Surveys of Queen Conch Populations and Reproductive Biology on the Little Bahama Bank, The Bahamas

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EXECUTIVE SUMMARY

In June 2014, Community Conch conducted field studies on the Little Bahama Bank to estimate the density, abundance, population structure and reproductive rates of queen conch stocks in the shallow commercial fishing grounds in an arc along the edge of the Bank between West End, Grand Bahama and the Pelican Cays in the eastern Abaco Islands (Fig. 1).

Average density of flared-lip queen conch ("adults") over the Little Bahama Bank was 30.1 "adults"/ha (no. per hectare = no./10,000 m^2) (Table 2). This density was higher than values found in some areas of The Bahamas such as the Exuma Cays and Bight of Abaco, but substantially lower than the densities observed in the southwest Berry Islands, the Grassy Cays (Andros Island), and in the Jumentos and Ragged Islands during previous surveys (Table 7). All of these high density sites had values > 100 "adults"/ha but populations in the southwest Berry Islands and the Grassy Cays were dominated by the smaller, undesirable, "samba" conch. Highest average densities in the 2014 surveys were found on the Mantanilla Shoal (69/ha) and near Carter's Cays (49/ha); all other locations had densities between 3.5 and 34 adults/ha (Table 2). The minimum density required for reproduction is 56 conch/ha. Densities of three year old conch (here called "subadults" or "rollers") were low, with an average value of just 8.3/ha in the areas surveyed.

Mating pairs of queen conch were observed in just 21 of the 215 kilometer-long lines surveyed throughout the study area (Table 5). Ninety percent of mating occurred where "adult" densities were between 43 and 453 flared-lip conch per hectare. This corresponds closely with other heavily fished areas in The Bahamas and supports the recommendation of conch experts that fishery management for the species should be designed to achieve *minimum* densities of 100 adults/ha.

Average shell length of "adult" conch was 205 mm on the Little Bahama Bank (Table 4), and shell lengths were relatively consistent over the ten survey areas. This overall average was slightly larger than the average observed at most other regions surveyed over the last 6 years in The Bahamas, but generally comparable to Andros Island, the Exuma Land and Sea Park, and Mores Island, Abaco. Average shell lip thickness was highest (27 mm) on the Mantanilla Shoal at the northern edge of the Bank, indicating that this is the oldest and least heavily exploited part of the conch population. All of the other locations had conch with relatively thin shell lips (averages = 5-15 mm) indicating that those sub-populations were very young and heavily exploited. Studies of queen conch reproduction have shown that few individuals with shell lip thicknesses <15 mm are sexually mature. Lip-thickness data indicate that only about 16% of the flared-lip conch on the Little Bahama Bank are sexually mature.

The estimated total abundance for the surveyed area was 1.96 million "adults" and 0.54 million "subadults" (Table 6). While the 2014 surveys covered the

areas planned for survey, these values probably represent an underestimate because queen conch distribution was more extensive than the total area that could be covered during the survey period, and because depths in some of the fishing grounds identified as historically important were greater than that which could be surveyed with high precision. However, the generally low density of "adult" conch, the low average age of "adult" conch (i.e., thin shell lips), and the very low density "subadults" present important reasons for concern. The low "subadult" density could result from a weak 2011 year class or a more generalized loss of recruitment to the area. The predominance of thin-lipped "adults" indicates that older conch are quickly removed from the populations around the Little Bahama Bank (with a couple of exceptions locally), and only a small proportion of the total population are sexually mature.

Based upon the collection of data over the last six years for most of the widely dispersed conch fishing grounds of The Bahamas, there is a trend for local conch populations to be overfished to densities incapable of reproduction and for densities to increase with distance from human settlements. The best example of a fully functioning population other than in the Exumas Cays Land and Sea Park is the significant adult breeding population in the most remote part of the Jumentos Cays in the southern Bahamas. With the exception of substantial populations of queen conch on Mantanilla Shoal and in localized areas of Mantanilla Reef and near Carter's Cays, the 2014 survey showed that conch populations on the Little Bahama Bank are typical of the overexploited populations now widespread in The Bahamas. **It is clear that current management and regulations are not adequate to sustain conch resources in the Bahamas.** The following management and research recommendations stem from the now abundant data on the current status of queen conch resources:

- Establish a network of marine protected areas (MPAs), fishery cooperatives and a sustainable fishery certification program.
- Protect the southern populations from international poaching.
- Update regulations to reflect the need for a minimum lip thickness at harvest, the hazard to the conch populations when hookah (compressed air) is used, and the importance of a seasonal closure.
- Develop area-specific management plans for each major conch resource with harvest quotas.
- Evaluate the impact of ending export.
- Research population connectivity using molecular genetics and the impact of discarding knocked conch in active fishing grounds.

INTRODUCTION

1.1. Focus of study

The goal of the 2014 surveys was to quantify the density, abundance, population structure, and reproductive potential of queen conch (*Strombus gigas*) in historically important fishing grounds identified by the Bahamas Department of Marine Resources and fishers familiar with the Little Bahama Bank. The surveys were conducted with methods identical to studies made by Community Conch for the Bahamas Department of Marine Resources over the last 5 years allowing for direct comparisons.

METHODS

2.1. Study sites

Surveys were conducted for queen conch on the Little Bahama Bank at historically important fishing grounds. The survey was concentrated on the outer edge of the bank ranging from West End, Grand Bahama Island, clockwise around the bank to the Pelican Cays in the eastern Abaco Cays (Fig. 1). During the survey, in some locations where queen conch appeared to have broader distribution than that outlined by DMR, the survey was extended to include a larger area. For analytical purposes, the survey area was considered in terms of 10 general locations (Table 1).

The bank environment in the study area is characterized by broad sandy flats gradually increasing in depth from shallow intertidal areas near the islands to the edge of the bank. Survey depths ranged from 1.2 to 18 m, with a superimposed tidal range of ~1.5 m. These flats include coarse white sand with little vegetation, extensive meadows of turtle grass (*Thalassia testudinum*), extensive hard-bottom habitat covered with various macroalgae such as *Laurencia* and *Sargassum* species, and soft and hard corals. Small patch reefs and hard bottom habitat are common on the bank and more continuous reef areas (to several hectares) were encountered occasionally. Tidal currents, flowing primarily east and west, were particularly strong between the cays.

Water temperatures recorded during the survey ranged from 24.3 to 30.7˚C on the surface. This variation was associated with the state of the tide on the shallow bank, with cooler water entering the bank from the deep-water surrounding the Bank on flood tide.

2.2. Survey timing

This survey was conducted from 15 to 28 June 2014. This corresponds with the height of conch reproductive season in The Bahamas (Stoner et al., 1992), and allows for comparison with earlier stock assessments and observations on mating made in recent years at the Berry Islands (Stoner et al., 2009), Andros Island (Stoner

& Davis, 2010), the Exuma Cays (Stoner et al., 2011), Bight of Abaco (Stoner et al., 2012a), and the Jumentos Cays and Ragged Islands (Stoner et al., 2013).

2.3. Survey vessels

Two small powerboats (17 and 22 feet) were used to tow snorkelers on the shallow bank for observations on queen conch density and reproductive behavior (see below). Each boat was fitted with a Garmin GPS 441S unit and depth sounder. The position of grid corners for the conch grounds were uploaded into the GPS units for easy location in the field. Coordinates for the beginning and end point of each survey tow, along with depth and temperature data, were downloaded at the end of each day of sampling.

2.4. Survey protocol

Queen conch stock assessment on the Little Bahama Bank followed the methods developed by Community Conch for earlier surveys in the Berry Islands (see Stoner et al., 2009) and other shallow bank areas in The Bahamas. The use of similar protocols allows for direct comparison of data on conch density and reproductive behavior from earlier surveys.

Maps of the study site were overlaid with a grid of one minute latitude and longitude, yielding blocks approximately one nautical mile on a side (1855 m in the north-south dimension, 1656 m in the east-west dimension) and 307 hectares (ha) in surface area. Each block, identified by the latitude/longitude coordinate of the southeast corner, was surveyed by towing a snorkeler on the surface over a standard distance of 1,000 m (determined with GPS). In some of the locations where mapping was inaccurate, depths were too great to be surveyed by divers towed on the water surface (see below) and some of the survey blocks needed to be abandoned (28 total). In other cases, the survey was expanded because of the obvious distribution of queen conch beyond the boundaries established earlier.

The general approach was to tow the diver from the southeast corner of the block (or the nearest possible point) toward the center of the block in either northwest or southeast direction such that the center of the block was always surveyed. A transect 6 m wide was observed for conch, yielding a sample unit of 6,000 m^2. In some cases total distance covered was slightly longer or shorter than the design 1,000 m (e.g., because of shoals or land masses, or slight over-runs), and surface area was calculated independently for each block, eliminating land area, intertidal bank areas, and other habitats unlikely to support adult and subadult conch.

Each transect line was surveyed for:

a) Number of "adult" queen conch. These are identified by a flared shell lip and are at least 3.5 years old. (See below for elaboration on this definition.)
b) Number of "subadults" ("rollers"). These are large juvenile conch (greater than ~10 cm shell length) without a flared shell lip, and are typically between 2.5 and 3.5 years old.
c) Number of "juveniles". These are small juveniles (less than ~10 cm), and are generally 1-2 years old.
d) Number of mating pairs. Where two individuals are in copulation orientation, with shells in direct contact.

In past surveys, numbers of egg-laying females have also been recorded. However, this survey included a large number of tows that were in depth > 5 m and egg-laying could not be reliably assessed. Egg laying is not reported here.

In The Bahamas, a well flared shell lip provides the traditional definition of an "adult" and this is currently the only form legal for harvest. However, we know from histological studies in the Exuma Cays (Stoner et al. 2012b) and the Bight of Abaco that sexual maturity does not occur in the majority of queen conch until a *minimum* lip thickness of 10-15 mm is achieved. Therefore, where adult conch were abundant, opportunistic collections were made to measure for the following:

a) shell length (SL) (± 1 mm) with large Vernier calipers, and
b) shell lip thickness (LT) (± 1 mm) using small Vernier caliper, to provide an index of age.

For analytical purposes, queen conch with shell lip thickness ≥ 15 mm were considered to be mature, while those with lip thickness < 15 mm were classified as immature.

2.5. Analysis

Densities of "adult" and "subadult" queen conch were evaluated for patterns related to water depth and location on the Little Bahama Bank. Count data were standardized to number of conch per hectare (10,000 m^2) for each age group in each depth zone or geographic region. Total numbers of conch in a block were extrapolated from the density estimate for that block and its surface area. These numbers were then summed to yield an estimate for the total number of conch (abundance) for each general location and the overall survey area.

Depth zones considered for analysis were:
A: 0 - 2.5 m
B: 2.5 - 5.0 m
C: 5.0 - 10 m
D: 10 – 15 m

2.6 Genetic Sampling

Two hundred and sixty-eight (268) genetic samples were collected throughout the study area by Dr. Nathan Truelove (Smithsonian Marine Station, Fort Pierce, Florida) to evaluate population connectivity near Grand Bahama and the Abacos. These samples also represent a critical part in a larger study of genetic connectivity throughout The Bahamas and Caribbean Sea. Results of DNA analysis will be reported in a separate report from Dr. Truelove.

RESULTS

3.1. Densities and depth distributions

The Little Bahama Bank survey revealed relatively low numbers of "adult" and "subadult" queen conch, with totals of just 3,853 and 1,076, respectively, observed by the divers. Conch with flared shell lips were the most commonly observed, with these "adult" conch observed in 95.8% of the 215 tows. The average density was 30.1 "adults"/ha (SD = 59.3). Age-3 "subadults" were much less common, observed in 54.4% of tows, and the average density was just 8.3/ha (SD = 17.7) (Table 2).

Over the study area, highest average densities of queen conch with flared shell lips occurred on the Mantanilla Shoal on the northwestern edge of the Bank and near the Carter's Cays (Figs. 2, 3 & 4). However, even these densities were relatively low (68.8 and 49.2 "adults"/ha) (Table 2). The highest individual values were observed in localized populations near Carter's Cays (453 "adults/ha) and on the Mantanilla Shoal (342 "adults"/ha); however, most densities were much lower with substantial variation in each general location. At the Mantanilla Shoal, the conch were concentrated in the southwest sector with 4 blocks yielding more than 100 "adults"/ha. Few conch were observed in the northeast sector where there was little algal biomass providing food. In the Carter's Cays area, highest densities of "adults" were observed immediately south of the coral reef tract between Yankee Cay and Moraine Cay. The lowest densities of "adult" conch were found on the fishing grounds of West End off of Grand Bahama.

Subadults were relatively uncommon, with highest densities observed near Man-O-War Cay (30.3/ha) and Guana Cay (19.7/ha). However, densities at these two locations were highly variable and the averages were biased by one high count in each location (125/ha at Man-O-War Cay and 90/ha at Water Cay). All of the larger survey areas had subadult densities ranging from 0.4 to 8.4/ha (Figs. 5, 6, & 7), and the overall average for the Little Bahama Bank survey was just 8.3 subadults/ha.

Smaller age-1 and age-2 juveniles were observed in just 84 tows (39% of the tow lines). Counts ranged from just one individual to 69 (at Grand Cay) in a single tow. Densities > 50 juveniles/ha were observed in just five locations that can be

considered nursery grounds (one tow in 7 m depth east of Grand Cay, three at Mantanilla Reef in 9 to 15 m depth, and one in 2.7 m depth north of Wood Cay in the West End region, Figs 5,6 & 7); these were found in depths ranging from 2 to 15 m. However, young conch are often highly localized in very shallow areas, and density data based upon 1,000-m long tows is not very meaningful. Given the survey design, other undetected nurseries may exist in the survey area.

Densities of "adult" queen conch increased with depth (Table 3), stabilizing at values between 33 and 39.9/ha at depths > 5 m. Densities of "subadult" queen conch showed a reverse pattern, with highest values (11.9/ha) in the shallowest depth stratum (0 to 2.5 m), and average values between 4.2 and 10.0/ha in the deeper strata (Table 3). Only six counts were made in the shallowest depth interval, all in the West End sector, providing limited confidence in the depth pattern; however, a general movement of conch to deeper water with age is common in The Bahamas and other Caribbean locations.

3.2. Size and age structures

More than 300 living queen conch with flared shell lips were measured for shell length and lip thickness (Table 4). Flared-lip individuals on the Little Bahama Bank were highly variable in shell length (159-255 mm), with small but thick-lipped "samba" conch mixed with larger conch particularly obvious in the West End and Man-O-War Cay sectors. The overall average shell length was 205 mm (SD = 19 mm). The smallest "adults" occurred near Man-O-War Cay (mean = 190 mm)(Table 3) where about half of the individuals could be classified as "samba". However, there was wide variation in shell length within each of the geographic regions.

Average shell thickness over the study area was just 11 mm (SD = 7 mm) with substantial spread in the distribution and most of the measurements in the lower range (Fig. 8). Repeated measures of tagged queen conch in The Bahamas (Stoner & Sandt 1992) indicated that it takes nearly 5 years for an individual to reach 10 mm in shell lip thickness, and 45.1% of the total population sampled in this survey (n = 323) was in that young flared-lip age group. Queen conch with lip thickness ≥ 15 mm are likely to be sexually mature (Stoner et al. 2012b); those mature conch made up just 26.7% of the overall sample of conch with flared shell lips. However, there was substantial geographic variation in average shell lip thickness (Table 4). Thickest (i.e., oldest) conch were observed on the Mantanilla Shoal (mean = 27 mm, SD = 5), with relatively little variation among the 18 conch measured. Excluding this location, only 16.1% of the measured conch with flared shell lips are expected to be sexually mature.

3.3. Reproductive behavior

Mating pairs were observed on 21 of the 215 survey tows (9.8%) made on the Little Bahama Bank. This ranged from just one mating pair in a survey tow to five pairs observed in one tow on the Mantanilla Shoal. Mating was observed in only five of the geographic locations (Table 5), generally at locations with highest densities of

flared-lip conch (Table 2), except at Guana Cay where overall density was low but two mating pairs were observed on a tow line with 96 adults/ha. Mating frequencies, the percentage of adults engaged in mating, ranged from 1.39 to 6.15%. No mating at all was observed at 194 locations where adult densities were less than 25 "adults"/ha, and 90% of the mating was observed on individual tows where densities were between 43 and 453 flared-lip conch per hectare.

3.4. Overall stock assessments

The Little Bahama Bank survey represented more than 65,000 hectares (650 km^2) spread over a distance of approximately 170 nautical miles (312 km) along the west, north, and northeast edge of the bank where queen conch have been abundant historically (Table 6). Extrapolating densities over the geographic blocks surveyed, the estimate for total numbers of queen conch on the Little Bahama Bank in June 2014 was almost 2 million conch with flared shell lips and more than half a million "subadults". Ninety-one percent of the queen conch on the Little Bahama Bank were located between the Mantanilla Shoal and the Carters Cays where highest densities were observed (Table 2). Unlike "adults", "subadult" numbers did not follow geographic density patterns. Highest numbers were observed near Carters Cays, north of West End, and on Mantanilla Reef (Table 6). While flared-lip conch were abundant on the Mantanilla Shoal, "subadults" were rare there totaling just over 4000 individuals. Otherwise, "subadult" conch were found in relatively low densities throughout the region except for a few locations discussed earlier, and the overall proportion of "subadults" was just 21.6% of the conch older than 3 years, with "adults" making up 78.4% of these large conch. However, these proportions varied substantially with location (Table 6). "Subadults" made up more than half of the conch older than 3 years at West End and near Man-O-War Cay, and the value was near parity near Guana Cay.

DISCUSSION

4.1. Population characteristics and comparisons

Average densities of queen conch with flared shell lips ("adults") on the Little Bahama Bank were in the low to mid-range of values observed in other surveys conducted in The Bahamas over the last six years (Table 7). While the average density was higher than values observed in some other locations such as the east coast of Andros Island, the Bight of Abaco, and on the banks of the Exuma Cays, it should be noted that the average density of 30 "adults"/ha is biased by relatively high densities on the Mantanilla Shoal and near Carters Cays. Also, the highest densities observed on individual tow lines were 453 "adults"/ha at Carters Cays and 342/ha on the Mantanilla Shoal. These are very low values compared with high individual observations in the most productive fishing grounds such as the Jumentos Cays where densities were sometimes > 1000 "adults"/ha. No historically important fishing ground on the Little Bahama Bank had "adult" densities above the minimum threshold identified by Stoner & Ray-Culp (2000) for reproduction (i.e., 56/ha), and

none was close to the value of 100/ha recommended by the Queen Conch Expert Panel (CFMC, 2012) for a sustainable fishery (see below).

Shell lip thickness provides a good indication of exploitation rate. The east coast of Andros Island, the Lee Stocking Island area in the Exuma Cays, the Bight of Abaco, and the as yet unprotected waters of the Berry Islands Marine Fishery Reserve are all heavily fished as characterized by conch with lip thicknesses averaging < 10 mm (Table 7). Average shell lip thickness was only slightly higher on the Little Bahama Bank (11 mm). This means that the conch in all of these areas are very young, and many of the flared-lip individuals have not reached reproductive maturity (see earlier reports – Stoner et al., 2011, 2012a). Measurements made during this survey indicate that only about 16% of the flared-lip queen conch on the Little Bahama Bank are sexually mature. This contrasts strongly with the thick shell lips of queen conch in the Exuma Cays Land and Sea Park where no fishing occurs, and in the Jumentos Cays and Ragged Islands where queen conch appear to be lightly fished and reproductive behavior is common.

Densities of "subadults" were very low on the Little Bahamas Bank, among the lowest observed in The Bahamas and in the range of values observed in the heavily fished Bight of Abaco (Table 7). An extreme low value for "subadult" density was recorded on the Mantanilla Shoal where "adults" were relatively common. Possible reasons for low numbers of "subadults" are discussed below.

Depth distributions of both "adult" and "subadult" queen conch on the Little Bahama Bank were similar to the patterns observed in other Bahamian locations. Highest densities of "adults" were found between 5 and 10 m depth, while highest densities of "subadults" occurred in shallower water (0 - 2.5 m). This is related to a general pattern of larval settlement on shallow sandy banks and seagrass meadows followed by migration with age to deeper water (Stoner, 2003). Also, it should be noted that maximum density of adult queen conch in depths ranging from 5 to10 m means that the vast majority of conch can be exploited with hookah gear, and that the deep-water reserve is relatively small.

4.2. Mating behavior – comparisons with earlier studies

The importance of high adult density for mating and reproduction in queen conch is now clearly established (Stoner & Ray-Culp, 2000; Stoner et al., 2012c), and the new observations from the Little Bahama Bank on mating closely follow patterns found in earlier studies for heavily fished populations. Only 39 mating pairs were observed in the entire survey, and almost all of these were found on Mantanilla Shoal and Reef, and in localized populations near Carters Cays where highest numbers of "adults" were counted. This was also associated with locations where thick-shelled individuals were observed. As observed in other locations around The Bahamas, no mating at all was found in individual survey lines with < 25 "adults'/ha, and most mating occurred where densities were twice that value. In the Exuma Cays Land and Sea Park, no mating has been found at densities < 56 "adults"/ha (Stoner & Ray-Culp,

2000); the lower threshold for mating seems to be variable and is much higher in some locations (Stoner et al., 2012c). However, the new findings support very well the recommendation (mentioned above) that densities be managed for a ***minimum* of 100 adults/ha** to insure adequate mating (CFMC, 2012). Heavily fished populations such as those in the Berry Islands, near Andros Island, and in the Bight of Abaco appear to require even higher densities, most likely because the natural age structures of the populations are disturbed and many of the flared-lip "adults" are not sexually mature (Stoner et al., 2009, 2012a; Stoner & Davis, 2010). The same is likely to be true on the Little Bahama Bank, except in those locations such as the Mantanilla Shoal where a relatively natural population structure (e.g., presence of mature older adults) has probably been conserved by the remoteness of that location from human settlements.

4.3. Stock assessment

Substantial numbers of queen conch exist on the Little Bahama Bank, but only in three primary locations, the Mantanilla Shoal and Reef and near Carter Cays, where 91% of the flared-lip individuals were found. The total number on the Bank was only 1.96 million individuals estimated for a very large survey area spanning 170 nautical miles along the bank edge and encompassing 65,000 ha.

The low average density of age-3 "subadult" conch (8.3/ha) resulted in low abundance values even on the Mantanilla Shoal where "adults" were relatively abundant. In June 2014, the total number of "subadult" conch on the Little Bahama Bank was estimated at just over half a million individuals. The low density of "subadults" on the Little Bahama Bank could represent weak larval recruitment to the nursery grounds in 2011, or a more generalized loss of recruitment in the northern Bahamas. The general lack of queen conch mating on the Little Bahama Bank presents considerable reason for concern since it is likely that the Bank is relatively isolated from other conch populations in The Bahamas and possibly dependent upon local spawning (i.e., spawners living on the Little Bahamas Bank). The young age structure of queen conch in most regions of the Bank indicate that reproduction is not possible and the stocks are overfished.

MANAGEMENT AND RESEARCH RECOMMENDATIONS

Information on queen conch populations derived from field surveys conducted between 2009 and 2014 indicates a declining resource, particularly near human population centers. Very low adult densities and minimal reproduction have been observed at the following locations:

- East coast of Andros Island
- Berry Island Marine Reserve
- Berry Islands West Bank
- Lee Stocking Island
- Exuma Cays Land and Sea Park
- Bight of Abaco - Sandy Point
- Bight of Abaco - Mores Island
- Little Bahama Bank, except for the Mantanilla Shoal and Carters Cays

It is clear that current management and regulations are not adequate to sustain the resources in these areas. These conch populations require a combination of enforcement, temporary halt of fishing to rebuild stocks, and protection of upstream fisheries to revive recruitment.

Six bank areas surveyed have densities of adult queen conch sufficient for reproduction. These include:

- Berry Islands southwest fishing ground (sambas)
- Grassy Cays south of Andros (sambas)
- Jumentos Cays
- Mantanilla Shoal
- Carter's Cays (localized population)

Highest average density (149 adults/ha) was observed in the Jumentos Cays, the fishing ground most distant from any human population center. Although the southwest Berry Islands and the Grassy Cays have >100 adults/ha, the populations were dominated by stunted, "samba" conch which are undesirable to fishers. This overview of the current status of conch resources leads to the following management and research recommendations for The Bahamas.

5.1 Management Recommendations

- Establish a broad network of marine protected areas. It is now well known that a network of protected areas is required to insure reproduction and larval supply over a geographic range as large as The Bahamas. The Exuma Cays Land and Sea Park is probably supplying larvae to more northern and western locations, but more protected areas need to be established throughout the archipelago, including the southernmost regions such as the Jumentos Cays and Ragged Islands. Fishery models indicate that about 20% of a subject population needs to be protected in no-take fishery reserves to insure sustainable harvests throughout the unprotected habitat. Genetic studies now being undertaken by the Smithsonian Institution will provide guidance for placement of MPAs.

- Protect southern conch (and other commercially important marine species) from international poachers. Poaching is particularly common on the Cochinos Bank and Cay Lobos, west of the Ragged Islands.

- Establish a system of fishery cooperatives. Cooperatives would allow landings to be monitored, fisheries data to be collected and fishers to receive a higher price for their products.

- Establish a sustainable fishery certification program. A certification program could be used to verify that conch sold in local restaurants and exported were caught according to updated regulations.

- Update regulations. Conch research in The Bahamas over the past 6 years has generated reproductive information that should be incorporated into revised regulations to improve management. Of particular importance:

    - Implement a minimum lip thickness regulation of 15mm.
    - Require that conch be landed in the shell or with the operculum (foot) attached for monitoring of maturity.
    - Prohibit the use of hookah to catch queen conch (or at least more strictly enforce current regulations that prohibit the use of hookah in water less than 30' during the closed lobster season).
    - Institute a closed season coordinated with nearby Caribbean countries.

- Develop site specific management plans. Data collected to date show that each of the major conch fishing grounds (e.g. Bight of Abaco, Berry Islands, South Andros, Ragged Islands) have populations of conch with at least somewhat unique characteristics of growth rates, size and age distributions, mortality, reproductive rates, and harvest by the primary groups of fishers working in the area. Furthermore, new genetic studies are beginning to show that some of the grounds are probably isolated from one another in terms of recruitment process. Thus, these populations might need to be managed individually. For practical reasons all of the fishing grounds should be subject to the same harvest regulations for conch size or age (i.e., lip thickness), fishing gear, and season, etc., but isolated fishing grounds might require individual harvest quotas or even closures.

- Evaluate the impacts of ending queen conch export. Export is estimated to make up 20 to 25% of the conch resources landed in The Bahamas. While some fishermen serve only the fresh conch market, others, particularly those in the out islands, are dependent on the export market. However, it is reported that juveniles are often illegally harvested for the frozen export market. The impact of curtailing export needs to be evaluated and consideration made for compensating those most impacted by such an action.

5.2 Research Recommendations

- Study molecular genetics. Despite gaining significant insight from ongoing conch surveys, management would benefit greatly from information on the connectivity of queen conch populations among the island groups. New methods in molecular genetics would help to identify pathways of larval supply over the nation and which reproductive stocks are most critical to fisheries recruitment. Genetic studies would also help in the design of the most efficient and effective network of marine protected areas.
  Such a study has been initiated for The Bahamas in a cooperative relationship between Community Conch and the Smithsonian Institution. Results of this work are not anticipated until late 2015 or early 2016.

- Knocked conch experiment. A commonly heard idea in The Bahamas is that discarding knocked conch onto a living conch community is detrimental to fisheries. This hypothesis should be investigated in several locations with the help of local fishermen.

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Table 1. Ten locations surveyed for queen conch on the Little Bahama Bank during June 2014. These represent historically important fishing grounds identified by the Bahamas Department of Marine Resources. The sites are in order moving clockwise around the west, north and east edges of the bank from West End, Grand Bahama Island to the Abaco Cays. The number of tows is equivalent to the number of 1 nautical mile square boxes surveyed in the region.

Location	Dates surveyed	Depth range and averages (m)
A: West End	15-18 June	1.2 -9.1 (4.1)
B: Mantanilla Shoal	20 June	8.0 – 14.0 (11.3)
C: Mantanilla Reef	21-22 June	3.1 – 18.0 (10.2)
D: Grand Cay	23-24 June	2.2 – 9.8 (5.9)
E: Carters Cays	23-25 June	2.1 – 14.5 (6.5)
F: Allan's/Pensacola Cay	25 June	4.6 – 8.2 (6.6)
G: Manjack Cay	26-June	4.4 – 6.4 (5.6)
H: Guana Cay	26 June	2.1 – 4.5 (3.6)
I: Man-O-War Cay	28 June	3.5 – 9.4 (5.7)
J: Pelican Cays	28 June	3.2 – 10.6 (6.2)

Table 2. Densities of "adult" and "subadult" queen conch by geographic region in the shallow bank environment of the Little Bahama Bank in June 2014. Values for each general location are reported as mean and standard deviation for the numbers of individuals per hectare (no./10,000 m^2). See Methods for a full description of the regions. The number of tows is equivalent to the number of 1 nautical mile square blocks surveyed in the location.

Location	No. of tows	Adult density	Subadult density
A: West End	55	3.65 ± 4.25	8.36 ± 16.1
B: Mantanilla Shoal	19	68.8 ± 115	0.70 ± 1.49
C: Mantanilla Reef	41	33.9 ± 43.1	7.13 ± 12.7
D: Grand Cay	22	25.5 ± 29.2	8.06 ± 10.9
E: Carters Cays	54	49.2 ± 77.3	10.1 ± 19.9
F: Allan's/Pensacola Cay	6	8.57 ± 5.31	1.17 ± 1.56
G: Manjack Cay	4	6.67 ± 6.09	0.42 ± 0.83
H: Guana Cay	5	21.7 ± 42.0	19.7 ± 39.4
I: Man-O-War Cay	5	15.3 ± 21.6	30.3 ± 54.2
J: Pelican Cays	4	22.8 ± 13.8	8.40 ± 11.4
Combined data	215	30.1 ± 59.3	8.3 ± 17.7

Table 3. Densities of "adult" and "subadult" queen conch by depth interval in the shallow bank environment of the Little Bahama Bank in June 2014. Values for each depth interval are reported as mean and standard deviation for the numbers of individuals per hectare (no./10,000 m^2).

Depth interval	No. of tows	Adult density	Subadult density
A: 0 to 2.5 m	6	3.33 ± 3.33	11.9 ± 12.6
B: 2.5 to 5.0 m	68	16.4 ± 36.8	10.0 ± 17.6
C: 5.0 to 10 m	99	39.9 ± 71.7	8.55 ± 20.4
D: 10 to 15 m	42	33.0 ± 56.5	4.25 ± 9.73
Combined data	215	30.1 ± 59.3	8.3 ± 17.7

Table 4. Shell length and lip thickness data for queen conch with flared shell lips collected on the Little Bahama Bank in June 2014. Values for shell length and lip thickness are mean and standard deviation, followed by the total range (parentheses). Data are reported for nine general locations ranging from West End, Grand Bahama to the Abaco Cays. No data were collected near Manjack Cay.

Location	No. measured	Shell length (mm)	Lip thickness (mm)	Proportion ≥ 15 mm lip thickness
A: West End	18	196 ± 21 (159-230)	7 ± 5 (2-22)	11.1
B: Mantanilla Shoal	18	201 ± 15 (171-236)	27 ± 5 (17-36)	100
C: Mantanilla Reef	71	219 ± 18 (178-255)	13 ± 8 (3-33)	38.0
D: Grand Cay	37	204 ± 13 (170-233)	7 ± 3 (2-14)	0
E: Carters Cays	87	194 ± 13 (164-221)	12 ± 4 (3-21)	29.9
F: Allan's/Pensacola Cay	22	222 ± 14 (192-251)	5 ± 2 (3-11)	0
H: Guana Cay	27	196 ± 12 (180-221)	5 ± 4 (1-15)	3.7
I: Man-O-War Cay	16	190 ± 16 (163-226)	9 ± 4 (3-19)	12.5
J: Pelican Cays	32	220 ± 14 (199-247)	15 ± 6 (4-28)	21.9
Combined data	328	205 ± 19 (159-255)	11 ± 7 (1-36)	26.7

Table 5. Mating behavior observed in queen conch with flared shell lips ("adults") on the Little Bahama Bank in June 2014, by location. The value for percent mating is based upon the assumption that each pair is made up of one male and one female.

Location	No. of "Adults" Counted	No. of mating pairs observed	% of "Adults" mating
A: West End	121	0	0
B: Mantanilla Shoal	785	14	3.57
C: Mantanilla Reef	816	8	1.96
D: Grand Cay	343	4	2.33
E: Carters Cays	1579	11	1.39
F: Allan's/Pensacola Cay	32	0	0
G: Manjack Cay	16	0	0
H: Guana Cay	65	2	6.15
I: Man-O-War Cay	46	0	0
J: Pelican Cays	50	0	0
Combined data	3854	39	1.92

Table 6. Estimated total abundance of "adult" and "subadult" queen conch on the Little Bahama Bank in June 2014, by location. It should be noted that while "adult" conch may be legally harvested in The Bahamas, the majority of "adult" conch with flared shell lips are not sexually mature. Growth to a shell lip thicknesses ≥ 15 mm is needed for maturity (see Table 4 for proportions of measured conch at each location).

Location	Area surveyed (ha)	No. of "Adults"	No. of "Subadults"	% "Adults"
A: West End	16,885	61,668	141,191	30.4
B: Mantanilla Shoal	5833	401,387	4070	99.0
C: Mantanilla Reef	12,587	426,692	89,802	82.6
D: Grand Cay	6448	169,684	49,075	77.6
E: Carters Cays	16,119	790,697	163,984	82.8
F: Allan's/Pensacola Cay	1842	15,777	2151	88.0
G: Manjack Cay	1075	6147	512	92.3
H: Guana Cay	1535	33,258	30,188	52.4
I: Man-O-War Cay	1535	23,537	46,562	33.6
J: Pelican Cays	1228	27,956	10,311	71.2
Combined data	65,087	1,956,802	537,846	78.4

Table 7. Comparisons of population parameters for "subadult" and "adult" queen conch in Bahamian locations surveyed by Community Conch, 2009 to 2014. In 2009, the conch population in the Berry Islands Marine Fishery Reserve was not yet protected from fishing. Values reported for density, shell length and lip thickness are mean ± standard deviation. Data reported are for bank areas < 15 m deep where fishing can occur by free-diving and hookah. Data from surveys conducted at greater depths, primarily in the Berry Islands and Exuma Cays, are not incorporated here. nd = no data. Sources of comparative data include: Stoner et al. 2009, 2011, 2012a, 2013; Stoner & Davis 2010).

Location surveyed	Year of survey	Number of survey lines	Density of "subadults" (no./ha)	Density of "adults" (no./ha)	Shell length (mm)	Lip thickness (mm)
Berry Islands SW fishing ground	2009	73	70.2 ± 140.5	118 ± 282	153 ± 20	15 ± 3
Berry Islands West bank	2009	70	0.6 ± 1.9	0.7 ± 1.8	nd	nd
Berry Islands Marine Fishery Reserve	2009	42	12.4 ± 30.5	4.4 ± 8.5	190 ±30	3 ± 2
East coast of Andros Island	2010	82	53.8 ± 65.7	3.5 ± 15.2	210 ±42	8 ± 9
Grassy Cays, Andros Island	2010	58	35.1 ± 60.1	117 ± 162	177 ±27	15 ± 7
Lee Stocking Island, Exuma Cays (banks only)	2011	70	73.1 ± 18.9	5.8 ± 15.2	190 ± 21	9 ± 7
Exuma Cays Land and Sea Park (banks only)	2011	52	10.9 ± 4.5	16.6 ± 50.5	200 ± 22	21 ± 10
Sandy Point, Bight of Abaco	2012	87	10.1 ± 18.9	6.4 ± 9.6	187 ± 19	6 ± 4
Mores Island, Bight Of Abaco	2012	115	7.8 ± 20.6	9.8 ± 16.7	198 ± 24	9 ± 5
Jumentos Cays & Ragged Islands	2013	176	14.8 ± 49.1	122 ± 138	186 ± 20	19 ± 7
Little Bahama Bank	2014	215	8.3 ± 17.7	30.1 ± 59.3	205 ± 19	11 ± 7

Figure 1. Study area map of the Little Bahama Bank locations where queen conch were surveyed in June 2014. The Pelican Cays (not shown on this map) represent a small marine protected area located well to the south of Man-O-War Cay on the eastern edge of the Bank.

Figure 2. Spatial pattern of "adult" queen conch densities in West End in June 2014.

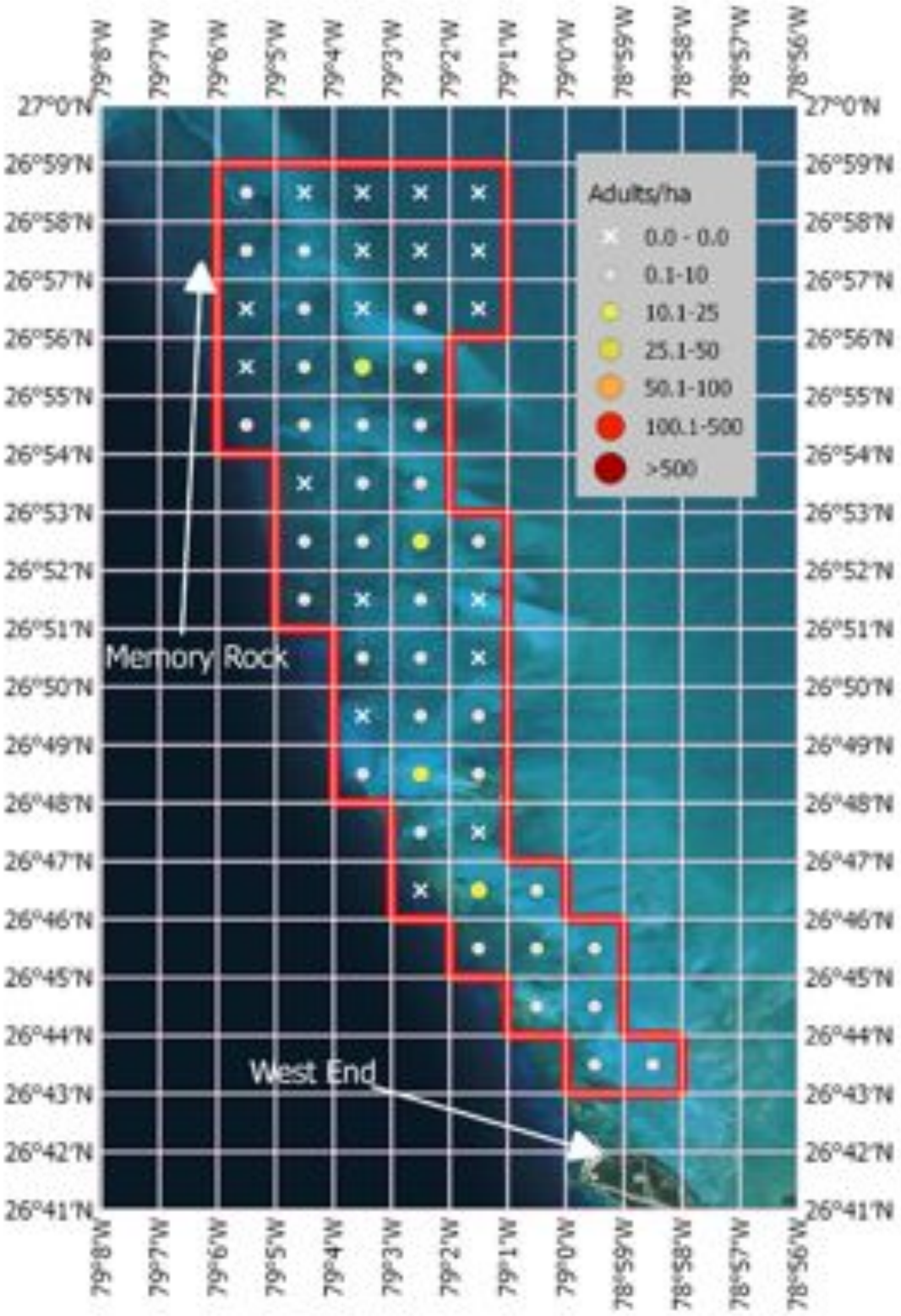

Figure 3. Spatial pattern of "adult" queen conch densities at Mantanilla Shoal and Mantanilla Reef in June 2014.

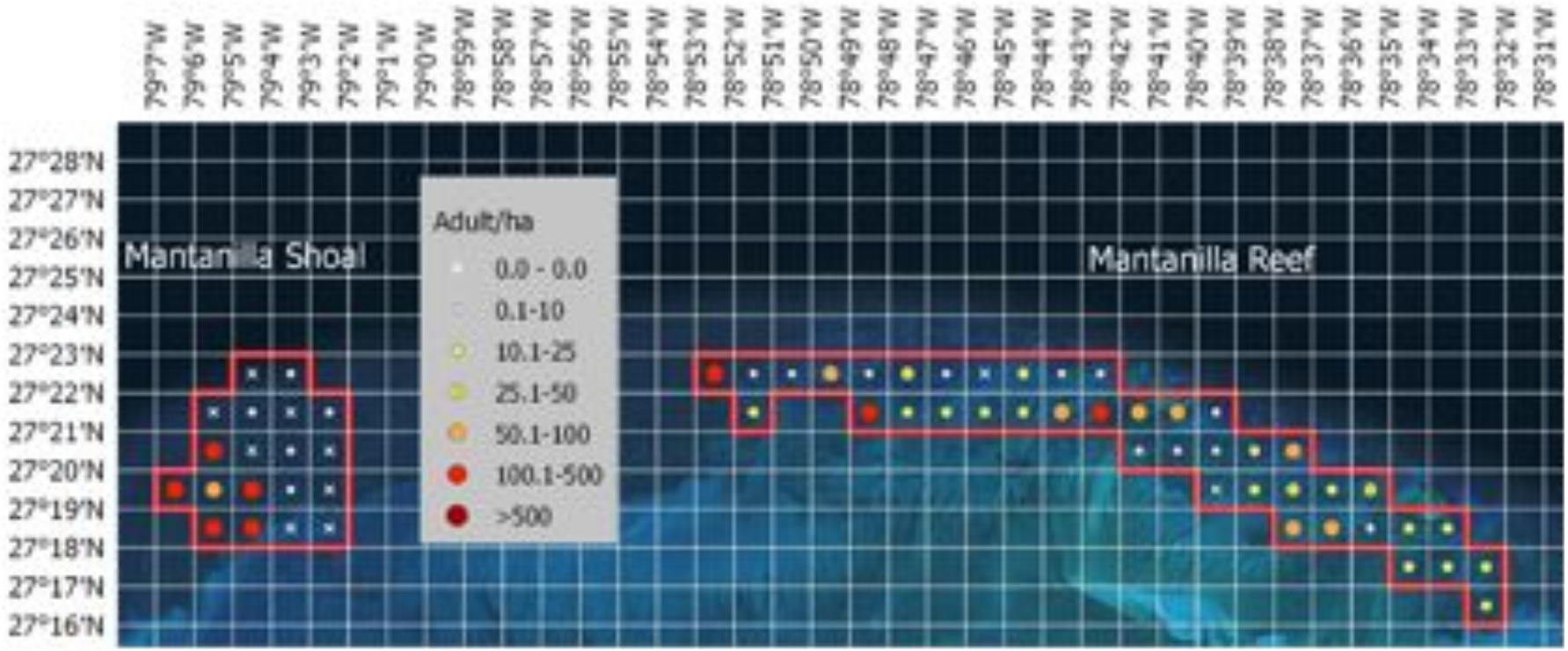

Figure 4. Spatial pattern of "adult" queen conch densities in Carter's Cays, Grand Cay, and Allan's Pensacola in June 2014.

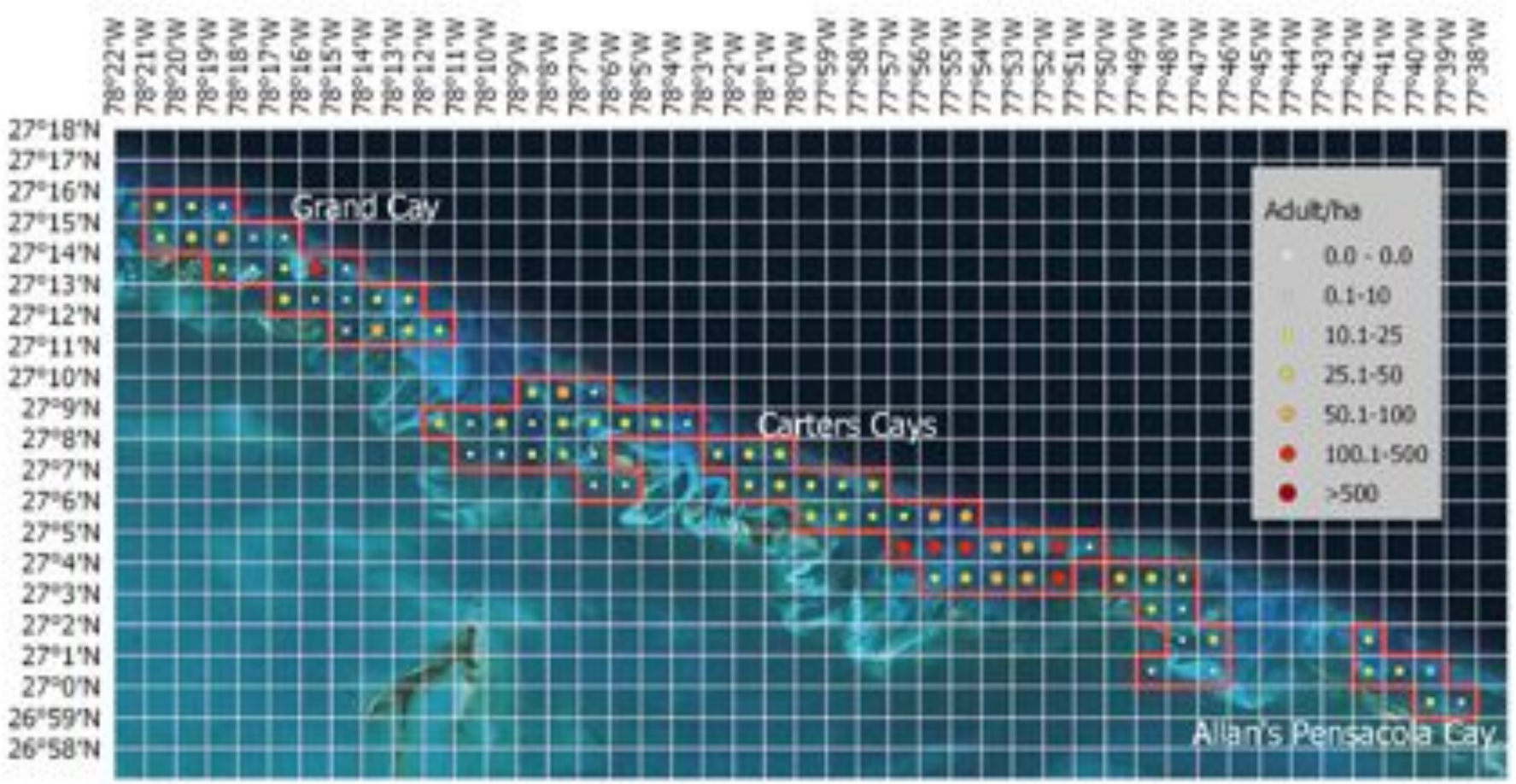

Figure 5. Spatial pattern of "sub adult" queen conch densities in West End in June 2014.

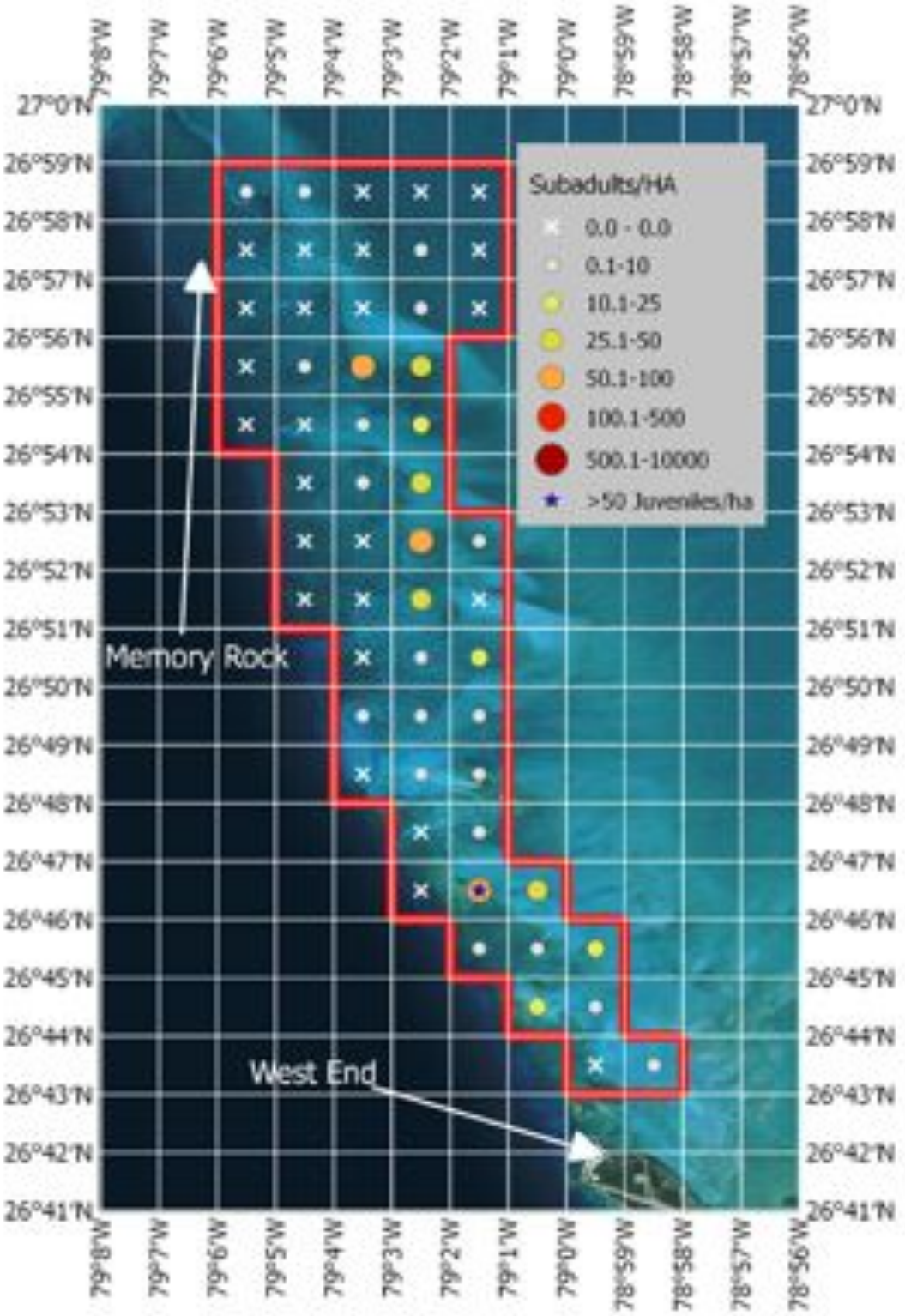

Figure 6. Spatial pattern of "sub adult" queen conch densities in Mantanilla Shoal and Mantanilla Reef in June 2014.

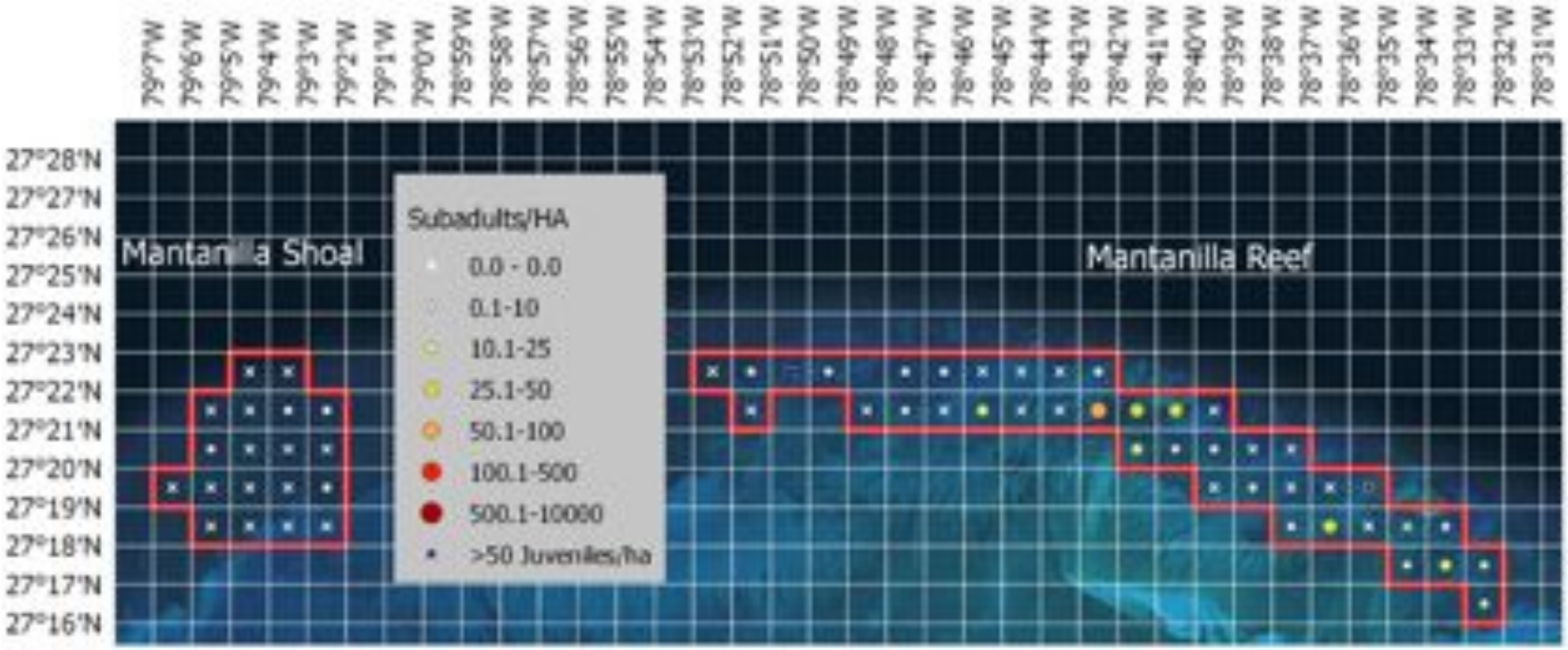

Figure 7. Spatial pattern of "sub adult" queen conch densities in Carter's Cays, Grand Cay, and Allan's Pensacola in June 2014.

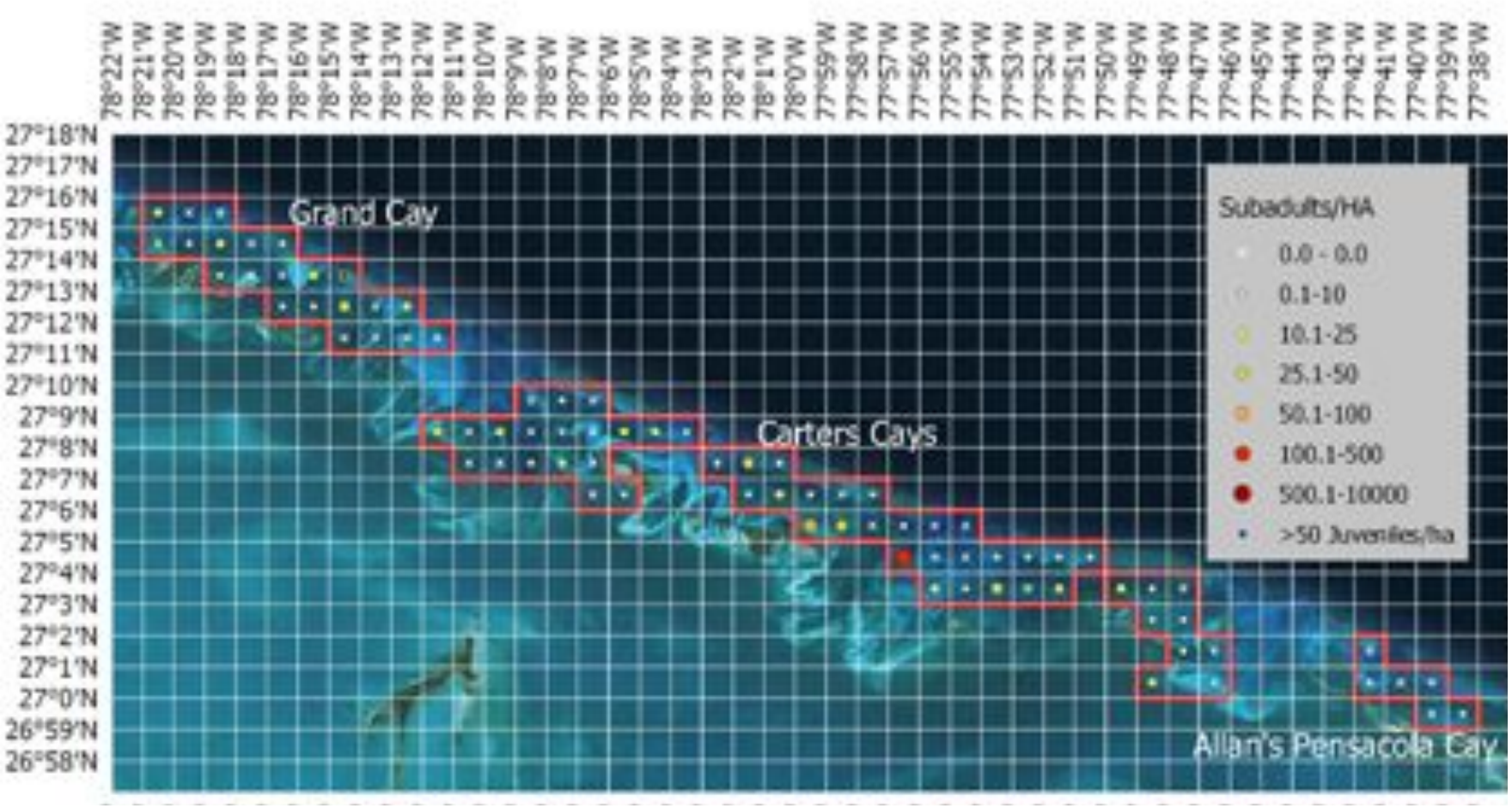

Figure 8. Frequency distribution of queen conch with flared shell lips on the Little Bahama Bank during June 2014. Conch with lip thicknesses ≥ 15 mm are considered to be reproductively mature. These totaled just 26.7% of the 323 individuals measured