# Surveys of Queen Conch Populations and Reproductive Biology in the Jumentos Cays and Ragged Islands The Bahamas

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## Project Sponsor, Contributors, and Volunteers

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### Project Contributors


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Fuel in Duncan Town( Etienne Maycock) capt of ----- man on the ground with pump. CB to finish.

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# EXECUTIVE SUMMARY

In June 2013, Community Conch conducted field studies in the Jumentos Cays and Ragged Islands to survey the density, abundance and population structure of queen conch stocks in the shallow commercial fishing grounds between Water Cay in the north and Little Ragged Island at the southern extreme of the island chain. High winds precluded deep-water diving to the east of the cays and surveying the Cochinos Banks.

Average density of flared-lip queen conch ("adults") over the Jumentos Cays and Ragged Islands was 122 "adults"/ha) (no. per hectare = no./10,000 $m^2$). These densities were slightly higher than those found in the Berry Islands and the Grassy Cays (Andros Island) during previous surveys. Density values decreased generally from north to south in the island chain, ranging from a high of 168 "adults"/ha near Flamingo Cay to just 10/ha in the southern sector encompassing Raccoon Cay to Little Ragged Island. The minimum density required for reproduction is 56 conch/ha. Densities of three year old conch (here called "subadults" or "rollers") were relatively low, with an average value of 14.8/ha in the island chain. The numbers of mating pairs observed in 176 survey lines throughout the study area revealed that most mating occurred at "adult" densities > 85/ha. This corresponds closely with other lightly 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 186 mm. This average is comparable to that observed in the Berry Islands Marine Reserve, on the bank at Lee Stocking Island and near Sandy Point, Abaco. This average length was a little larger than those found in the SW fishing ground of the Berry Islands and near the Grassy Cays south of Andros where small or "samba" conch predominate. Average shell lip thickness was highest (28 mm) near Seal Cay in the central part of the island chain, indicating that this is the oldest and least heavily exploited part of the conch population. The lowest average lip thickness (11 mm) was observed in the southern sector of the survey between Raccoon Cay and Ragged Island, revealing a very young population that is heavily exploited. Shells in decades-old conch middens reflected the average size and shell lip thickness found in the surrounding living populations except in the south, near Ragged Island, where the conch landed appear to be larger than the conch observed in the surrounding living populations. The number of juvenile conch in conch middens appears to be increasing with time, as has been the case throughout The Bahamas.

The estimated total abundance for the surveyed area was 6.2 million "adults" and 759,000 "subadults". While the 2013 surveys covered approximately twice the area pre-planned, these values are probably underestimates because queen conch distribution was more extensive than the total area that could be covered during the

survey period. While the high density and abundance of "adult" queen conch with high average lip thickness in the Jumentos Cays and Ragged Islands is encouraging with respect to other fishing grounds in The Bahamas, the relatively low density of "subadults" suggests reason for concern. The low "subadult" density could result from a weak 2010 year class or a more generalized loss of recruitment to the area. Low numbers of thin-lipped queen conch in the island chain indicates that recruitment to the area may have slowed in recent years.

Based upon the collection of data over five years in ten conch fishing grounds, there is a clear 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. Densities declined with proximity to Duncan Town in the southern Ragged Islands. This overview of the current status of conch resources in the Bahamas leads to the following recommendations:

Bahamas Wide

- Establish a network of marine protected areas, fishery cooperatives and a sustainable fishery certification program.
- Update regulations esp. those related to minimum lip thickness at harvest, use of hookah and seasonal closure.
- Develop area specific management plans for each major conch resource,
- Evaluate the impact of ending export.
- Research population connectivity using molecular genetics and the impact of discarding knocked conch in active fishing grounds.

Ragged Islands and Jumentos Cays

- Establish an MPA in the Jumentos Cays
- Establish a conch quota for the Ragged Islands
- Protect southern conch populations from international poachers

# INTRODUCTION

## 1.1. Focus of study

The goal of the 2013 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 Jumentos and Ragged Islands. These fishing grounds are located primarily on the shallow bank between Water Cay at the north end of the Jumentos Cays and Little Ragged Island at the south end of the Ragged Island chain. Fishing for queen conch in the study area is believed to be relatively light compared with other areas in The Bahamas. Fishers from Duncan Town, the only settlement in the Ragged Islands, gather queen conch in the immediate vicinity of Ragged Island and Little Ragged Island, and rarely venture north of Buena Vista Cay. Others traveling from Great Exuma (north of the study site) and from Long Island (east of the study site) fish for conch primarily in the northern sector of the Jumentos Cays.

While living queen conch were the primary focus of this survey, piles of harvested conch shells (shell middens) found throughout the island chain were also explored for size and shell thickness information. These data allow comparison of the size and age structures of conch exploited over time with the current living population.

# METHODS

## 2.1. Study sites

Surveys were conducted for queen conch in the Jumentos Cays and Ragged Islands from Water Cay in the north to Little Ragged Island in the south (Fig. 1). Emphasis was placed on the bank environment immediately to the west of the island chain, including the pass areas. Windy weather during most of the survey period precluded diving in the deeper shelf waters to the east of the cays. However, it is clear that the vast majority of queen conch in the area are located on the very extensive bank and not on the narrow island shelf to the east (see Discussion).

The bank environment west of the cays is characterized by broad sandy flats ranging from intertidal to 12 m depth or greater. 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 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. Survey depths ranged from 0.6 to 13 m, with a superimposed tidal range of ~1.5 m. Water temperatures recorded during the survey ranged from 24.2 to 27.8˚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 sound north of Columbus Bank on the flood tide.

## 2.2. Survey timing

The surveys were conducted from 15 to 28 June 2013. This survey period 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), and Bight of Abaco (Stoner et al., 2012a).

## 2.3. Survey vessels

Two small powerboats (17-22 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

The queen conch stock assessment in the Jumentos Cays and Ragged Islands 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, 1711 m in the east-west dimension) and 317 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 1000 m (determined with GPS). 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 6000 $m^2$. In some cases total distance covered was slightly longer or shorter than the design 1000 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, random 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 position in the Jumentos Cays and Ragged Islands. 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 geographic region and the island chain overall.

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

Six geographic segments were defined by latitude to evaluate an apparent north-south pattern of queen conch density. Each of these segments was 6 to 8 nautical miles (11 - 15 km) in the north-south dimension, except for the most

southerly segment ranging from the northern end of Raccoon Island to the northern end of Hog Cay (8 nautical miles) combined with a small survey area south and west of Little Ragged Island (2 nautical miles, 3.7 km).

The latitudinal boundaries for the geographic regions were as follows from north to south (Fig 1):

| | |
|---|---|
| A: Water and Lanzadera Cays: | 23° 04' to 22° 56' N |
| B: Flamingo Cay to Man-O-War Cay: | 22° 56' to 22° 48' N |
| C: Jamaica Cay: | 22° 48' to 22° 40' N |
| D: Seal Cay to North Channel Cay: | 22° 40' to 22° 32' N |
| E: Nurse Cay: | 22° 32' to 22° 24' N |
| F: Raccoon Cay to Buena Vista Cay: | 22° 24' to 22° 16' N |
| and Little Ragged Island | 22° 10' to 22° 08' N |

### 2.6. Midden surveys

Queen conch shell middens are common along the shorelines of protected coves and beaches on the leeward (west) side of the Jumentos Cays and Ragged Islands. These represent locations where conch are "knocked" to extract the meats. Middens for this survey were classified either as young or old. Young middens were comprised of shells retaining some pink interior color and the presence of peristracum (a brown skin-like coating) on the outside of the shells. These shells were most likely deposited within the last five or ten years. Old middens were made up of shells sun-bleached to white or grey and showing signs of erosion. These shells were most likely deposited more than 10 years ago and some likely date to 50 years or more. Midden locations are reported in the Results section.

Sampling points were chosen where there were large deposits of shells, and shells were gathered for measurement at one to three points at a location depending upon the areal extent of the shells. To prevent unintentional bias, all of the whole queen conch shells located on the surface of the deposit within an approximately two meter radius were measured. These included both conch with flared shell lips and juveniles, whichever were present. Each was measured for total length and lip thickness (for shells with a lip flare) as described above. All of the shells measured were "knocked" and thus reflect fishing mortality.

## RESULTS

### 3.1. Densities and depth distributions

More than 12,000 queen conch were counted for this survey. Conch with flared shell lips were the most commonly observed, with these "adult" conch found in 89.8% of the 176 tows. The average density was 122 "adults"/ha (SD = 138). Age=3 "subadults" were much less common, observed in 54.5% of tows, and the average density was just 14.8/ha (SD = 49.1) (Table 1).

Over the study area, highest average densities of queen conch with flared shell lips occurred in the northern segments of the island chain, near Water Cay, Flamingo Cay, and Jamaica Cay (Table 1). Densities remained above 100 "adults"/ha near the Seal Cays, but declined rapidly in the more southerly segments. However, density estimates were highly variable within all of the survey segments as evident in the mapped data (Figs. 2 & 3). Average "subadult" density was highest (30.5 conch/ha) near Raccoon Cay in the southernmost region (Table 1; Figs. 4 & 5 ), but this value occurred because of one very high value (525 "subadults"/ha) in very shallow water near Margaret Cay. Excluding this count, all of the regions had "subadult" densities near the overall average of ~15/ha.

Smaller age-1 and age-2 juveniles were observed in just 27 tows. These counts ranged from just one individual to > 450 in a tow, but young conch were highly aggregated, as is typical for the species, and density data based upon 1000-m long tows is not meaningful. Densities > 50 juveniles/ha were observed in seven locations that can be considered nursery grounds; these were found in depths ranging from 2 to 9 m, and are shown in Figures 4 & 5 . However, this survey was not designed to search for nurseries which are often localized in very shallow areas, and others undoubtedly exist in the survey area.

Densities of "adult" queen conch increased with depth (Table 2), stabilizing at 140/ha at depths > 5 m. Densities of "subadult" queen conch showed a reverse pattern, with highest values in the shallowest depth stratum (0 to 2.5 m), and average values between 2.5 and 13.1/ha in the deeper strata (Table 2). Only four counts were made in the shallowest depth interval (with one very high value near Margaret Cay mentioned above), 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 600 living queen conch with flared shell lips were measured for shell length and lip thickness (Table 3). On average, flared-lip individuals in the Jumentos Cays and Ragged Islands were relatively small, with a mean total length of just 186 mm (SD = 20 mm). The smallest "adults" occurred near Flamingo and Jamaica Cays (Table 3), averaging just 175 to 178 mm shell length. However, there was wide variation within each of the geographic regions.

Average shell thickness was 19 mm (SD = 7 mm), with substantial spread of the data (Table 3; Fig. 6 ). Thinnest shell lips occurred in the southernmost segment near Raccoon Cay, with "adults" averaging just 11 mm in lip thickness. Thickest (oldest) conch were found in the central part of the island chain between Seal Cay and Nurse Cay. Conch with lip thicknesses < 10 mm are probably 4 or 5 years old; these made up 10.4% of the population sampled (n = 683). Those with lip thickness ≥ 15 mm are likely to be mature (Stoner et al. 2012b), and those mature conch made up 77.7% of the population.

### 3.3. Queen conch in middens

More than 500 queen conch shells found in middens were measured for total length and lip thickness. The range of shell length observed in conch from middens was broad (Table 4), with both large and small queen conch being harvested. The smallest individuals were found in old middens with numerous conch < 140 mm TL around Man-O-War and Raccoon Cays. On average, the largest individuals were observed in conch landed in Duncan Town, although a large range of size was evident. At locations other than Duncan Town the average lengths of queen conch in middens were very near the values observed in the living populations observed in the island chain. These findings indicate that Duncan Town fishers select large conch for the dried conch market being pursued at present.

Shell lip thicknesses for shells in the northern middens south to Raccoon Cay averaged 21 to 24 mm and ranged from 8 to 35 mm (Table 4). Those at Duncan Town had thinner lips on average (12 to 16 mm), but with ranges similar to the living conch in the southern segment (Table 3). Also, the Duncan Town middens revealed substantial numbers of conch without a flared shell lip (juveniles), and 25% of the recently collected conch represented illegal capture of juveniles (Table 4). Immature conch (i.e., conch without a flared shell lip or without a lip ≥ 15 mm thick were relatively rare in older middens in the northern part of the island chain while more than half of those landed in Duncan Town were probably immature (Table 4). Although the sample size is small, based upon a comparison of old and recent middens, the harvest of illegal (without a flared lip) and immature(<15mmLT) conch seems to have increased over time.

### 3.4. Reproductive behavior

Mating pairs were observed on 72 of the 176 survey tows (41%) made in the island chain. This ranged from a single pair to more than 20 pairs observed in one tow near Water Cay. In a few cases, where conch densities were very high, more than one male was observed associated with one female. The number of mating pairs observed was loosely correlated with the density of adults calculated for a tow (Fig. 7 ). No mating at all was observed at 104 locations where adult densities were less than 22 “adults”/ha, and 90% of the mating occurred at locations where densities were greater than 85 “adults”/ha (Fig. 7 ).

### 3.5. Overall stock assessments

The Jumentos Cays and Ragged Island surveys represented more than 50,000 hectares (500 km$^2$) spread over a distance of approximately 62 nautical miles (114 km) of the island chain (Table 5). The survey area held more than 6.2 million queen conch with flared shell lips and 759,000 “subadults” in June 2013 (Table 5). Highest densities (Table 1) and highest numbers (Table 5) of queen conch with flared shell lips occurred in the northern segments, and more than half of these “adult” conch occurred

in the area between Water Cay and Flamingo Cay. “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 10.8%, with “adults” making up 89.2% of the large conch. With the exception of the Raccoon Cay region, “adults” made up 84 to 95% of the large observed conch.

# DISCUSSION

### 4.1. Population characteristics and comparisons

Average densities of queen conch with flared shell lips (“adults”) in the Jumentos and Ragged Islands were among the highest values observed in surveys conducted in The Bahamas over the last five years (Table 6). The only other sites with “adult” densities over 100/ha were the southwest bank fishing grounds in the Berry Islands and near the Grassy Cays at the south end of Andros Island. However, both of the latter two areas are much smaller in areal extent than the Jumentos Cays and Ragged Islands, and the numbers of “adults” found there are much lower. For example, the southwest Berry Island fishing had ~2.5 million conch dispersed over ~21,500 ha and the Grassy Cays had ~2 million conch over ~17,000 ha, while more than 6.2 million “adults” were dispersed over ~50,000 ha in the Jumentos Cays and Ragged Islands. Furthermore, the Berry Islands location is heavily fished and both the average size and average lip thickness for conch there is substantially lower than for conch in the Jumentos and Ragged Islands (Table 6). Many of the Berry Islands conch are the small phenotype conch known as “sambas” and these are not desirable for fishers. Conch in the Grassy Cays are also small and relatively thin lipped.

In fact, shell lip thickness provides a good indication of exploitation rate. The east coast of Andros Island, 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 areas characterized by conch with lip thicknesses averaging < 10 mm (Table 6). This means that the conch in 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). This contrasts strongly with the thick shell lips of queen conch in the Exuma Cays Land and Sea Park where no fishing occurs, the average conch is much older, and where reproduction occurs at a high rate. Shell thickness was also high in all but the southernmost Ragged Islands. This suggests that the northern populations, especially those beyond the normal range of Duncan Town fishers, are currently subjected to relatively light fishing pressure. The thickest and oldest average conch population in the Jumentos and Ragged Islands occurred between Seal Cay and Nurse Cay. This area is the least protected from physical energy (i.e., most exposed to high waves) and is the deepest area along the island chain; therefore, this area probably receives the lowest fishing pressure.

There are several reasons for the relatively low exploitation rate of queen conch in the northern parts of the Jumentos Cays and Ragged Islands. First, this conch population occurs in a location distant from fishing communities in the Exuma Cays

and Long Island. Traditionally, conch in the Ragged Islands have been dried for transport to a limited market for that kind of product, and the cost of transport for live or fresh conch does not offset the financial gain. Second, much of the adult conch population in the Jumentos Cays and Ragged Islands occurs in water depths greater than 10 m, making collection by free divers more difficult there than in other locations in the northern Bahamas such as the Berry Islands Bank or Bight of Abaco where conch are found in shallower water. Third, the conch in the Jumentos Cays and Ragged Islands are not very large, averaging just 186 mm shell length. As evident from measurements in the shell middens of Duncan Town, a larger conch is preferred.

"Adult" queen conch had highest densities in the northern segments of the island chain and because of very extensive beds of conch there "adult" conch were most abundant in the northern segments. It seems likely that surface currents in the Jumentos Cays and Ragged Islands travel in generally north and west direction as is the case in the Exuma Cays. This would serve to transport conch larvae from spawning grounds in the southern island chain to the north and west, concentrating settlement in the northern Jumentos Cays and broadly over the bank. However, a generally low density of "subadult" queen conch in the Jumentos Cays may result from relatively low reproductive frequencies in the upstream Ragged Islands population. Presently, it is also likely that the Jumentos Cays serve as a source of larval recruitment for queen conch populations further north in the Exuma Cays, the Grassy Cays, and the Sand Bores area at the south end of the Tongue of the Ocean. Larval recruitment to the southern part of the survey area (i.e., Ragged Islands) may depend upon upstream sources in the Acklin's Island or Turks and Caicos Islands. Studies of molecular genetics and oceanography will be needed to help understand population connectivity among the island groups.

Depth distributions of both "adult" and "subadult" queen conch in the Jumentos Cays and Ragged Islands were similar to the patterns found 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). It can be noted that maximum density of adult queen conch in depths < 10 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. Harvest observed in conch shell middens

Comparison of old and recent middens at Duncan Town indicates that the harvest of illegal juvenile queen conch and immature is increasing. This probably reflects the relatively low density of adult conch in the area observed in 2013, and the desire to land large individuals. Twenty-five percent juveniles in the recent landings at Duncan Town is somewhat lower than the incidence in certain other locations around The Bahamas (Community Conch, unpubl. data), but should be a concern for managers.

### 4.3. 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 Jumentos Cays and Ragged Islands on mating closely follow patterns found in earlier studies for lightly fished populations. For example, when numbers of mating pairs were plotted against density of "adult" conch there was no mating at densities < 25 "adults"/ha and most mating occurred when densities were > 85/ha (Fig. 7 ). 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 of the expert panel on queen conch management (CFMC, 2012) that densities be managed for a minimum of 100 adults/ha to insure adequate mating. 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).

### 4.4. Stock assessment

Large numbers of queen conch exist in the Jumentos Cays and Ragged Islands. Average densities were high, the areal extent of the population was much broader than anticipated in pre-survey planning, and the area surveyed for this stock assessment yielded an estimated 6.2 million flared-lip individuals. It should be pointed out that this number represents an area nearly twice as large as the traditional fishing grounds identified by the Department of Marine Resources and fishers interviewed in the Ragged Islands. Some of the area represented, in fact, is probably rarely fished because of water depth and distance from markets, as discussed above. However, the number of conch present in the Jumentos Cays and Ragged Islands is probably larger than the number estimated because substantial conch densities extended to the boundaries of the survey area in some places, especially in the northern sectors and west of the area surveyed. Also, weather conditions during the survey period precluded the intended explorations for conch on the island shelf to the east of the island chain. However, it is unlikely that the narrow shelf provides habitat for large numbers of conch, and three dives on the east side of the island chain near Water Cay revealed very few conch. Traditionally, conch fishing has occurred primarily on the shallow bank to the west in protected waters. Substantially more than 6 million flared-lip queen conch probably exist on the banks to the west of the Jumentos and Ragged Islands, but much of this population is beyond the normal range of small-boat fisheries and occurs at depths not typically exploited by free divers. Most, however, would be available to hookah fishers in settled weather.

The high density and abundance of flared-lip queen conch in the Jumentos Cays and Ragged Islands is a positive finding in light of rapidly declining populations in other parts of The Bahamas. However, the density of age-3 "subadult" conch was

relatively low, raising some concerns. In June 2013, the average density of "subadult" conch in the Jumentos Cays and Ragged Islands was 14.8/ha. This is higher than the severely overfished populations in the Bight of Abaco (7.8 to 10.1 "subadults"/ha) and parts of the Exuma Cays and Berry Islands (Table 6), but substantially below densities observed at Andros Island and in the fishing ground at the southwest corner of the Berry Islands bank. The relatively low density of "subadults" in the Jumentos Cays and Ragged Islands could represent weak larval recruitment to the bottom in 2010, or a more generalized loss of recruitment to the area. It is possible that low densities of "subadults" in the Jumentos Cays is related to heavy fishing in the Ragged Islands. Evidence for a generalized loss of recruitment is indicated by the low abundance of thin-lipped (young) conch observed in the area. Future monitoring could reveal whether recruitment to the Jumentos Cays and Ragged Islands is beginning to fail.

# MANAGEMENT AND RESEARCH RECOMMENDATIONS

Information on queen conch populations derived from field surveys conducted between 2009 and 2013 indicates a declining resource particularly near human population centers. In seven of the ten bank areas surveyed, the densities are so low that only minimal reproduction occurs. These areas include:

- East coast of Andros
- Berry Island Marine Reserve
- Berry Islands West Bank
- Lee Stocking Island
- Exumas Cays Land and Sea Park
- Bight of Abaco - Sandy Point
- Bight of Abaco - More's Island

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

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

- Berry Islands southwest fishing ground
- Grassy Cays south of Andros
- Jumentos Cays

Although the southwest Berry Islands and the Grassy Cays have >100 adults/ha, the populations are dominated by stunted conch which are undesirable to fishers. The newly surveyed Jumentos Cays, the most distant from any human population center, have the highest density (149 adults/ha) of what is considered normal sized conch even though their average shell length is on the low end of the range (185 mm). Their

high average lip thickness (20 mm) indicates a mature population actively involved in reproduction. The only weakness of this population is the low number of subadults indicating low recruitment which is unexplained at this time.

This overview of the current status of conch resources in the Bahamas leads to the following management and research recommendations.

### 5.1 Over the Bahamian Archipelago

- 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 other 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.

- Establish a system of fishery cooperatives. Cooperatives would allow landings to be monitored, fisheries data to be collected and fishers to receive a good 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 5 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
    - -Institute a closed season coordinated with nearby Caribbean countries

- Develop site specific management plans. Data collected to date show that each major conching area is an independent fishery and with unique growth, size, distribution, mortality and use characteristic and should be managed as such. Each major conching area should have site specific management recommendations.

- 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. The impact of curtailing export needs to be evaluated and consideration made for compensating those most impacted by such an action.

- Study molecular genetics. Despite gaining significant insight from ongoing conch surveys, informed 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.

- 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.

### 5.2 The Jumentos Cays and Ragged Islands

- Establish a marine protected area in the Jumentos Cays. An area west of Water, Flamingo and Jamaica Cays could be designated as a reserve in order to insure continued reproduction that feeds other major conch grounds down current. The protected area should be monitored for recruitment as its subadult populations are currently low. Since this area is not heavily fished, it is a closure more likely to be accepted by fishermen.

- Establish a quota for the Ragged Islands. The density and lip thickness results of this survey indicate that the area around Duncan Town is being depleted and is now populated primarily with immature conch. To prevent the resource from being totally degraded (as in the Bight of Abaco), catch and landing data should be collected in order to establish a quota for this area.

  A second option for a quota would be to impose a harvest of 8% of the biomass as recommended by the 2012 workshop of queen conch experts (CFMC, 2012). Based upon the stock assessment reported here (and using numbers of adults instead of total biomass) this would mean that not more than 500,000 adults should be harvested per year from the Jumentos Cays and Ragged Islands. The current level of harvest is unknown.

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

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**Table 1.** Densities of "adult" and "subadult" queen conch on the shallow bank environment of the Jumentos and Ragged Islands in June 2013. Values for each geographic region 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 boxes surveyed in the region.

| Geographic region | No. of tows | Adult density | Subadult density |
|---|---|---|---|
| A: Water Cay | 43 | 146 ± 151 | 9.6 ± 31.8 |
| B: Flamingo Cay | 39 | 168 ± 137 | 11.2 ± 17.4 |
| C: Jamaica Cay | 22 | 154 ± 148 | 26.0 ± 54.3 |
| D: Seal Cay | 22 | 126 ± 110 | 11.9 ± 20.8 |
| E: Nurse Cay | 23 | 91 ± 143 | 3.9 ± 6.9 |
| F: Raccoon Cay | 27 | 10.0 ± 32.0 | 30.5 ± 105 |
| Combined data | 176 | 122 ± 138 | 14.8 ± 49.1 |

**Table 2.** Densities of "adult" and "subadult" queen conch on the shallow bank environment of the Jumentos and Ragged Islands in June 2013. 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 | 4 | 5.8 ± 6.2 | 155 ± 247 |
| B: 2.5 to 5.0 m | 22 | 15.2 ± 32.2 | 2.5 ± 5.8 |
| C: 5.0 to 10 m | 132 | 140 ± 146 | 13.1 ± 32.6 |
| D: 10 to 15 m | 18 | 140 ± 101 | 10.4 ± 30.4 |
| Combined data | 176 | 122 ± 138 | 14.8 ± 49.1 |

**Table 3.** Shell length and lip thickness data for queen conch with flared shell lips collected in the Jumentos and Ragged Islands in June 2013. Values for shell length and lip thickness are mean and standard deviation, followed by the total range (parentheses). Data are reported for six major geographic areas ranging from north to south.

| Geographic region | No. measured | Shell length (mm) | Lip thickness (mm) |
|---|---|---|---|
| A: Water Cay | 236 | 195 ± 21 (149-244) | 19 ± 5 (3-35) |
| B: Flamingo Cay | 120 | 175 ± 17 (139-223) | 16 ± 6 (3-30) |
| C: Jamaica Cay | 175 | 178 ± 17 (141-227) | 18 ± 8 (1-35) |
| D: Seal Cay | 11 | 193 ± 17 (148-210) | 28 ± 6 (1-28) |
| E: Nurse Cay | 116 | 188 ± 16 (152-228) | 23 ± 6 (5-35) |
| F: Raccoon Cay | 25 | 192 ± 12 (177-220) | 11 ± 7 (2-27) |
| Overall | 683 | 186 ± 20 (139-244) | 19 ± 7 (1-35) |

**Table 4.** Shell length and lip thickness data for queen conch with flared shell lips collected from shell middens located on the shorelines in the Jumentos and Ragged Islands in June 2013. Values for shell length and lip thickness are mean and standard deviation for those shells with a flared lip, followed by the total range (parentheses). Data are reported for eight sites ranging from north to south. All of the shells were old, except for those collected at the last midden on the list. These were freshly captured shells (see text). The percentage of immature conch includes both juveniles and individuals with shell lips < 15 mm.

| Midden location | No. measured | Shell length (mm) | Lip thickness (mm) | % Juvenile | % Immature |
|---|---|---|---|---|---|
| Water Cay (north) | 76 | 199 ± 21 (143-242) | 21 ± 5 (8-33) | 0 | 0 |
| Water Cay (south) | 100 | 194 ± 22 (145-246) | 24 ± 4 (15-35) | 0 | 7.0 |
| Flamingo Cay | 74 | 204 ± 17 (155-280) | 21 ± 4 (12-30) | 1.4 | 5.4 |
| Man-O-War Cay | 9 | 180 ± 20 (125-213) | 23 ± 4 (15-32) | 0 | 0 |
| Raccoon Cay | 78 | 182 ± 24 (136-240) | 21 ± 4 (9-30) | 0 | 10.3 |
| Duncan Town boat channel | 81 | 195 ± 14 (158-241) | 16 ± 9 (3-36) | 13.6 | 54.3 |
| Duncan Town alternate channel | 44 | 205 ± 14 (172-254) | 14 ± 5 (3-22) | 9.1 | 52.3 |
| Duncan Town alternate channel Recent landings | 84 | 213 ± 23 (167-263) | 12 ± 8 (2-27) | 25.0 | 69.0 |

**Table 5.** Estimated total abundance of "adult" and "subadult" queen conch in the Jumentos and Ragged Islands in June 2013, by major geographic region.

| Geographic region | Area surveyed (ha) | No. of "Adults" | No. of "Subadults" | % "Adults" |
|---|---|---|---|---|
| A: Water Cay | 12,727 | 1,939,598 | 130,215 | 93.7 |
| B: Flamingo Cay | 10,968 | 1,852,923 | 133,932 | 93.2 |
| C: Jamaica Cay | 6277 | 973,727 | 177,488 | 84.6 |
| D: Seal Cay | 6720 | 843,773 | 82,528 | 91.1 |
| E: Nurse Cay | 6974 | 606,737 | 28,283 | 95.5 |
| F: Raccoon Cay | 6467 | 37,723 | 206,948 | 15.4 |
| Combined data | 50,134 | 6,254,480 | 759,393 | 89.2 |

**Table 6.** Comparisons of population parameters for "subadult" and "adult" queen conch in Bahamian locations surveyed by Community Conch, 2009 to 2013. 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, 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 | 2011 | 70 | 73.1 ± 18.9 | 5.8 ± 15.2 | 190 ± 21 | 9 ± 7 |
| Exuma Cays Land and Sea Park | 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 & Ragged Islands | 2013 | 176 | 14.8 ± 49.1 | 122 ± 138 | 186 ± 20 | 19 ± 7 |

**Figure 1.** Map of the Jumentos Cays and Ragged Islands where queen conch were surveyed in June 2013.

**Figure 2.** Spatial pattern of "adult" queen conch density over the Jumentos Cays and Ragged Islands in June 2013. Densities are shown for all conch with flared shell lips; not all of these are reproductively mature (see text). Horizontal lines show the boundaries of latitude used for evaluating geographic (north-south) variation in conch density over the study site.

**Figure 3. Spatial pattern of "adult" queen conch density over the Jumentos Cays and Ragged Islands shown in high resolution. Figures 3a, b and c represent the north, central and south segments of the survey area.**

**Figure 4.** Spatial pattern of "subadult" queen conch densities over the Jumentos Cays and Ragged Islands in June 2013. Seven locations where juveniles (age-1 and age-2) conch were abundant are shown with stars . Horizontal lines show the boundaries of latitude used for evaluating geographic (north-south) variation in conch density over the study site.

**Figure 5. Spatial pattern of "subadult" queen conch density over the Jumentos Cays and Ragged Islands shown in high resolution. Figures 5a, b and c represent the north, central and south segments of the survey area.**

**Figure 6.** Frequency distribution of queen conch with flared shell lips in the Jumentos and Ragged Islands during June 2013. Conch with lip thicknesses ≥ 15 mm are considered to be reproductively mature. These totaled 77.7% of the 683 individuals measured.

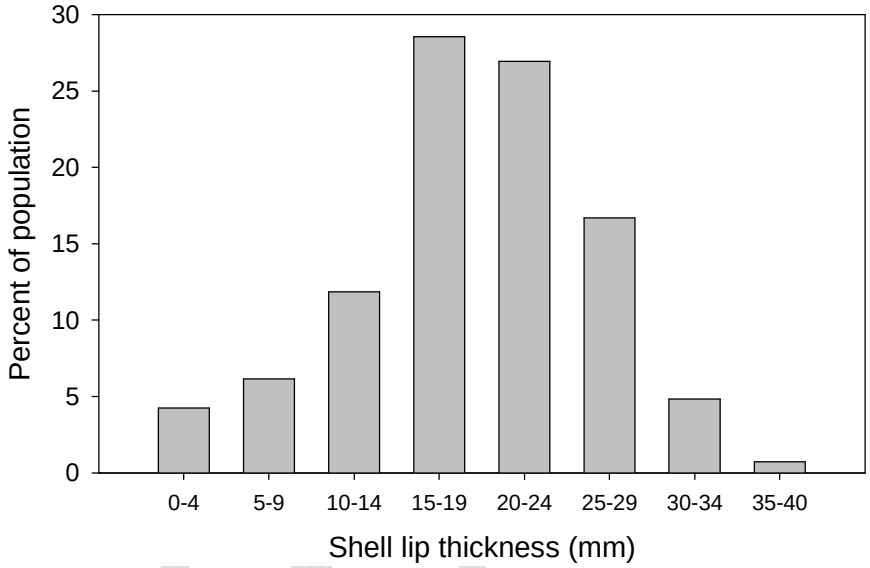

**Figure 7.** Relationship between the number of mating pairs and the density of queen conch with flared shell lips ("adults") in surveys conducted in the Jumentos and Ragged Islands during June 2013. Density is shown on a $\log_{10}$-transformed axis (untransformed values in parentheses). One hundred seventy-six counts were made.