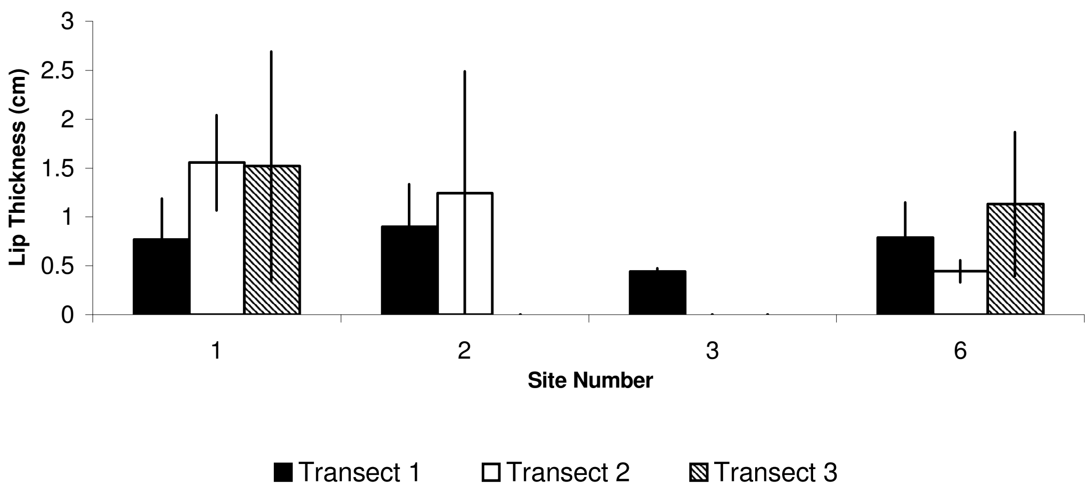

Figure 3: Mean lip thickness of *Strombus gigas* at each of four sites in the St. Eustatius Marine Park, Spring 2003. Absence of transect within site indicates absence of conch within the transect. Site 1, n = 26; Site 2, n = 25; Site 3, n = 5; Site 6, n = 33.

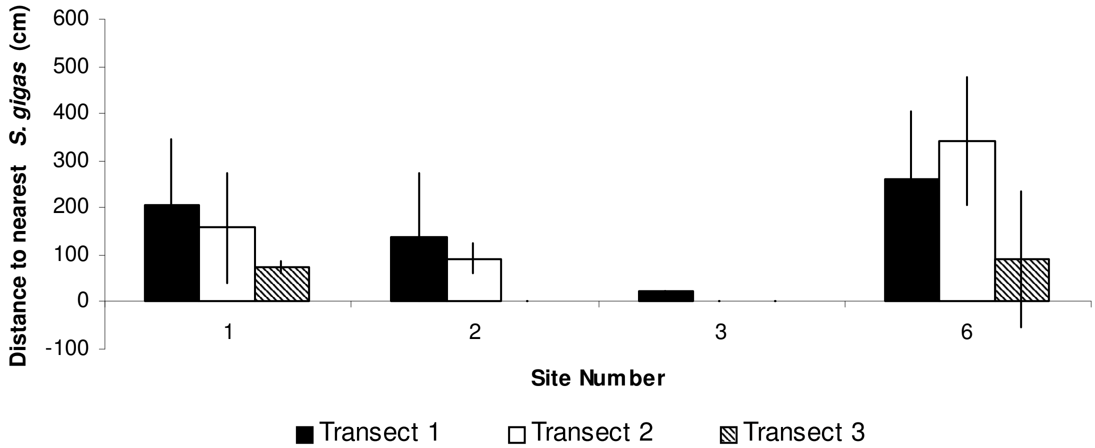

Figure 4: Mean distance to nearest conspecific neighbour (next nearest *Strombus gigas*) at each of four sites in the St. Eustatius Marine Park, Spring 2003. Absence of transect within site indicates absence of conch within the transect. Only neighbours within 500 cm were measured. Site 1, n = 11; Site 2, n = 15; Site 3, n = 1; Site 6, n = 20.

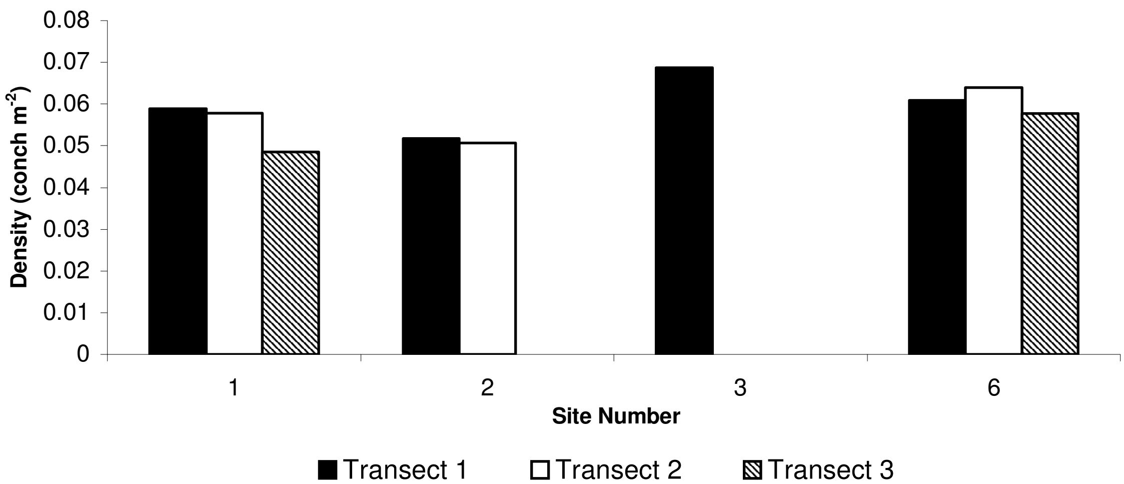

Figure 5: Mean density of conch at each of four sites in St. Eustatius Marine Park, Spring 2003. . Absence of transect within site indicates absence of conch within the transect. Site 1, n = 26; Site 2, n = 25; Site 3, n = 5; Site 6, n = 33.

Table 2: Distribution of *S.gigas* at each site, according to the Standardized Morisita Index of Dispersion (n = 3; df = 2).

Site	I_d	M_u	M_c	I_p	**Distribution**
1	1.163	0.915	1.234	-0.96	Uniform
2	1.533	0.915	1.234	0.585	Clumped
3	3	0.0255	3.689	-1.02	Uniform
6	1.006	0.9391	1.1681	-0.049	Uniform

Discussion

Density of *Strombus gigas* in St. Eustatius (Fig. 5) is three times greater than densities reported for Turks and Caicos (Krause, 1997), but drastically lower than densities reported for beds at similar depths in the Bahamas and Dominican Republic (Stoner and Ray, 1996; Posada *et al.*, 1999). It is important to note that elsewhere in the Caribbean conch beds are located and fished at shallow depths (<10 m) (Randall, 1964) and deeper beds are often the location of winter migration grounds, when conchs are thought to aggregate (Hesse, 1979; Stoner, 1989; Stoner and Sandt, 1992). For this reason, we must be careful in drawing comparisons between Statia's conch population and the conch populations of other Caribbean islands. The results of this survey suggest that Statia's conch population may be very unique because the shallowest bed is located at 60 feet and conchs have been observed in depths up to 110 feet. Statia conchs may also be unique in other ways due to their close proximity to the genetically unique conch population in neighbouring St. Kitts (Mitton *et al.*, 1989). St. Kitts conch population has been found to be genetically different from other Caribbean populations (Mitton *et al.*, 1989). Further study will be required to determine if queen conchs in the St. Eustatius Marine Park bare a genetic resemblance to other Caribbean populations or if they are part of the unique St. Kitts pool.

The exploratory phase of the study was able to reveal two sites (4, 5) where migration of conchs may be rapid and one site (Site 7) that may be a migration ground due to the presence of conchs at greater than average depths. It is important to note that in the exploration phase of the study numerous conchs were present at Site 3 (Zeelandia). However, when the site was returned to conduct the detailed survey most conchs were gone (Fig. 2-5). There were reports of fishing activity in this area in the days prior to our visit, which would explain the scarcity of conchs. This is an important factor to take into consideration when conducting a survey of this nature as it is beyond our control but must be dealt with in analysis of the data.

Significant differences in siphonal length (Fig. 2) and lip thickness (Fig. 3) between sites and transects may be related to bottom composition (Ray *et al.*, 1995). Age of conchs differed between beds where coral rubble was the dominant bottom composition (Sites 1 and 2) and where sand with algal cover was the dominant bottom cover. This may indicate that conchs on a sandy bottom with algal cover grow slightly larger than those on a coral rubble bottom (Ray *et al.*, 1995). Increased siphonal length among Zeelandia and Drop Off conchs may indicate that food is more readily available at these sites and predation is lower. However, due to the migratory nature and locomotory ability of *S. gigas* we cannot assume that the same individuals remain with the same general area of the bed for long periods of time (Stoner *et al.*, 1995; Stoner, 1989; Hesse, 1979; Hesse, 1980). That is, conch may be growing elsewhere and at the time of the study were located at their respective beds. Youngest conchs were found at Zeelandia and Drop Off and older conch at Outer Statia Harbour and West of Barracuda Reef. This information may be useful in determining the location of active breeding populations of conch. It may also be useful for locating juvenile populations that are buried in the sand, possibly near the sites where the youngest conchs are found (Davis *et al.*, 1984; Iversen *et al.*, 1986).

S. gigas displayed a uniform distribution at most sites with the exception of West of Barracuda where conchs displayed a clumped distribution (Table 2). This result may indicate that conchs at this site aggregate on the bed relative to certain resources such as food (Ray *et al.*, 1995). As the literature suggests, aggregation may be an attempt to avoid predation or a display of reproductive behaviour (Iversen *et al.*, 1986; Stoner and Schwarte, 1994). The result of a clumped distribution of *S. gigas* at Site 2 is consistent with the bottom composition of the site. Coral rubble of various sizes and reef were both represented here with the greatest number of conchs in the rubble area where transect 1 was randomly located. The rubble areas, because they have more algae, tend to provide greater nutritional resources for conchs. The uniform distribution displayed at other sites may be indicative of a more uniformly distributed food source and less predation pressure.

During the video survey stage of the study, locomotory and reproductive behaviour were observed. At site 2 individuals moved up to 1.5 meters in a matter of minutes. At site 6 (Drop Off) mating behaviour was observed. The male was observed pursuing the female from as far away as 3 meters. Once the male was within a few centimetres of the female the female would move away from the male. The male continued his pursuit and upon reaching the female copulation occurred. Occurrence of reproductive behaviour at these sites is consistent with the findings of D'Asaro (1965) who found that the ideal habitat for spawning is coral sand low in organic content. Egg masses were observed at Site 3 and Site 6; they have the appearance of a clump of string entangled in sand. These observations are a direct indication that Statia has an active reproductive conch population.

<u>Conservation and Protection of *Strombus gigas* in St. Eustatius:</u>

The Marine Environment Regulation Sint Eustatius provides the regulatory basis for managing the conch population in Statia. The St. Eustatius Marine Park is responsible for enforcing the regulations regarding the queen conch fishery on the island. Due to the lack of strict enforcement of these regulations the conch population may find itself in danger in the future. Queen conchs are collected with SCUBA equipment, more than 20 conchs per person per year are being collected, and catch is not being reported to the marine park manager. All of these are violations of the Marine Environment Regulations and threaten the survival of a healthy conch population for generations to come. Because catches are not reported it is not known if most conchs being collected are greater than 19cm (siphonal length) and have a fully-grown lip, which may mean immature individuals may be being removed prior to reproducing. Most conch surveyed met regulation size, which is encouraging because it means that juveniles are being left and allowed to reach sexual maturity thereby replenishing the population. The author believes that the most important of the five regulations governing conch collection on the island is the need for fishermen to report their catch. This will allow for effective management of the fishery through determination of maximum sustainable yields and other fisheries and population indictors.

The St. Eustatius Marine Park serves as a unique place to study the effectiveness of marine management on *S. gigas* populations because of the presence of beds both within and outside of no-take reserves.

Recommended Further Studies of the *Strombus gigas* population in the St. Eustatius Marine Park:

This is the first quantitative study conducted on the *Strombus gigas* population in St. Eustatius. It was able to meet its goals of determining the location of various conch beds and habitats. Being the first study, it has also opened up a world of possibilities for study. Future studies may include:

1) Identification of migratory or wintering grounds and monitoring the movement of individuals between these deeper beds and shallower beds through utilization of a tagging program. Such a tagging program could be conducted in co-operation between the Marine Park and local fishermen.
2) Collection of sediment cores from various locations around the island for in an attempt to locate settlers and juveniles. Cores would have to penetrate up to 20 cm into the sandy substrate.
3) Larval studies to determine recruitment and settlement success of gastropod veliger larvae. This study could also encompass reproductive success.
4) Behavioural studies of locomotion and reproductive behaviour of *Strombus gigas*
5) Collection of a broad range of information on ocean and local currents, tides, and bathymetry of the Marine Park. Collection of data on water quality parameters such as temperature and salinity would also prove useful for many projects including those on conch.

In order for such projects to be carried out the infrastructure must be provided. The Marine Park is the ideal organization to carry out such projects as it has resources such as a boat, computer, SCUBA equipment, video camera, diver propulsion vehicles and other minor equipment acquired during the current study. However, increased storage and work space is needed if the Marine Park is to be capable of operating in a scientific research capacity. Construction and supply of a basic science laboratory is needed as well as knowledgeable personnel to carry out the studies. Such personnel could be recruited via the Park's internship program, hired through grant to the Park, or the Park could actively recruit researchers from the academic community to pursue a scientific research mandate.

Acknowledgements

This study would not have been possible without the help of several volunteers including: Darrell Davis, Peter Esteban, and Edgar Antonia. Expertise, guidance and support throughout the study was provided by Kay Lynn Plummer-Hernandez, Nicole Esteban, Gershon Lopes, Reynaldo Redan, Rozenn Le Scao, and Maile Sullivan. Special thanks to Walter Blair for being there for every dive, driving the boat, keeping watch for us during the exploratory phase, and providing local knowledge of the waters surrounding Statia. Special thanks also goes to Dive Statia, Scubaqua, and Golden Rock Dive Center for tank fills and to the Benthic Ecology Lab at Dalhousie University for donation of underwater slates and waterproof paper. This study was funded by a grant from the Department of Environment and Nature Conservation (MINA) at the Ministry of Public Health and Social Development of the Government of the Netherlands Antilles in Curaçao.

Literature Cited

Appeldoorn, R.S. 1994. Queen conch management, research: status, needs and priorities. 301-319. *In* Appeldoorn and Rodriguez eds. Queen conch biology, fisheries and mariculture. Fundacion Cientifica. Los Roques, Caracas, Venezuela.

Appeldoorn, R.S. 1984. The effect of size on mortality of small juvenile conch (*S. gigas and S. costatus*). J. Shell. Res. 4(1). 37-43.

Berg, C.J. Jr. 1975. Behaviour and ecology of Conch (Superfamily Strombacea) on a deep subtidal algal plain. Bull. Mar. Sci. 25(3). 307-317.

Brownell, W.N. and Stevely, J.M. 1981. The biology, fisheries, and management of the queen conch, *Strombus gigas*. Mar. Fish. Rev. 43(7). 1-12.

Creswell, L. 1984. Ingestion, assimilation and growth of juveniles of the queen conch *S. gigas* fed experimental diets. J. Shell. Res. 4(1). 23-30.

D' Asaro, C.N. 1965. Organogenesis, development, and metamorphosis in the queen conch, *Strombus gigas*, with notes on breeding habits. Bull. Mar. Sci. 15(2). 359-416.

Davis, M., B.A. Mitchell, J.L. Brown. 1984. Breeding behaviour of the queen conch *S. gigas* held in natural and enclosed habitat. J. Shell. Res. 4(1). 17-21.

Davis, M. 2000. The combined effects of temperature and salinity on growth, development, and survival for tropical gastropod veligers of *S. gigas*. J. Shell. Res. 19(2). 883-889.

Hesse, K.O. 1979. Movement and migration of the queen conch, *Strombus gigas*, in the Turks and Caicos Islands. Bull. Mar. Sci. 29(3). 303-311.

Iversen, E.S., D.E. Jory, S.P. Bannerot. 1986. Predation on queen conch (*S. gigas*) in the Bahamas. Bull. Mar. Sci. 39(1). 61-75.

Krause, C. and Bautil, B. 1997. Population density of the queen conch, *Strombus gigas*, within the Six Hills Cay area of the Caicos Bank, TCI, BWI. School for Field Studies: Center for Marine Resource Studies.

Mitton, J.B., C.J. Berg Jr., K.S. Orr. Population structure, larval dispersal and gene flow in the queen conch, *Strombus gigas*, of the Caribbean. Biol. Bull. 177. 356-362.

Marine Environment Regulation Sint Eustatius. 1996. Design. NR.3. Article 7. Island Territory of Sint Eustatius. 6 pgs.

Posada, J.M., I. Mateo R., M. Nemeth. Occuremce, Abundance, and Length Frequency Distribution of Queen Conch, *Strombus gigas*, in shallow waters of the Jaragua National Park, Dominican Republic. Carib. J. Sci. 35(1-2). 70-82.

Randall, J.E. 1964. Contributions to the biology of the queen conch, *Strombus gigas*. Bull. Mar. Sci. Gulf and Carib. 14(2). 246-295.

Ray-Culp, M., M. Davis, A.W. Stoner. 1997. The micropredators of settling and newly settled queen conch. J. Shell. Res. 16(2): 423-428.

Ray, M., A.W. Stoner. 1995. Growth, survivorship, and habitat choice in a newly settled seagrass gastropod, *S. gigas*. Mar. Ecol. Prog. Ser. 123. 83-94.

Siddal, S.E. 1984. Density dependent levels of juveniles of the queen conch *S. gigas*. J. Shell. Res. 4(1). 67-74.

Stoner, A.W., R.N. Lipcius, L.S. Marshall Jr., A.T. Bardales. 1988. Synchronous emergence and mass migration in juvenile queen conch. Mar. Ecol. Prog. Ser. 49. 51-55.

Stoner, A.W. 1989. Winter mass migration of juvenile queen conch *Strombus gigas* and their influence on the benthic environment. Mar. Ecol. Prog. Ser. 56. 99-104.

Stoner, A.W. and V.J. Sandt. 1992. Population structure, seasonal movements and feeding of queen conch, *Strombus gigas*, in deep-water habitats of the Bahamas. Bull. Mar. Sci. 51(3). 287-300.

Stoner, A.W. and Schwarte, K.C. 1994. Queen conch, *Strombus gigas*, reproductive stocks in the central Bahamas: distribution and probable sources. Fish. Bull. 92. 171-179.

Stoner, A.W., J. Lin, M.D. Hanisak. 1995. Relationships between seagrass bed characteristics and juvenile queen conch (*S. gigas*) in the Bahamas. J. Shell. Res. 14(2). 315-323.

Stoner, A.W. and Ray, M. 1996. Queen conch, *Strombus gigas* in fished and unfished locations of the Bahamas: effects of a marine fishery reserve on adults, juveniles, and larval production. Fish. Bull. 94. 551-565.

Stoner, A.W. 1997. The status of queen conch, *Strombus gigas*, research in the Caribbean. Mar. Fish. Rev. 59(3). 14-22.