Report

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SUMMARY

Data on conch abundance, density and habitat type were collected in six shallow backreef embayments (1 to 7 m in depth) on St. Croix, three on the northeast coast (Cottongarden Bay, Teague Bay and Yellowcliff Bay) from October 1998 to September 1999, and three on the southeast coast (Turner Hole Bay, Robin Bay and Great Pond Bay) from July 2000 to September 2001. The conch data were collected as a secondary objective in determining the importance of backreef embayments as fisheries nursery grounds (Mateo and Tobias 2001 and 2004). This report analyzes the conch data collected and compares conch abundance, density and habitat type in the six embayments.

The total conch density for the combined northeast (7.75 ha) and southeast (6.78 ha) embayments was 43.8 conch/ha. Total conch density was higher in the northeast embayments (52.6 conch/ha) than in the southeast embayments (33.6 conch/ha). Mean density of measured conch less than legal harvestable size (<22.8 cm) from all bays was 32.9 conch/ha (SD = 15.13). Mean density of measured conch of harvestable size (≥22.8 cm) from all bays was 4.7 conch/ha (SD = 2.65). Significant differences were found between embayments. Adult conch densities were extremely low for reproduction (Stoner and Ray 1996).

The backreef embayments studied were found to contain predominately juvenile conch. Length-frequency data show a mean conch size in all bays of 17.1 cm (SD = 1.21); 87% of the conch measured were less than legal harvestable size (≥22.8 cm).

Seagrass (*Thalassia testudinum and Syringodium filiforme*) was the dominant habitat type found in the six embayments. A total of 98% of all conch observed were recorded in sand, algal plain and seagrass habitats or combinations thereof. Of this total, 79% of all conch <22.8 cm and 63% of all conch ≥22.8 cm were found in seagrass or seagrass combination habitats. The substantial numbers of juvenile conch found in seagrass habitats indicates that the backreef embayments serve as important nursery habitat.

The bank-barrier reef structure may also be a physical barrier to the movement and inshore/offshore migration of conch. This barrier effect could artificially enhance the numbers of adult conch found within the embayments, if conch movement is restricted. This could facilitate locating and harvesting of these resources.

Both juvenile and adult conch densities were lowest in Cottongarden Bay on the northeast coast. On the southeast coast, Robin Bay and Great Pond Bay juvenile densities were low and adult conch densities in all three southeast bays were uniformly low. These low conch densities may be the result of an illegal and undocumented harvest, which targets legal as well as undersized conch both in and out of season. Pressure on the resource may be greater in more geographically isolated, unpopulated coastal areas with limited shoreline access.

Additional conch research in these embayments is recommended. Specific study topics include: recruitment of conch larvae; currents/hydrodynamics within the bays; habitat for juvenile conch <7.0 cm; habitat identification where conch were found during census surveys; conch lip

measurements; conch tagging studies to identify movement; shoreline surveys to determine recreational conch harvest; and seasonal abundance and distribution of conch egg masses.

It is also recommended that adult conch be seeded in protected "No-Take"embayments in the East End Marine Park to increase inshore stock abundance. Also, enforcement of existing conch regulations is needed.

INTRODUCTION

Queen conch (*Strombus gigas*) is a large marine gastropod found in the Caribbean Sea and tropical Western Atlantic, ranging from Bermuda to northern Brazil (Valle-Esquivel 2002a). The depth range of queen conch is from shallow subtidal waters to 76 m (Chakalall and Cochrane 1996). Conch are benthic grazers, feeding on macroscopic and unicellular algae and detritus where clear water and sandy substrate support algae and seagrass production (Valle-Esquival 2002a; and Chakalall and Cochrane 1996). Preferred habitats for conch are shallower than 18 to 24 m and include seagrass and sandy algal beds, gravel, coral rubble, smooth hard coral and beach rock bottoms (CFMC 1996). Conch densities decrease significantly below 30 m due to light limitations for plant growth (Randall 1964). Overfishing continues to deplete available stocks throughout its range, reducing the economic importance of a once highly valuable commercial resource (Appeldoorn and Rodriguez 1994).

Dammann (1969) and Clavijo et al. (1986) reported that the conch fishery was the third most important fishery, behind fish and lobster, in the U.S. Virgin Islands. Available habitat to support the conch fishery is limited to waters of the surrounding shallow insular shelf platform. The approximate size of this habitat is estimated to be 34,300 ha for St. Croix and 162,925 ha for St. Thomas and St. John (CFMC 1999). Despite a smaller shelf platform, the majority of conch landings in the U.S. Virgin Islands are recorded from St. Croix (Tobias 1987; Garcia-Moliner 1997; and Tobias et al. 2000).

Wood and Olsen (1983) determined that the conch resources of the Virgin Islands had been seriously depleted by the late 1970's. In an effort to uniformly manage conch resources in the territory, conch regulations were approved in 1994, which established an annual closed season (July to September), bag limits (150 conch/commercial fisher/day and six conch/recreational fisher/day, not to exceed 24 conch/boat) and size limits (≥22.8 cm total length or 9.5 mm lip thickness). In addition, regulations required that conch be landed whole in the shell (VIRR 1994; and CFMC 2001) to make enforcement of minimum sizes practicable.

The queen conch fishery around St. Croix is artisanal. Most commercial vessels are outboard-powered, fiberglass constructed and less than 8 m in length (Kojis 2004). Conch are collected by hand using scuba or snorkeling gear. Wood and Olsen (1983) calculated the maximum sustainable yield for conch from St. Croix at 60,000 lbs/yr. Valle-Esquivel (2002b) reported dramatic changes in St. Croix conch landings since the late sixties, increasing to a maximum of 59,000 lbs in 1979, and fluctuating to a level of 20,000 to 30,000 lbs annually since then. Rosario (1995) and Rivera (1999) identified 25 and 28 conch fishers, respectively, in their studies of the commercial conch fishery from St. Croix. Kojis (2004) reported that 215 commercial fishers were registered in St. Croix during the fishing year of July 2003 to June 2004; 84 fishers (39.1%) reported harvesting conch. This suggested that fishing effort for queen conch has increased while reported commercial landings have remained relatively constant. Thus, an increased effort has not resulted in a significant increase in landings (Valle-Esquivel 2002a).

Gordon (2002) reported conch densities around St. Croix to be 72.3 juvenile conch/ha and 27.4 adult conch/ha. These density values were higher than in St. Thomas and St. John. The highest mean adult densities were found in the 19 to 24 m depth range. Juvenile conch abundance decreased with increasing water depth. However, no surveys were conducted in shallow, inshore waters (0 to 6 m depth range) during this 2001 survey.

This report presents data on conch abundance, density and habitat type in six shallow, backreef embayments (1 to 7 m depth) on St. Croix, three on the northeast coast (Cottongarden Bay, Teague Bay and Yellowcliff Bay) and three on the southeast coast (Turner Hole Bay, Robin Bay and Great Pond Bay). The conch data presented here was collected secondarily during surveys of fish communities in these embayments. The results from that study showed the ecological importance and fishery value of the backreef embayments as nursery grounds for recreationally important finfish species (Mateo and Tobias 2001 and 2004). The presence of queen conch in these areas, and the importance of this species as a fishery resource and as part of the benthic community around the U.S. Virgin Islands, motivated field staff to collect detailed information on presence, location, depth, size and density of conch individuals. A secondary objective of the original backreef study thus became to collect conch data so that it would be available for later analyses such as for size distribution, density, and abundance of juvenile and adult queen conch and to characterize their preferred habitat types.

METHODOLOGY

Study Area

Six embayments were sampled in this study: Cottongarden Bay (CB), Teague Bay (TB), and Yellowcliff Bay (YB) on the northeast coast, and Turner Hole Bay (THB), Robin Bay (RB) and Great Pond Bay (GPB) on the southeast coast. The bays are part of the nearly continuous bank-barrier reef system extending from Pull Point to Lamb Point on the northeast coast (commonly referred to as the Teague Bay bank-barrier reef system) and from East Point to Vagthus Point on the southeast coast of St. Croix (Figure 1). This extensive reef complex forms a protective barrier against wind and wave energy for numerous backreef embayments (Mateo and Tobias 2001 and 2004). Embayments range in depth from 1 meter on their eastern and western extremes to 7 to 8 m in the interior lagoons. The distance from shore to the bank-barrier reef in the northeastern embayments varies from 500 to 700 m. The approximate embayment lengths are 600 m, 1200 m and 900 m for Cottongarden Bay, Teague Bay and Yellowcliff Bay, respectively. The southeast embayments of Turner Hole and Robin Bay are approximately 300 m wide and 1000 m long. Great Pond Bay, approximately 900 m wide and 2.5 km long, is bounded on its landward side by a baymouth bar and on the seaward side by a contiguous coral-algal reef (Bruce et al. 1989).

Burke et al. (1989) and Hubbard (1989) described habitat zonation patterns in embayments on the northeast and southeast coast, respectively. In general, seagrass (*Thalassia testudinum* and *Syringodium filiforme* form beds of varying density) and sediment-dwelling organisms, such as mollusks and echinoderms, dominate in the lagoon. Calcareous algal species, including *Halimeda* spp. and *Penicillus* spp., and many other species of macroalgae are abundant in seagrass beds. Deeper portions of lagoons consist of extensive sandy areas with sparse seagrass cover. The bottom is extensively hummocked in these areas with sand mounds 10 to 20 cm in height created by the burrowing shrimp *Callianassa* spp. An abrupt transition from lagoon to backreef is marked by scattered coral colonies of *Montastraea annularis*, *Porites astreoides* and *Diploria* spp., many of which have died since the descriptions of Burke et al. (1989) and Hubbard (1989).

Survey Method

The transect methodology used to survey conch abundance and density was identical to that used to survey fish species composition and abundance in these embayments (Mateo and Tobias 2001 and 2004). Monthly sampling was conducted in the northeast embayments from October 1998 to September 1999 and in the southeast embayments from July 2000 to September 2001. Due to bad weather and adverse sea conditions, no sampling was conducted during the months of November 2000 and April 2001. Bad weather and adverse sea conditions also prevented sampling Great Pond Bay in December 2000 and March 2001 and Robin Bay in December 2000 and August 2001.

For each bay, a 20 x 20 m grid was established over a nautical chart and the intersecting points were given a consecutive number. Transect locations were then selected using random numbers from intersecting points on the grid. Ten 50-m transects were randomly selected for location and direction in each embayment. A weighted transect tape with buoys on each end to identify the transect from the surface was deployed from a surface vessel while the vessel's captain maintained the desired compass heading. Upon deploying the transect, two divers entered the water at the starting point and simultaneously conducted the monthly conch censuses along a 2-m wide belt transect on either side of the transect line (survey area = 100 m^2 per diver). When only one diver was available, surveys were competed by the diver counting conch first on one side of the transect and then on the other side. All queen conch encountered along the transect were counted and total shell length (apex of the spire to the end of the siphonal canal) was measured (mm) with a caliper and recorded.

Information on habitat type was also recorded. Percent habitat cover was estimated from linear coverage along transects (Mateo and Tobias 2001 and 2004). The proportional composition of the habitat covered in each transect was estimated by measuring the combined length of the transect line overlying each substratum type and dividing it by the transect length. The benthic habitat categories selected were similar to the habitat classification scheme used by the National Oceanic and Atmospheric Administration's National Ocean Service (Kendall et al. 2001):

- Patch reef: isolated, elevated calcareous structure (not part of the contiguous reef) with a vertical profile that often, but not always contains live coral.
- Rubble: low-relief calcareous structure composed primarily of dead/dying coral fragments that are not attached to the substrate.
- Sand: areas of open sand with very little or no (<10% cover) plants or coralline material represented.
- Algal plain: sand bottom dominated by *Dictyota* spp., *Halimeda* spp., and/or *Udotea* spp., which may include sparse stands of *S. filiforme* and *T. testudinum*.

- Seagrass: monospecific or nearly monospecific stands of *T. testudinum*, mixed with varying densities of *S. filiforme*.

The data collected were used to determine conch length-frequencies, conch densities by size categories, total conch density, frequency of conch by habitat type and by size for each of the six embayments. From October 1998 to February 1999, some of the conch in the northeastern embayments were not directly measured but recorded in size categories (<100 mm, 100-200 mm and >200 mm). These data were omitted from conch length-frequency plots but included in calculations of total conch density. All conch in the southeast embayments were individually measured. Total conch density data were tested for normality using a Kolmogorov-Lilliefors Normality test and the Levene Median Test was used to test equal variance (Zar 1984). If the data failed the normality test even after log (x +1) transformation and the equal variance test, non-parametric statistics were used to analyze the data. A Kruskall-Wallis One-way ANOVA on ranks for unequal sample size was used to test for significant differences among embayments for conch density. A Dunn's All Pairwise Multiple Comparison test was used to test for differences among embayments, following a probability adjustment for the number of comparisons.

RESULTS

The total number of conch observed and total conch density in the northeast and southeast embayments on St. Croix in September 1998 to October 1999 and July 2000 to September 2001, respectively, is shown in Table 1. A total of 636 conch were observed in the embayments, 408 on the northeast coast and 228 on the southeast coast. The combined survey area comprised 14.53 hectares of bottom habitat, 7.75 ha in the northeast embayments and 6.78 ha in the southeast embayments. The total conch density for the combined northeast and southeast embayments was 43.8 conch/ha. Total conch density was higher in the northeast embayments (52.6 conch/ha) than in the southeast embayments (33.6 conch/ha).

Table 2 shows the summary of conch number and density in the northeast and southeast embayments on St. Croix in September 1998 to October 1999 and July 2000 to September 2001, respectively. Northeast embayments averaged 258.3 transects/embayment and 136 conch/embayment. Of the conch measured in northern embayments, 94.0 conch/embayment were <22.8 cm and 14.3 conch/embayment were ≥22.8 cm.

Southeast embayments averaged 226 transects/embayment and 76 conch/embayment. All conch were measured in southern embayments. There was an average of 67.3 conch/embayment <22.8 cm and 8.7 conch/embayment ≥ 22.8 cm.

The number of conch observed and area surveyed in the northeast and southeast embayments on St. Croix is shown in Table 3. A total of 775 transects were surveyed in the northeast embayments, 278 in Cottongarden Bay (2.78 ha), 260 in Teague Bay (2.60 ha) and 237 in Yellowcliff Bay (2.37 ha). The most conch were observed in Teague Bay (170 conch; 0.65 conch/100 m^2) and the fewest conch in Cottongarden Bay (105 conch; 0.37 conch /100 m^2). Yellowcliff Bay had 133 conch (0.56 conch/100 m^2).

A total of 678 transects were conducted in the southeast embayments (see Table 3), 251 in Turner Hole Bay (2.51 ha), 208 in Robin Bay (2.08 ha) and 219 in Great Pond Bay (2.19 ha). The most conch were found in Turner Hole Bay (144 conch; 0.57/100 m^2). Similar abundances of conch were found in Robin Bay (38 conch; 0.18/100 m^2) and Great Pond Bay (46 conch; 0.21/100 m^2).

Conch density and conch size (in relation to the legal harvest size of 22.8 cm) in the northeast and southeast embayments are shown in Table 4 and Figures 2 and 3, respectively. Conch density in Cottongarden Bay was 37.76 conch/ha (28.40 conch/ha <22.8 cm and 2.27 conch/ha ≥22.8 cm). Conch density for Teague Bay was 65.38 conch/ha (44.23 conch/ha < 22.8 cm and 5.38 conch/ha ≥ 22.8 cm). Conch density in Yellowcliff Bay was 56.11 conch/ha (38.81 conch/ha <22.8 cm and 9.70 conch/ha ≥ 22.8 cm).

In the southeast embayments, Turner Hole Bay conch density was 57.37 conch/ha (53.38 conch/ha <22.8 cm and 3.98 conch/ha ≥22.8 cm). In Robin Bay, conch density was 18.27 conch/ha (15.38 conch/ha <22.8 cm and 2.88 conch/ha ≥22.8 cm). Conch density in Great Pond Bay was 21.00 conch/ha (16.43 conch/ha < 22.8 cm and 4.56 conch/ha ≥ 22.8 cm.

Mean density of conch <22.8 cm (measured conch only) from all bays was 32.9 conch/ha (SD = 15.13) (calculated from Table 4). Mean density of conch ≥22.8 cm (measured conch only) from all bays was 4.7 conch/ha (SD = 2.65). A total of 83 conch from the northeast embayments were not directly measured and were not included in conch density calculations

A total of 83 conch from the northeast embayments were counted, but not directly measured, and recorded in three size categories (<100 mm, 100-200 mm and > 200 mm). Twenty four conch were counted in Cottongarden Bay (11 conch < 100 mm and 13 conch = 100-200 mm), 41 conch from Teague Bay (6 conch < 100 m, 23 conch =100-200 mm and 12 conch >200 mm) and 18 conch from Yellowcliff Bay (1 conch < 100 mm, 6 conch = 100-200 mm and 11 conch > 200 mm).

Total conch density data was significantly different among embayments (Kruskall-Wallis One-way ANOVA, F = 4.878905, P = 0.000197, df = 5). However, when the probability or alpha value was adjusted for multiple comparisons of six embayments and the data retested by the Dunn's Method, the data did not show a significant difference among embayments.

The length-frequency histogram for all conch found in the northeast and southeast embayments is shown in Figure 4. A total of 553 conch were measured, 87.5% (484 conch) were < 22.8 cm (minimum legal harvest size) and 12.5% (69 conch) were ≥22.8 cm.

Length-frequency histograms for the conch found in the northeast embayments of Cottongarden Bay, Teague Bay and Yellowcliff Bay are shown in Figure 5. In Cottongarden Bay, mean conch size was 16.5 cm (+/- SD = 3.75 cm); 92% of the measured conch were <22.8 cm. Mean conch size in Teague Bay was 17.3 cm (+/-SD = 4.32 cm); 89 % of the measured conch were <22.8 cm. In Yellowcliff Bay, mean conch size was 19.2 cm (+/- SD = 4.24 cm); 88% of the measured conch were <22.8 cm.

Length-frequency histograms for the conch found in the southeast embayments of Turner Hole Bay, Robin Bay and Great Pond Bay are shown in Figure 6. Mean conch size in Turner Hole Bay was 15.6 cm (+/- SD = 4.40 cm); 93 % of the conch were <22.8 cm. Mean conch size in Robin Bay was 16.7 cm (+/- SD = 4.8 cm); 84% of the conch were <22.8 cm. Mean conch size in Great Pond Bay was 17.5 cm (+/- SD = 5.28 cm); 78% of the conch were <22.8 cm.

The distribution of the five major habitat types within each embayment (seagrass, patch reef, algal plain, sand and rubble) is shown in Figure 7 (data from Mateo and Tobias 2001 and 2004). In the northeast embayments of Cottongarden Bay, Teague Bay and Yellowcliff Bay, the dominant habitat type was seagrass (94%, 84% and 61%, respectively). Algal plain was the second most abundant habitat type in Yellowcliff Bay (26%) and Teague Bay (12%). The dominant habitat type in the southeast embayments was seagrass in Turner Hole Bay and Robin Bay (80% and 85%, respectively) followed by sand (12% and 9%, respectively). Great Pond Bay habitat was dominated by sand (60%), seagrass (19%) and algal plain (19%).

The number of conch recorded by habitat type is shown in Figure 8 for the northeast embayments and Figure 9 for the southeast embayments. Most (97.7%) conch observed were recorded from three habitat types (sand-S, algal plain-AL and seagrass-SG) and five combinations of these habitat types (S/AL, SG/S, S/SG, S/AL/SG and AL/SG). In northeast embayments (Figure 8), 98% of conch observed in Cottongarden Bay were found in seagrass (92%) and algal plain/seagrass habitat (6%). In Teague Bay, 91% of conch observed were found in seagrass combination (62% algal plain/seagrass and sand/algal plain/seagrass) and seagrass (29%) habitat. In Yellowcliff Bay, 83% of conch observed were found in seagrass combination (60%-algal plain/seagrass) and seagrass (23%) habitat.

In the southeast embayments (Figure 9), 81% of conch observed in Turner Hole Bay were found in seagrass combination (42% seagrass and 39%-sand/algal plain/seagrass and sand/seagrass) habitats. In Robin Bay, 85% of conch observed were found in seagrass (53%) and seagrass combination (32%-sand/seagrass and sand/ algal plain/seagrass) habitats. In Great Pond Bay, 43% of conch observed were found in seagrass and seagrass combination habitats, 33% were found in sand/algal plain habitats and 15% were found in sand habitats.

The distribution of conch by size and habitat type for the northeast and southeast embayments is shown in Figures 10 and 11, respectively. In Cottongarden Bay, 99% of conch < 22.8 cm were found in seagrass and 100% of conch ≥ 22.8 cm were found in seagrass (Figure 10). In Teague Bay, 47% of conch < 22.8 cm were found in seagrass combination habitats and 24% in only seagrass habitat. The majority of conch ≥22.8 cm were found in seagrass (42%) and sand/algal plain (25%) habitats. In Yellowcliff Bay, conch < 22.8 cm were found in algal/seagrass (47%), seagrass (24%) and sand/seagrass (14%) habitats. The majority of conch ≥22.8 cm were found in sand/seagrass (50%) and seagrass (25%) habitats.

In the southeast embayments (Figure 11), in Turner Hole Bay, 43% of conch <22.8 cm were found in seagrass, 25% in sand/algal plain/seagrass and 17% in sand/seagrass habitats. All conch ≥22.8 cm in Turner Hole Bay were found in seagrass. In Robin Bay, 57% of conch < 22.8 cm were found in seagrass, 21% in sand/seagrass and 18% in sand/algal plain/seagrass habitats. Most of the conch ≥22.8 cm (60%) were found in seagrass. The majority of conch <22.8 cm in

Great Pond Bay, were distributed between sand/algal plain, sand/seagrass and sand habitats (31%, 28% and 16%, respectively). Conch ≥22.8 cm were found predominately in sand/algal plain (38%) and sand (25%) habitats.

DISCUSSION

This study represents the first assessment of conch populations in the shallow (1 to 7 m depth), protected embayments of St. Croix, U.S. Virgin Islands. Conch densities in this study (43.8 conch/ha combined study area; 52.6 conch/ha and 33.6 conch/ha for the northeast and southeast embayments, respectively) were found to be greater than those determined by previous researchers for St. Croix of 7.6 conch/ha (Wood and Olsen 1983) and for St. Thomas/St. John of 9.70, 12.25 and 22.6 conch/ha (Wood and Olsen 1983; Friedlander et al.. 1994; and Friedlander, 1997, respectively) on the insular shelf platform. In relation to adjacent Caribbean waters, St. Croix backreef conch densities were greater than those reported by Torres-Rosado (1987) and Mateo (1997) for Puerto Rico (8.1 and 7.4 to 9.2 conch/ha, respectively). However, adult conch densities may not be sufficient to sustain inshore populations. According to Stoner and Ray (1996), adult conch densities <53 conch/ha adversely affect the ability of conch to locate a mate and reproduce. Therefore, conch densities in backreef embayments are extremely low for reproduction.

A more recent Virgin Islands conch study by Gordon (2002), designed to resurvey sites visited in 1981 by Olsen and Wood (1983), reported total conch densities around St. Croix to be 99.7 conch/ha (72.3 juvenile conch/ha and 27.4 adult conch/ha) on the insular shelf platform. The highest juvenile and adult densities were found in the 7 to 12 m depth and 19 to 24 m depth range, respectively. These results are significantly higher than conch densities previously determined by Olsen and Wood (1983) for St. Croix, as well as the results from this study.

Only four of the 16 sites surveyed by Gordon (2002) contained high numbers of conch, indicating the patchy distribution of the resource. One of these sites was in Buck Island National Monument waters, where harvest is now prohibited.

It is also possible that conch density recorded by Wood and Olsen (1983) was underestimated due to the methodology they used. Wood and Olsen (1983) used a surface vessel following a compass course to tow a diver in an underwater sled. The diver maintained the height of the sled above the substrate with controls on the sled and counted the conch observed through a portion of the sled frame. The opening through the sled frame at a specific height above the substrate was predetermined to be a specified area of bottom habitat. However, since the sled was not stopped when conch were observed, the numbers of conch could have easily been underestimated. Conch with heavily colonized shells or shells partially buried in the substrate could have been overlooked.

Differences in methodology make comparison of the present study to Gordon (2002) difficult. Surveys by Gordon (2002) covered an average of 1,869 m^2 of bottom habitat per survey. The sites were surveyed once, comprising 2.99 ha of total habitat. The present study utilized more extensive sampling in the six embayments, averaging 2.58 ha and 2.26 ha surveyed in each of the northeast embayments and southeast embayments, respectively. The sites were also resurveyed many times (monthly for a one-year period). Habitat differences are evident between the two studies (Gordon 2002 and this study). The shelf areas surveyed by Gordon (2002) comprised predominantly pavement (50%) and algal (27%) habitats. In the present study, seagrass was the dominant habitat type (71%) in embayments. Both studies show the importance of vegetative material as conch habitat. In Gordon (2002), the density of juveniles was greater in algae and the density of adults was greater in seagrass. In the present study, the abundance of both juvenile and adult conch were greater in seagrass habitats or combinations thereof.

Conch mature at 2.5 to 3 years of age and first reproduction occurs in years 3 to 4. By that time, the shell lip has formed and thickened to 5 mm (Appeldoorn 1996). Stoner and Ray (1996) reported that sexual maturity of conch begins at 20 cm shell length. The backreef embayments studied on the northeast and southeast coast of St. Croix were found to contain predominately juvenile conch. Length-frequency data show a mean conch size in all bays of 17.1 cm (SD = 1.21); 87% of the conch measured were <22.8 cm, the legal harvestable size. Stoner (1996) determined that conch nursery areas are shallow seagrass meadows from <5 to 6 m in depth. However, not all seagrass beds are nursery areas. Vast areas of seagrass meadows in Bahamas, Belize, Mexico and Florida have only small areas suitable as nursery grounds because they lack important recruitment and benthic habitat features (Stoner and Ray 1996). The most important nursery habitats appear to be determined by complex interactions of physical oceanographic features, seagrass and algal communities, and recruitment of larvae (Stoner 1996). The abundance of juvenile conch in the backreef embayments observed in this study would indicate that these embayments appear to have the requirements necessary to serve as nursery areas.

Five major habitat types were identified in the embayments, seagrass, patch reef, algal plain, sand and rubble (Mateo and Tobias 2001 and 2004). Seagrass (*T. testudinum* and *T. testudinum/S. filiforme*) was the dominant habitat type. A total of 98% of all conch observed were recorded in sand, algal plain and seagrass habitats, or combinations thereof, which comprised 96.3% of habitat surveyed. Of this total, 79% of all conch <22.8 cm and 63% of all conch ≥22.8 cm were found in seagrass or seagrass combination habitats. Friedlander (1997) found adult conch were most abundant in similar habitats around St. John.

Conch larvae remain part of the zooplankton community for 16 to 28 days (Stoner and Ray 1996). Prior to metamorphosis, conch larvae can be dispersed significant distances and also become trapped in current eddies or gyres and retained or transported back to their natal environs. The Teague Bay bank-barrier reef system on the northeast coast of St. Croix and the bank-barrier/calcareous algal ridge system on the southeast coast form a nearly continuous seaward barrier to the backreef embayments where conch studies were conducted (Burke et al. 1989; and Hubbard 1989). Although this reef feature reduces wind and wave energy to backreef environs, water exchange remains excellent from a predominantly easterly regime of tradewinds and seas (Burke et al. 1989; and Hubbard 1989). Current reversals (the flow of offshore water from a westerly to easterly direction) have also been recorded (Hubbard 1989). Strong tidal currents or a good flow of oceanic water are important criteria for a viable conch nursery area (Stoner 1996). The bays on the north and south coast (with the exception of Turner Hole Bay) are interconnected and longshore currents passing water over the reef or through natural passageways continually exchange water. The longshore current flows in an east-west direction

(W. Tobias, personal observation). Turner Hole Bay is separate to and located east of Robin and Great Pond Bays on the southeast coast and has a deepwater passage through the reef at its eastern end. The longshore current flows east to west but reverses west to east in the outer embayment (W. Tobias, personal observation). Water flow is reduced to the west where the reef system shoals to meet the western headland of Turner Hole Bay (W. Tobias, personal observation). As an oceanic island (not immediately surrounded by other land masses), St. Croix may receive recruitment of conch larvae from other nearby gene pools (Saba Bank to the east, Anguilla and the British Virgin Islands to the north, Puerto Rico to the west), as well as assist in replenishing its own conch population.

Conch have the ability to move up to 9 km in six months and the natural migration of conch is from inshore waters to spawn in the summer months to deeper offshore waters in the winter months (Appeldoorn 1996). Although the bank-barrier reef system affords great protection to backreef waters, the reef structure may also be a physical barrier to the movement and inshore/offshore migration of conch. Most of the embayments studied here are less than 1 km in length. Movement of adult and sub-conch in the embayments may be limited to an east-west direction. Access offshore is restricted to natural passageways or channels through the reef.

The bank-barrier reef structure becomes less continuous west of the study sites. This barrier effect could artificially enhance the numbers of adult conch found within the embayments, if movement is restricted. This could facilitate user groups in locating and harvesting the conch resource.

Historical accounts by St. Croix residents indicate that adult conch were so abundant in backreef embayments that they could be located in shallow water without a diving mask by feeling them with your feet (T. Skov, personal communication). At low tide, conch were exposed with their shells above the water surface. With increased demand and the use of outboard engines instead of sail power and the use of scuba gear instead of free diving, commercial fishers depleted adult conch resources in shallow inshore waters and now harvest conch in deeper water near the shelf edge (Rosario 1995; and CFMC 1996).

Presently, recreational and commercial fishing pressure may reduce both juvenile and adult conch densities in the backreef embayments. Both juvenile and adult conch densities were lowest in Cottongarden Bay on the northeast coast. On the southeast coast, Robin Bay and Great Pond Bay juvenile densities were low and adult conch densities in all three southeast bays were uniformly low. Beach camping on St. Croix is extremely popular, particularly during holiday periods. Recreational harvesting of marine resources is problematic for enforcement in general and at this time in particular. Beach camping activities occur in Cottongarden Bay at Cramer Park, a public park, and at Robin Bay and Great Pond Bay, more isolated areas where beach shacks have been constructed. Recreational fishers have been observed harvesting undersized conch in Teague Bay and conch shell middens occur on the shoreline in Yellowcliff, Robin and Great Pond Bays (W. Tobias, personal observation). Juvenile conch densities may be lower in Robin Bay and Great Pond Bay because these bays are more isolated and harvesting of juveniles can persist without observation from enforcement. In the absence of fishing, the backreef embayments would have more adult conch for stock replenishment.

CONCLUSION

The backreef embayments studied appear to be important nursery ground for juvenile conch. However, adult conch density observed is insufficient to support a once abundant inshore conch population. Shoreline conch middens show that the harvest of conch is opportunistic and both juvenile and adults are removed (CFMC 1999). While regulations established in the U. S. Virgin Islands in 1994 (VIRR 1994; and CFMC 2001) appear adequate to sustain conch harvests from shelf waters, enforcement of the regulations is limited at best and may be lacking in more isolated areas of the coastline. Increased enforcement presence, particularly at boat access facilities, and better monitoring of conch harvesting is necessary to determine the effectiveness of present management regulations. A public awareness program should be established to educate the public on the importance of managing conch resources and current rules and regulations.

There are over 2,000 registered boats in the U.S. Virgin Islands (Eastern Caribbean Center 2002) and it is estimated that approximately 10% of the population participate in recreational fishing activities (Jennings 1992; and Mateo 1999). However, no information is available on the exact number of recreational fishers, how many of them are harvesting conch and the potential impact of this harvest on conch resources. A recreational license system with mandatory data collection from licensed fishers should be instituted to enable fisheries managers to determine landings and fishing effort on the resource. Random shoreline surveys should be conducted to determine the accuracy of data submitted by recreational fishers.

Fishing is not the only adverse impact on conch resources. Important coastal fisheries habitat has been lost in the Virgin Islands due to habitat destruction from coastal development and water quality degradation from non-point source and point source pollution. To enhance protection to coastal waters and important essential fish habitats found therein, the Government of the Virgin Islands should adopt uniform development regulations for shoreline and inland areas.

Cottongarden Bay, Teague Bay, Yellowcliff Bay, Turner Hole Bay, Robin Bay and Great Pond Bay lie within the St. Croix East End Marine Park (EEMP), a 155 km territorial marine park established in 2002 (The Nature Conservancy 2002). These embayments comprise part of the EEMP's 27 km of shoreline. The waters of these embayments and those offshore have been identified as designated use zones. With the promulgation of rules and regulations for the EEMP and the hiring of dedicated enforcement officers and interpreters, it is anticipated that greater protection can be afforded to the essential fish habitat and marine resources found in these backreef embayments.

With the restriction of fishing effort anticipated in the EEMP, the introduction of adult conch from shelf waters in backreef embayments may help to supplement the inshore supply of conch larvae. The adult conch may serve as a valuable source of conch propagules to once again replenish an inshore conch population.

Future conch studies should be conducted to obtain specific information relevant to stock assessment. These studies in the backreef embayments should include information on the following:

1. recruitment of conch larvae;
2. currents/hydrodynamics within bays;
3. habitat for juvenile conch <7.0 cm;
4. habitat where conch are found during census;
5. conch lip measurements;
6. conch tagging studies to identify movement;
7. estimates of recreational conch harvest; and
8. seasonal abundance and distribution of egg masses.

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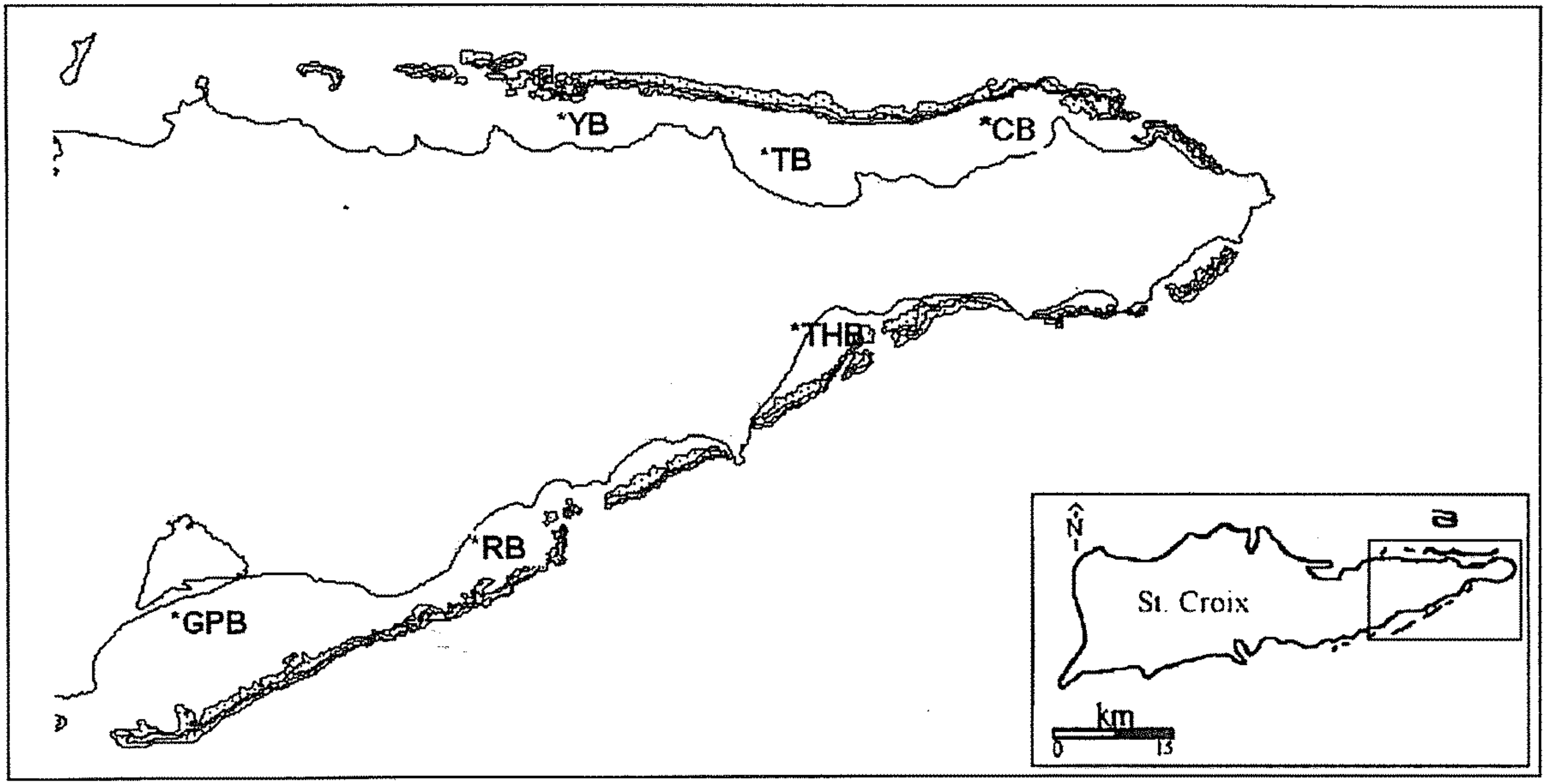
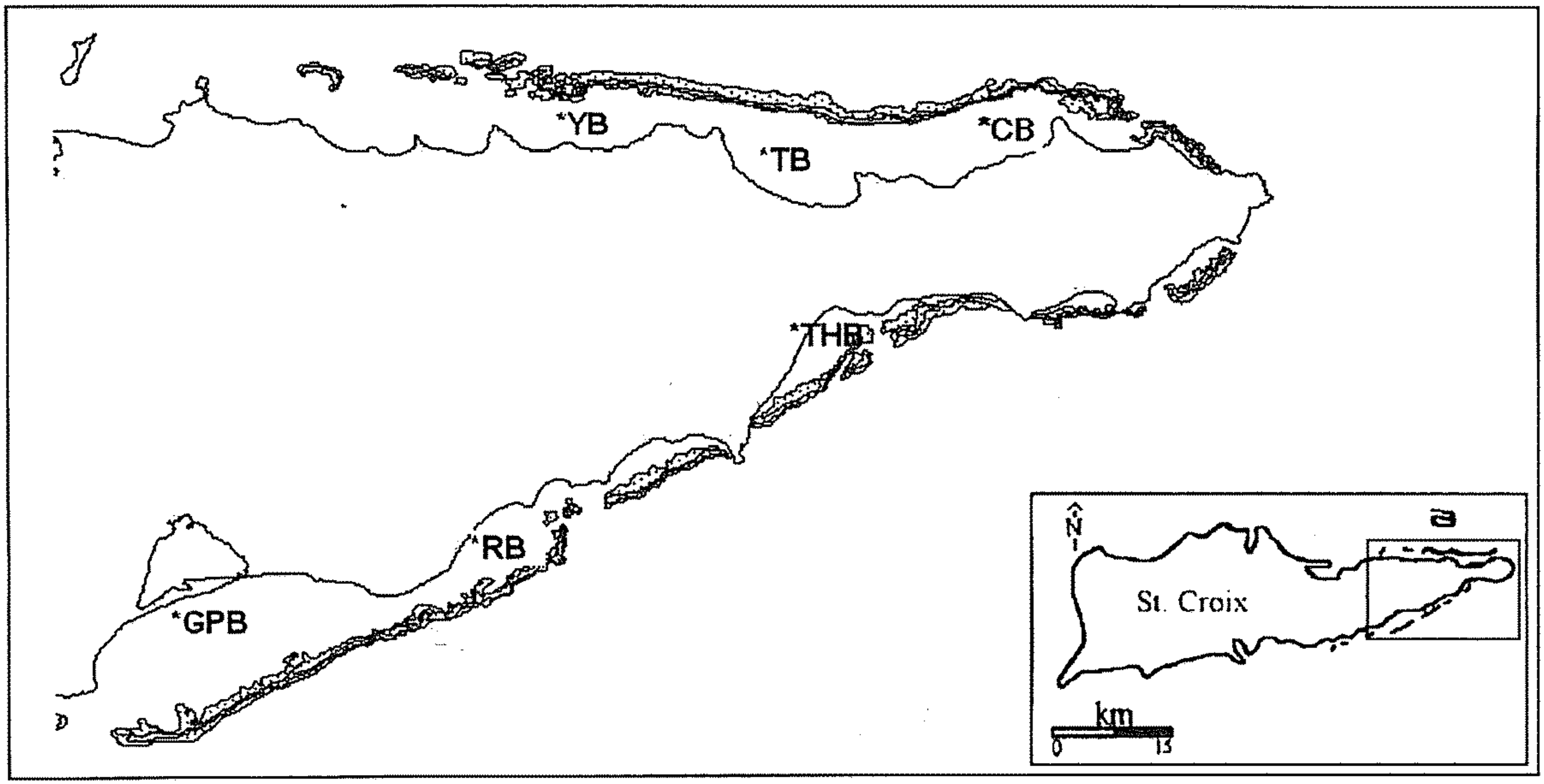


Figure 1: Location and site map of the back reef embayments sampled for conch on the northeast and southeast coasts of St. Croix, US Virgin Islands. CB – Cottongarden Bay, TB – Teague Bay, YB – Yellowcliff Bay, THB – Turner Hole Bay, RB – Robin Bay, GPB – Great Pond Bay.



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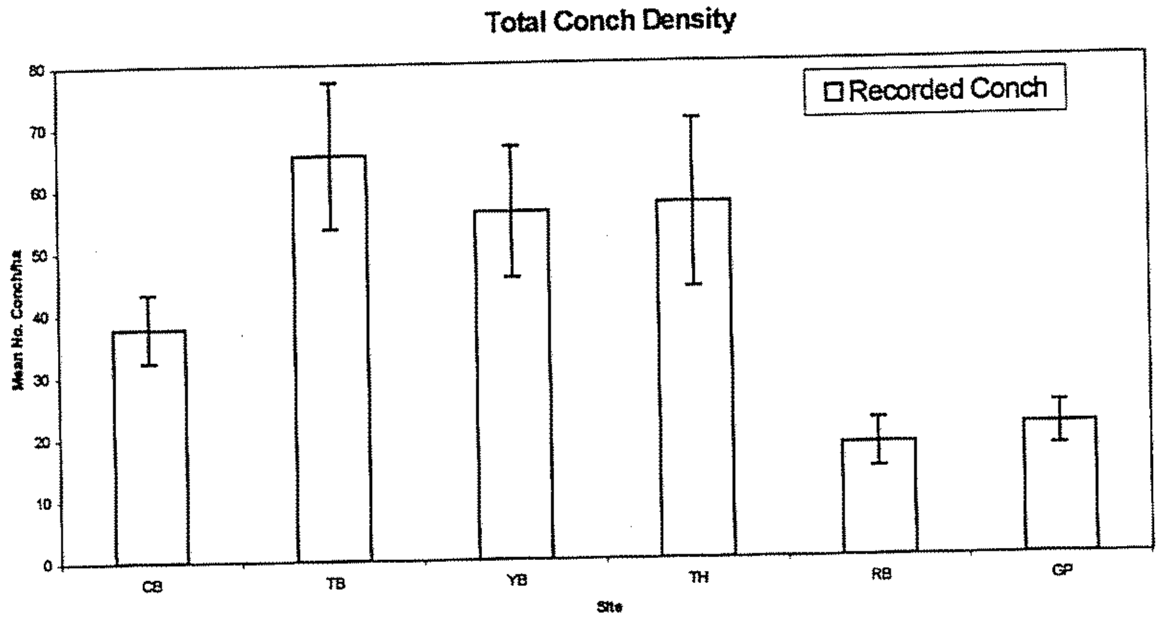


Figure 2: Total conch density for the back reef embayments. CB – Cottongarden Bay, TB – Teague Bay, YB – Yellowcliff Bay, THB – Turner Hole Bay, RB – Robin Bay, GPB – Great Pond Bay.

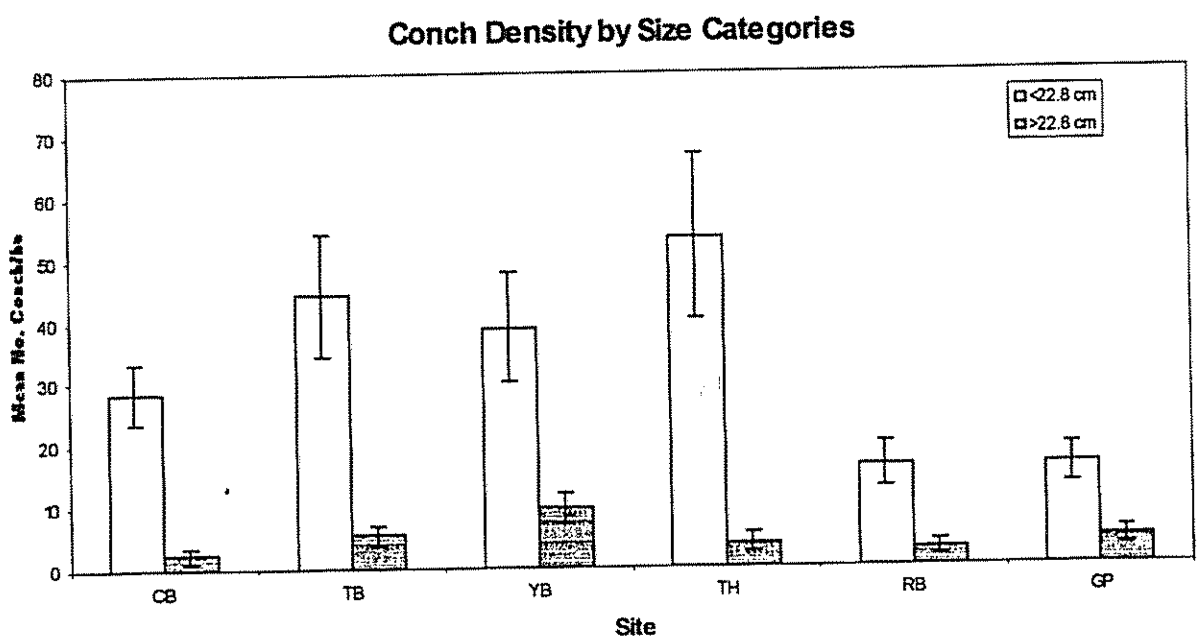


Figure 3: Conch density by size category for the back reef embayments. CB – Cottongarden Bay, TB – Teague Bay, YB – Yellowcliff Bay, THB – Turner Hole Bay, RB – Robin Bay, GPB – Great Pond Bay.

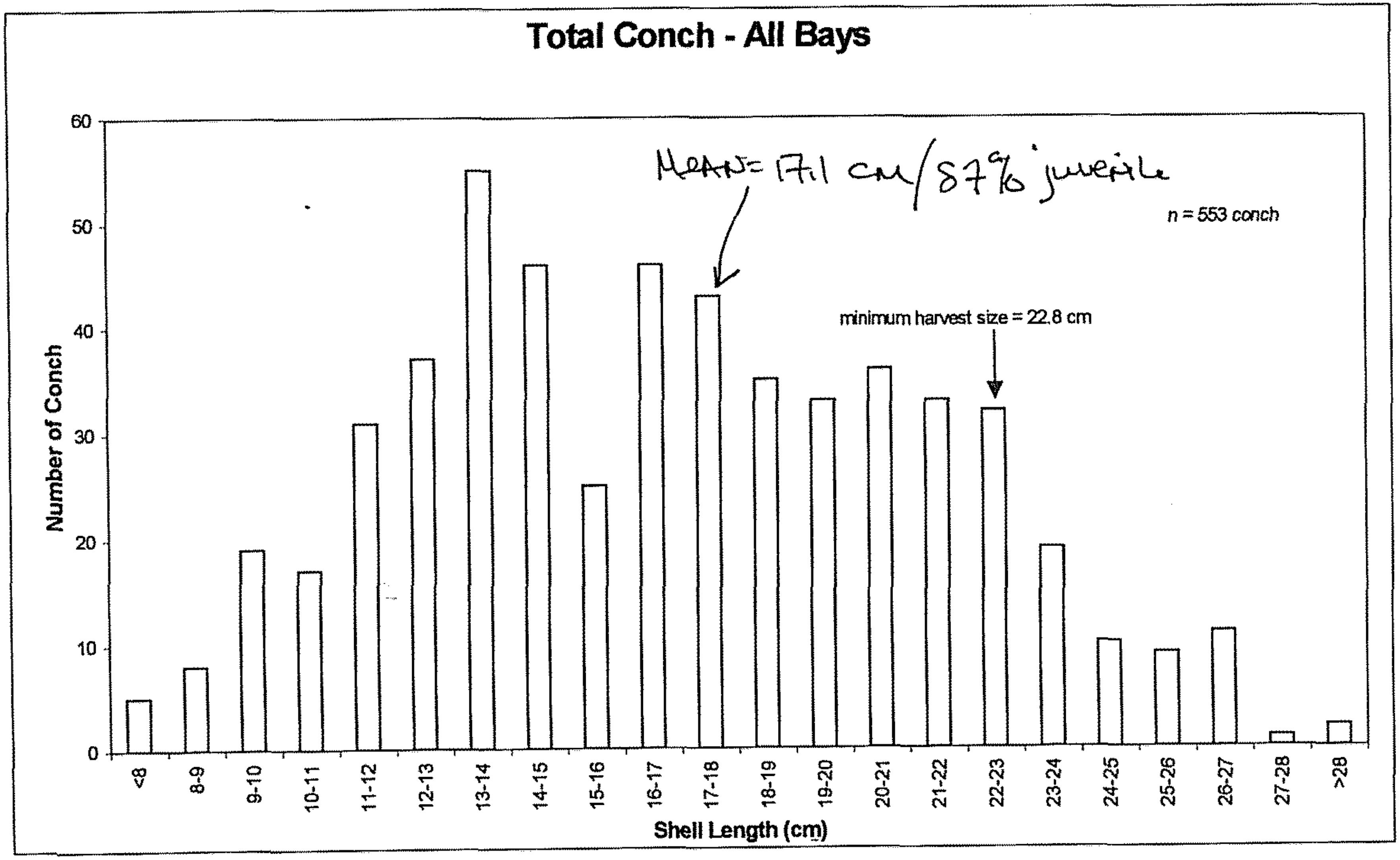


Figure 4: Length-frequency distribution for all conch found in the northeast and southeast embayments of St. Croix, U.S. Virgin Islands, in September 1998-October 1999 and July 2000-September 2001.

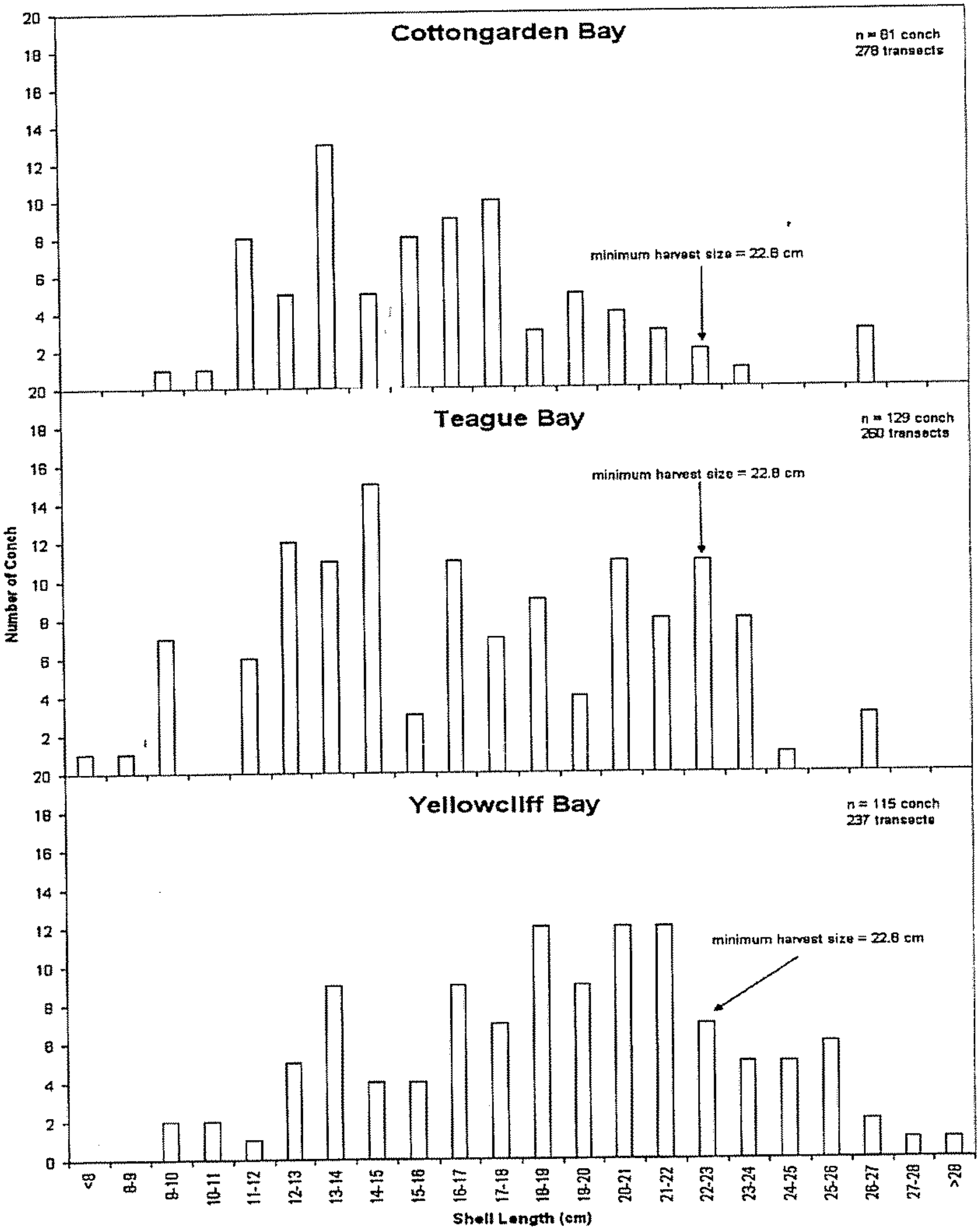


Figure 5: Length-frequency data for conch found in the northeastern embayments.

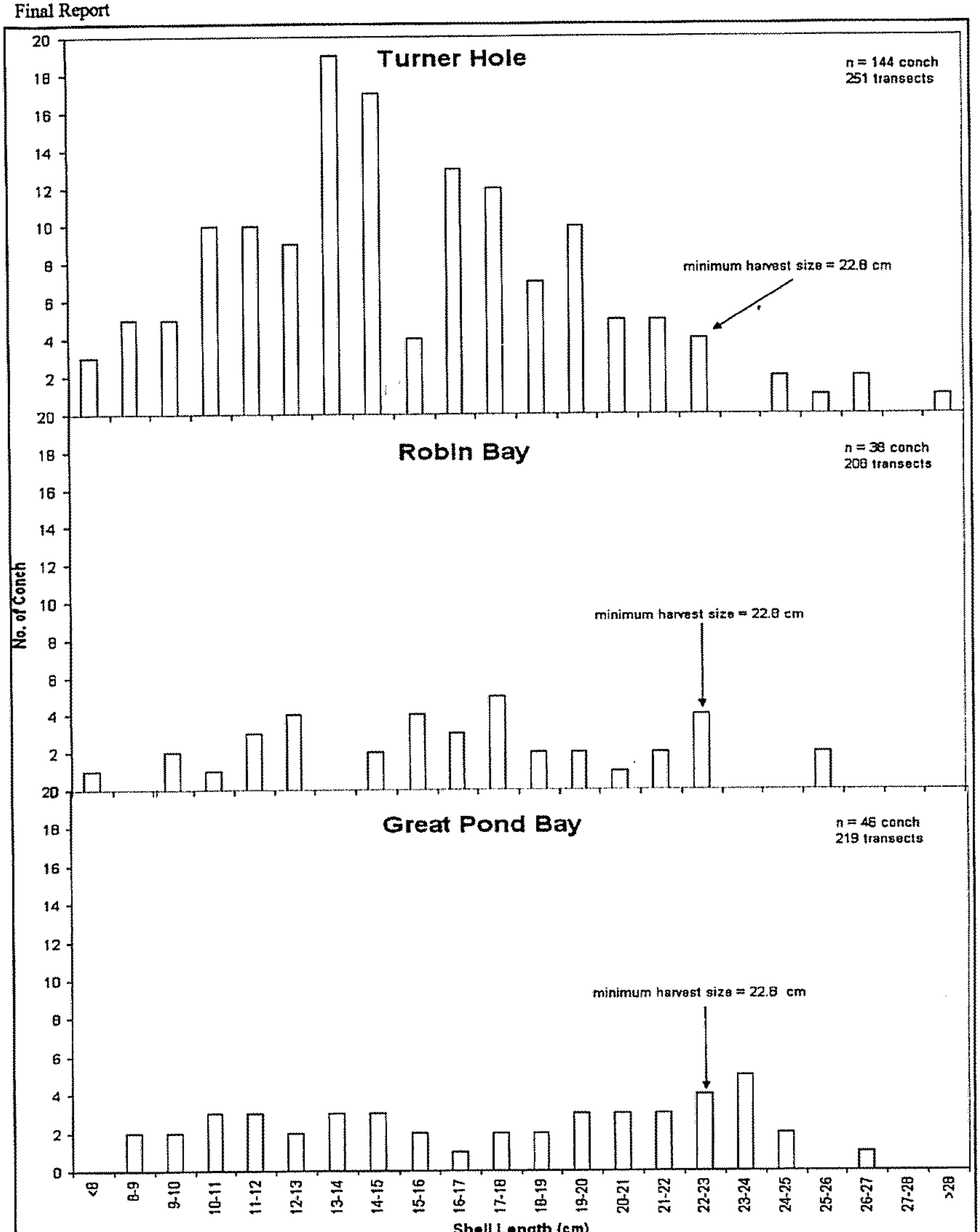


Figure 6: Length-frequency data for conch found in the southeastern embayments.

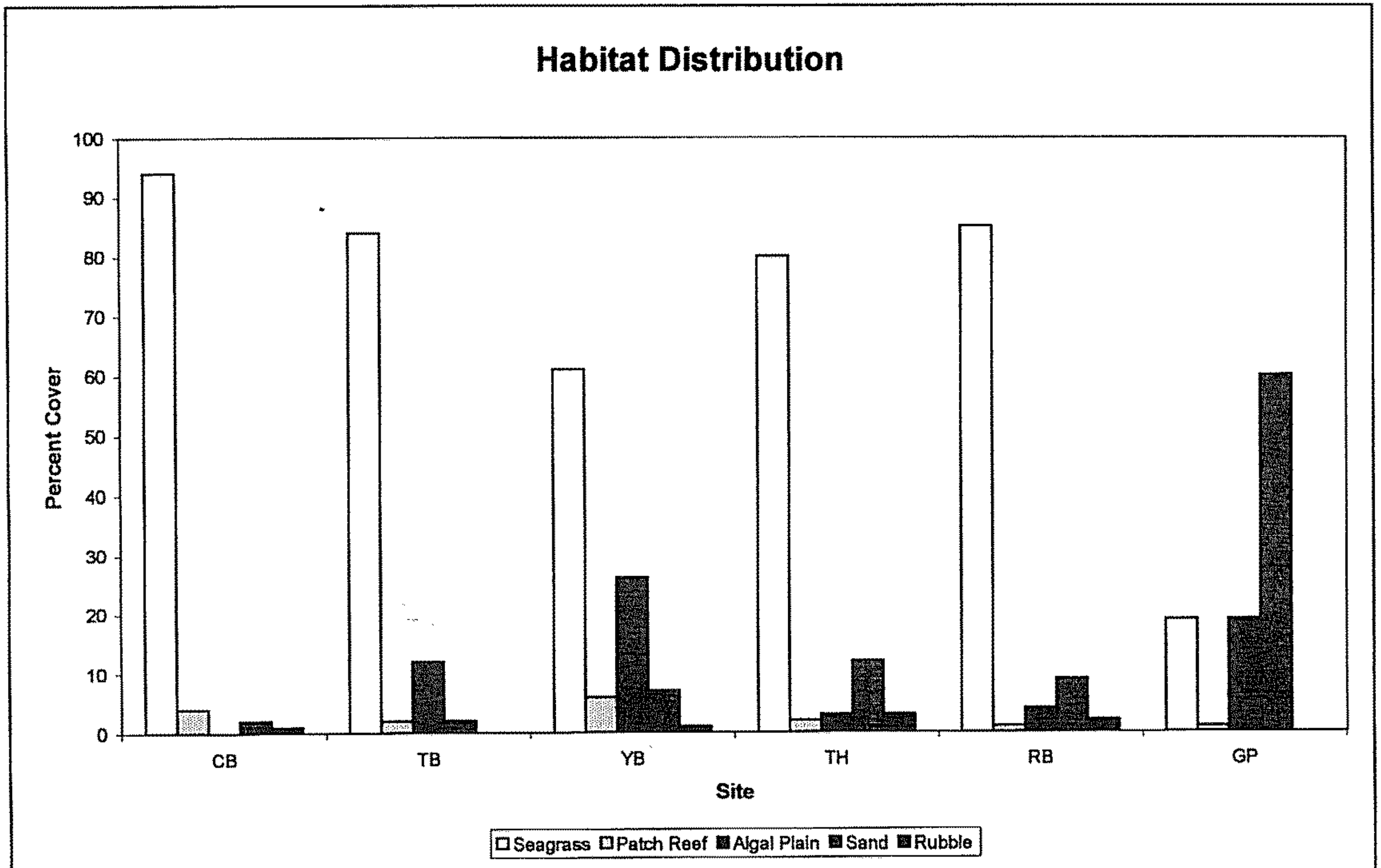


Figure 7: Percent cover of habitat in the back reef embayment study sites (from Mateo and Tobias 2001, 2004).
CB – Cottongarden Bay, TB – Teague Bay, YB – Yellowcliff Bay, THB – Turner Hole Bay, RB – Robin Bay, GPB – Great Pond Bay.

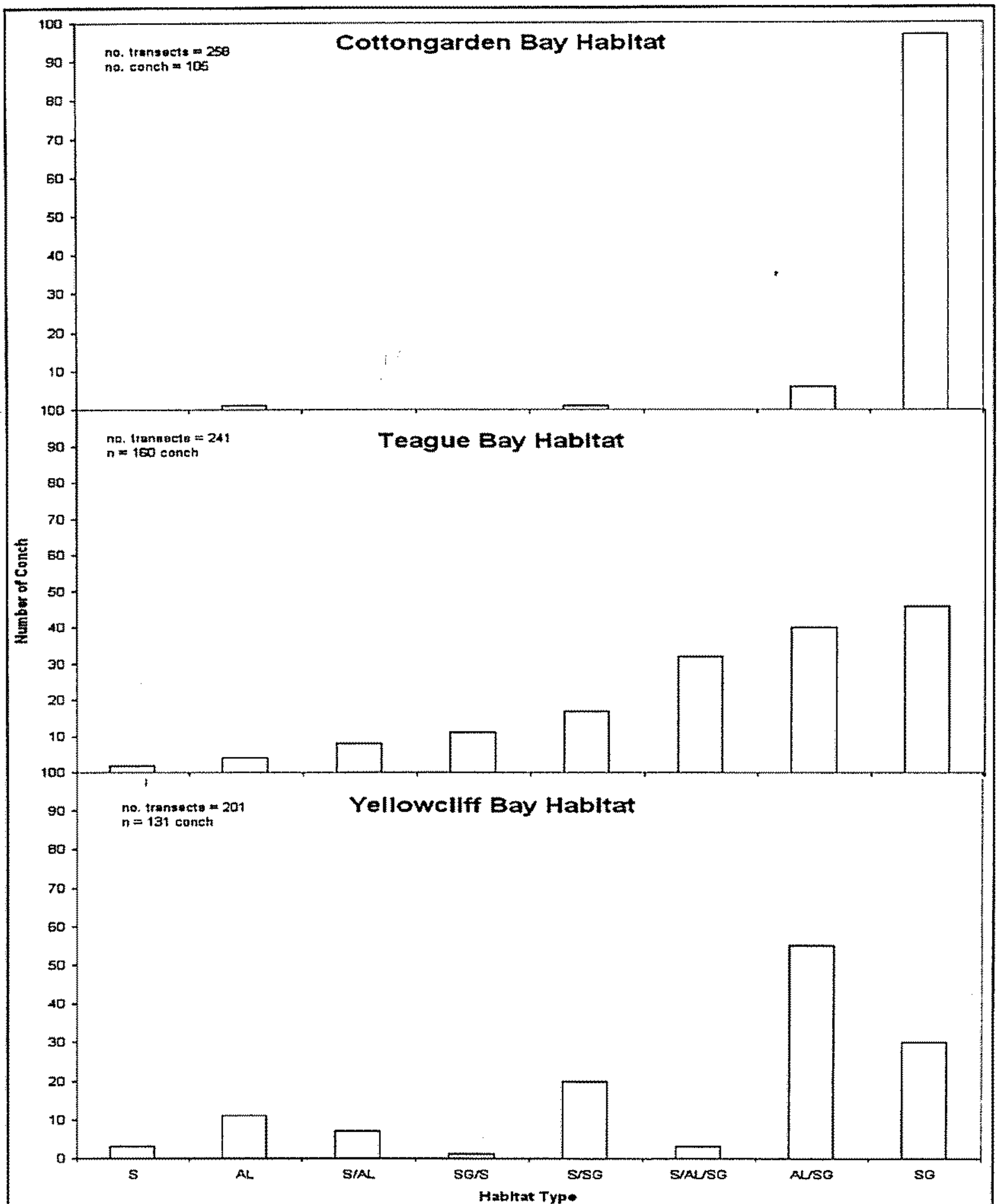


Figure 8: Number of conch by habitat type in the northeastern embayments. S = Sand, AL = Algal plain, S/AL = Sand / Algal Plain, SG/S = Seagrass / Sand, S/SG = Sand / Seagrass, S/AL/SG = Sand / Algal Plain / Seagrass, AL / SG = Algal Plain / Seagrass, SG = Seagrass.

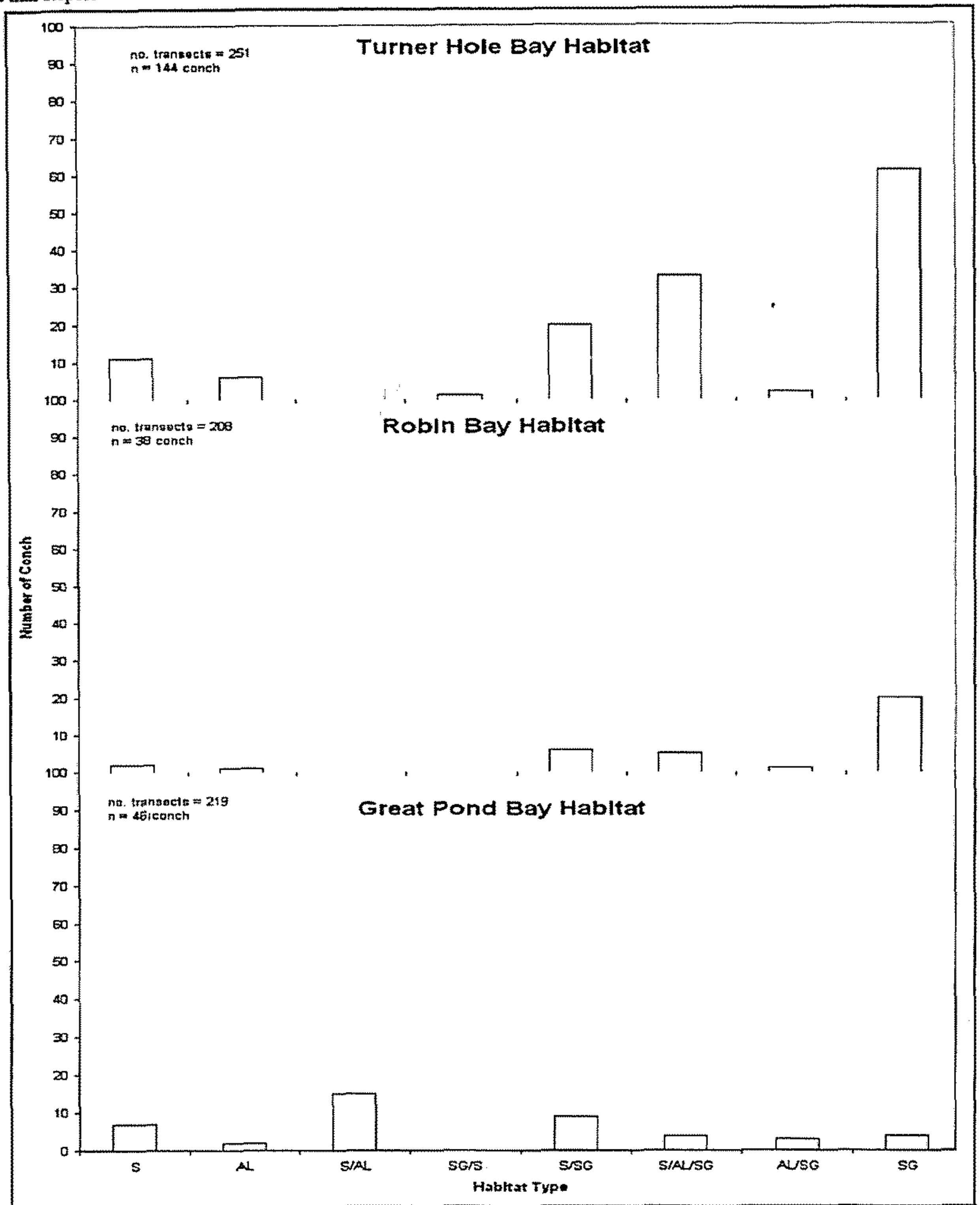
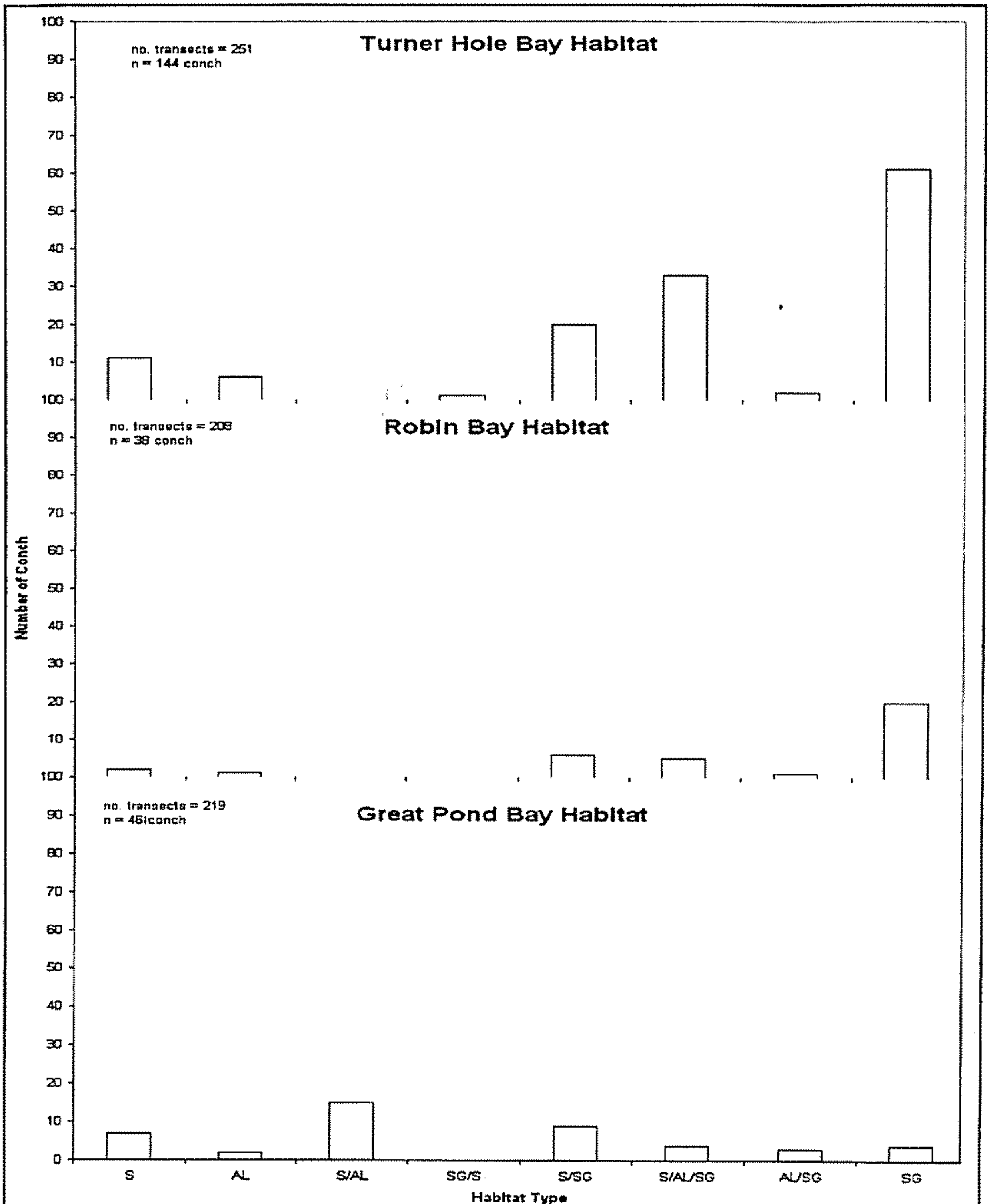


Figure 9: Number of conch by habitat type in the southeastern embayments. S = Sand, AL = Algal plain, S/AL = Sand / Algal Plain, SG/S = Seagrass / Sand, S/SG = Sand / Seagrass, S/AL/SG = Sand / Algal Plain / Seagrass, AL / SG = Algal Plain / Seagrass, SG = Seagrass.



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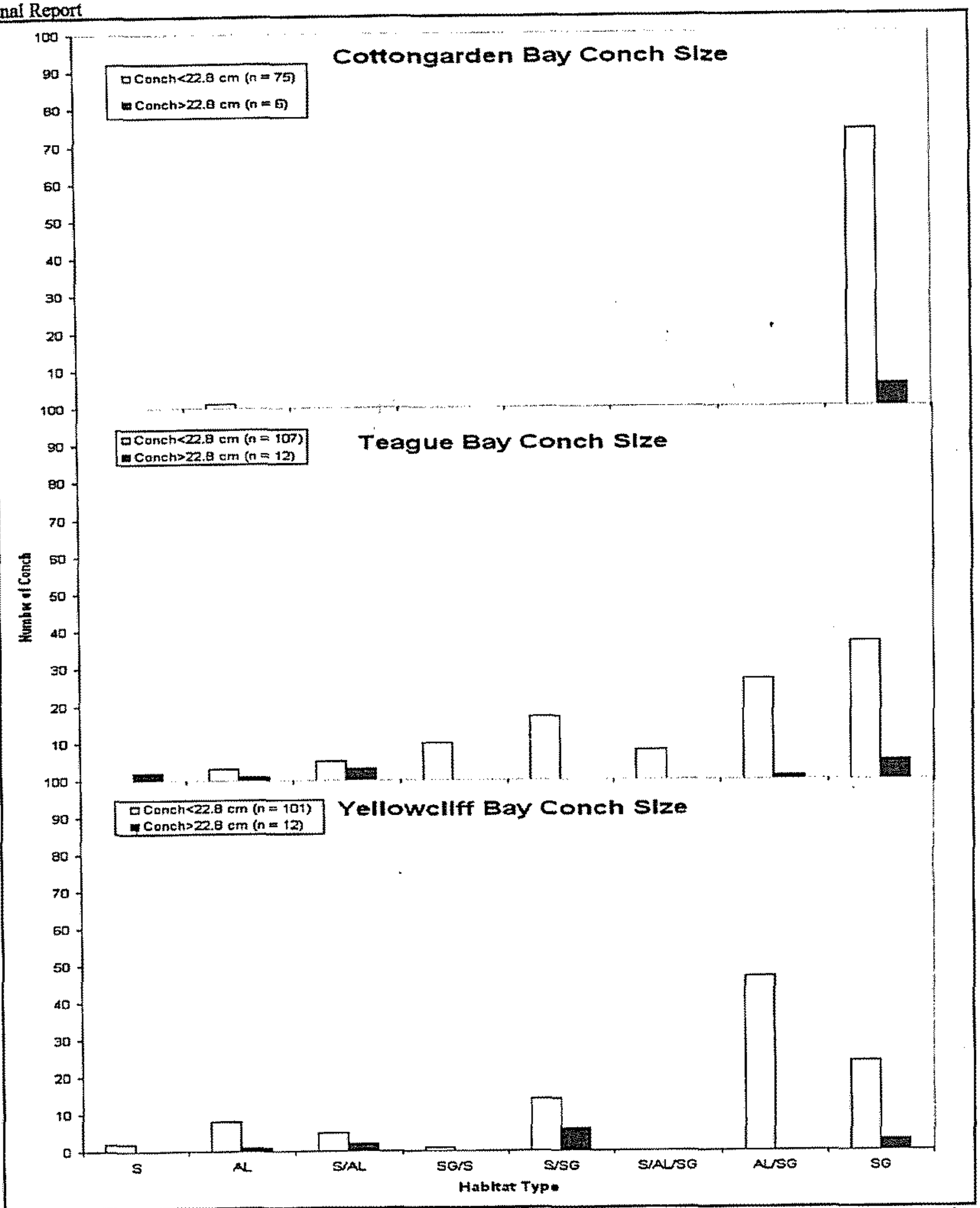

Figure 10: Number of conch by size and habitat type in the northeast embayments. S = Sand, AL = Algal plain, S/AL = Sand / Algal Plain, SG/S = Seagrass / Sand, S/SG = Sand / Seagrass, S/AL/SG = Sand / Algal Plain / Seagrass, AL / SG = Algal Plain / Seagrass, SG = Seagrass.

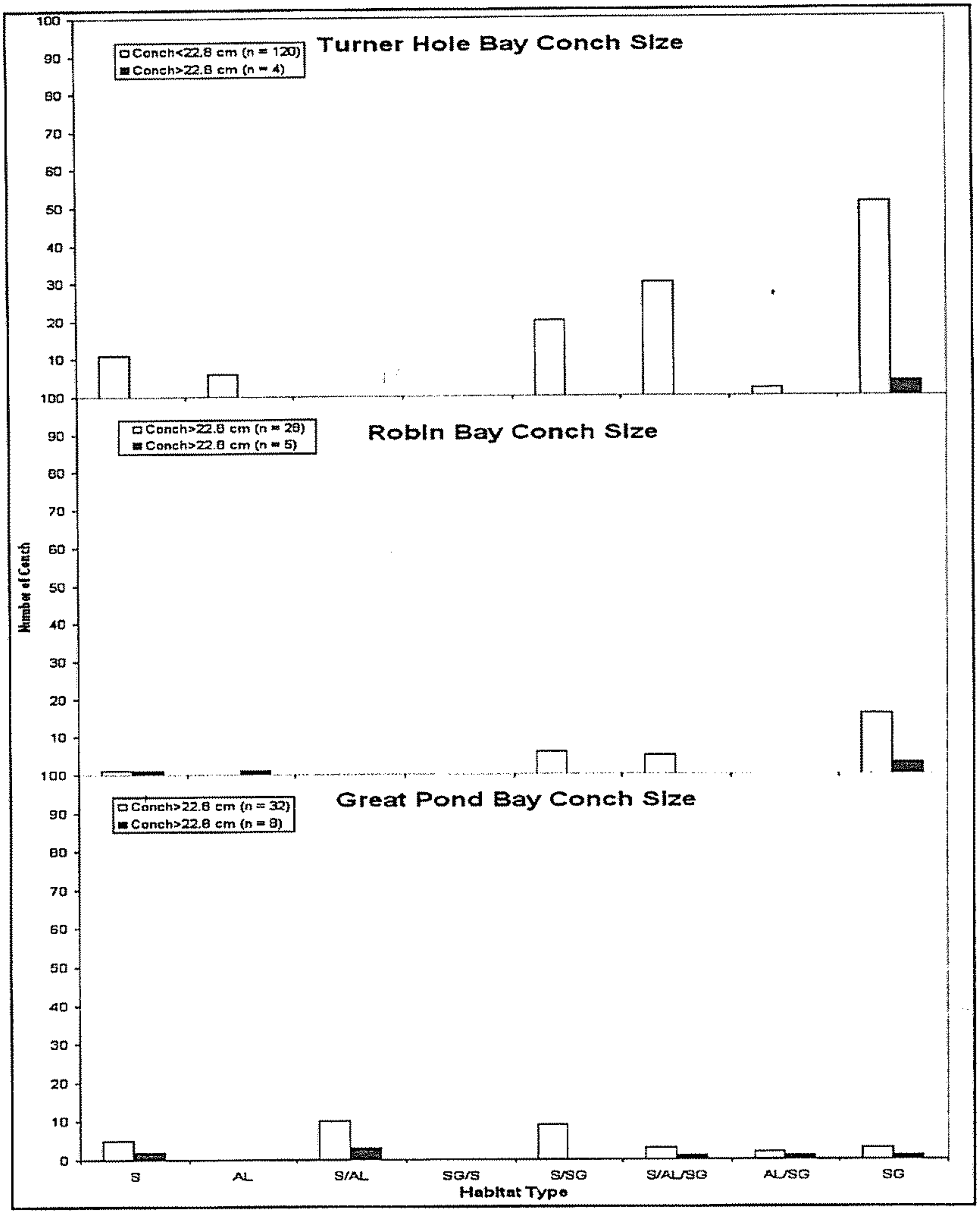

Figure 11: Number of conch by size and habitat type in the southeast embayments. S = Sand, AL = Algal plain, S/AL = Sand / Algal Plain, SG/S = Seagrass / Sand, S/SG = Sand / Seagrass, S/AL/SG = Sand / Algal Plain / Seagrass, AL / SG = Algal Plain / Seagrass, SG = Seagrass.

Table 1. Total number of conch observed and total conch density in the three northeast and three southeast embayments of St. Croix, U.S. Virgin Islands, September 1998-October 1999 and July 2000-September 2001, respectively.

	Northeast Embayments	Southeast Embayments	Combined Study Area (Northeast + Southeast Embayments)
Total Number of Conch	408	228	636
Total Area Surveyed (ha)	7.75	6.78	14.53
Total Density (total conch/ha)	52.6	33.6	43.8

Table 2. Summary of conch number and density in the three northeast and three southeast embayments on St. Croix, U.S. Virgin Islands from data collected in September 1998-October 1999 and July 2000-September 2001, respectively.

Site	Number of Transects*	Area Surveyed (m^2 - ha)	Number of Conch**			Density (conch/ha)***		
			Total	<22.8 cm	≥22.8 cm	Total	<22.8 cm	≥22.8 cm
Northeast Embayments								
Total	775	77,500 - 7.78	408					
Average/embayment	258.3	25,833 - 2.58	136	94.0	14.3	52.6	37.15	5.78
Southeast Embayments								
Total	678	67,800 - 6.78	228					
Average/embayment	226.0	22,600 - 2.26	76	67.3	8.7	33.6	28.39	3.84

* Transects = 50 m x 2 m = 100 m^2.

** The total number of conch represents the total conch recorded. All measured conch were placed in size categories of < or > 22.8 cm which represents the minimum harvest size. A total of 83 conch from the northeast embayments were not measured to the nearest millimeter but placed in size categories (18 conch <100 mm, 42 conch = 100-200 mm and 23 conch >200 mm). Therefore, the calculations of the average number and density of conch <22.8 cm and > 22.8 cm from the northeast embayments may be approximately 10-20% low.

*** Total conch density was determined from the total number of conch recorded.

Table 2. Summary of conch number and density in the three northeast and three southeast embayments on St. Croix, U.S. Virgin Islands from data collected in September 1998-October 1999 and July 2000-September 2001, respectively.

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*** Total conch density was determined from the total number of conch recorded.

Table 3. Number of conch observed in the northeast and southeast embayments of St. Croix, U.S. Virgin Islands, September 1998-October 1999 and July 2000-September 2001, respectively.

Site	Number of Transects*	Area Surveyed (m^2 - ha)	Total Conch Observed	Transect Depth (m) (Mean +/- SD)	Depth Range (m)	No. Conch/Transect (Mean +/- SD)	Range of Individuals/ Transect
Northeast Embayments							
Cottongarden Bay	278	27,800 - 2.78	105	3.0 (0.84)	1.2 - 5.5	0.37 (0.917)	0 - 6
Teague Bay	260	26,000 - 2.60	170	4.5 (1.65)	1.2 - 6.7	0.65 (1.893)	0 - 20
Yellowcliff Bay	237	23,700 - 2.37	133	4.8 (1.54)	0.9 - 7.3	0.56 (1.629)	0 - 17
subtotal	775		408				
Southeast Embayments							
Turner Hole	251	25,100 - 2.51	144	2.9 (1.01)	0.9 - 7.0	0.57 (2.144)	0 - 29
Robin Bay	208	20,800 - 2.08	38	1.9 (0.89)	0.6 - 6.7	0.18 (0.569)	0 - 5
Great Pond Bay	219	21,900 - 2.19	46	2.6 (0.72)	0.9 - 5.1	0.21 (0.508)	0 - 3
subtotal	678		228				
Total:	1,453		636				

* Transects = 50 m x 2 m = 100 m2

Table 4. Density of conch calculated in the northeast and southeast embayments on St. Croix, U.S. Virgin Islands from data collected in September 1998-October 1999 and July 2000-September 2001, respectively.

Site	Number of Transects*	Area Surveyed (m^2 - ha)	Number of Conch**			Density (conch/ha)***		
			Total	<22.8 cm	≥22.8 cm	Total	<22.8 cm	≥22.8 cm
Northeast Embayments								
Cottongarden Bay	278	27,800 - 2.78	105	75	6	37.76	28.40	2.27
Teague Bay	260	26,000 - 2.60	170	115	14	65.38	44.23	5.38
Yellowcliff Bay	237	23,700 - 2.37	133	92	23	56.11	38.81	9.70
subtotal:	775		408					
Southeast Embayments								
Turner Hole	251	25,100 - 2.51	144	134	10	57.37	53.38	3.98
Robin Bay	208	20,800 - 2.08	38	32	6	18.27	15.38	2.88
Great Pond Bay	219	21,900 - 2.19	46	36	10	21.00	16.43	4.56
subtotal:	678		228					
Total:	1,453		636					

* Transects = 50 m x 2 m = 100 m^2.

** The total number of conch represents the total conch recorded. All measured conch were placed in size categories of < or > 22.8 cm which represents the minimum harvest size. A total of 83 conch from the northeast embayments were not measured to the nearest millimeter but placed in size categories (18 conch <100 mm, 42 conch = 100-200 mm and 23 conch >200 mm). Therefore, the calculations of the average number and density of conch <22.8 cm and > 22.8 cm from the northeast embayments may be approximately 10-20% low.

*** Total conch density was determined from the total number of conch recorded.