Surveys of Queen Conch Populations and Reproductive Biology at Sandy Point and More's Island, Bight of Abaco, The Bahamas

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EXECUTIVE SUMMARY

Field work conducted by Community Conch during 2012 in the Bight of Abaco had two principal goals: 1) to survey the density, abundance and population structure of queen conch stocks in the shallow commercial fishing grounds off Sandy Point and More's Island and 2) to further explore relationships between queen conch shell lip thickness (an index of age) and reproductive maturity and compare it to similar data collected in 2011 near Warderick Wells (WW) in the Exuma Cays Land and Sea Park. The survey was conducted in June, using towed diver surveys at more than 200 locations.

Average "adult" queen conch densities were the lowest found by Community Conch in four years of surveying commercial conching sites in the Bahamas. In the Sandy Point area densities average 6.4 conch/ha and increased only to 9.8 conch/ha west of More's Island. The minimum density required for reproduction is 56 conch/ha. Subadults or "rollers" had similar low densities of 10.1 and 7.8 conch/hectare, at Sandy Point and More's Island, respectively. Average shell length ranged from 187 mm in Sandy Point to 198 mm in More's Island. These lengths are comparable to conch measured on the banks in the Berry Islands, off Lee Stocking Island and Warderick Wells and a little larger than those found off the Grassy Cays south of Andros. Average lip thickness ranged from 6 mm in the Sandy Point area to 9 mm west of More's Island indicating very young populations. In 202 tows, only three mating pairs were observed. The estimated total abundance for the surveyed areas was approximately 519,000 adults and 550,500 subadults.

Analysis of the gonad tissues from 57 queen conch collected during the spawning season of 2012 showed that most male conch do not reach sexual maturity until their shell lip thicknesses reach 10mm (more than 3/8"). Most females were not sexually mature until the shell lip thickness was 15mm. The conclusion from the 2011 study that queen conch in The Bahamas with lip thickness < 15 mm should not be harvested because they are not yet reproductively mature was borne out by this follow-up study in the Bight of Abaco.

Three observations suggest that queen conch in the Bight of Abaco are severely overfished: (1) densities of flared-lip individuals are extremely low, well below the minimum threshold required for reproduction, (2) the age structure of the populations at both Sandy Point and More's Island is very young, with very few individuals ≥ 15 mm LT, and (3) only three mating pairs were observed among more than a thousand flared lip conch encountered during two weeks of survey work in the middle of the reproductive season. Additionally, it is clear that conch fishers in the Bight of Abaco have become dependent upon compressed air and deep-water populations of queen conch as adult conch are now relatively rare on the traditional shallow-bank grounds. We predict that the Sandy Point and More's Island conch fishing grounds are approaching collapse.

Given the extremely low densities and low total numbers of queen conch in the Bight of Abaco, and almost total absence of reproductive behavior, it is clear that a rebuilding program is needed for both the Sandy Point and More's Island fishing grounds. The following measures could be considered:

a) Partial or total closure of the fishing grounds until densities reach 100 adults/ha.
b) End the use of compressed air for conch fishing or at any depth out of lobster season.
c) Establish a total allowable catch at the fishing grounds and monitor it.
d) Institute a closed season for conch fishing.

Informal interviews with Abaco fishermen suggest that they recognize the declining fishery for queen conch and favor a closed season however the current standing stock of adult conch in the Bight of Abaco is so low that it is doubtful that the increased reproductive output in a closed season would increase local recruitment. The success of any changes in fisheries management will likely depend upon community involvement in management decisions, and fisheries monitoring and enforcement.

INTRODUCTION

1.1. Focus of study

The goal of this stock assessment was to quantify the density, abundance, population structure, and reproductive potential of the queen conch (*Strombus gigas*) resources in two large and historically important fishing grounds identified by the Bahamas Department of Marine Resources in the Bight of Abaco. These fishing grounds are located on the shallow banks between Sandy Point, Abaco and the southeast corner of Sweetings Cay (Grand Bahamas Island). Queen conch landed from these two grounds are generally transported to Nassau for sale either in the shell or as cleaned and frozen meats.

METHODS

2.1. Study sites

Surveys were conducted for queen conch in the Sandy Point fishing ground and More's Island fishing ground (Fig. 1). The first is located immediately west and north of Sandy Point, Great Abaco Island, extending west to the bank edge south of Gorda Cay (Disney's "Castaway Cay") and north to the shoals south of More's Island. The second ground extends north from More's Island along the western edge of the bank to near Sweetings Cay at the southeast end of Grand Bahama Island.

Both fishing grounds are located on broad shallow sandy flats, characterized by interspersed seagrass beds of turtle grass (*Thalassia testudinum*) and manatee grass (*Syringodium filiforme*) and bare sand. Depths on the flats increase gradually to the bank edge where depths then increase quickly to more than 100 m. The flats are divided by northeast-to-southwest trending sand bars separated by deeper channels where tidal currents run strongly. Benthic brown algae (primarily *Sargassum* species) are present in some locations, notably in the deeper channels and near the bank edge where the hard bottom is scoured by currents and surge. The outer bank also has a sparse cover of soft corals and sponges on hard bottom or hard bottom interspersed with sand and occasional heads of hard coral. Survey depths ranged from 0.6 to 8.1 m (Table 1), with a superimposed tidal range of ~1.5 m. Ninety-five percent of the surveys occurred on the banks in < 5 m depth.

2.2. Survey timing

The surveys were conducted from 17 to 28 June 2012. 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), and the Exuma Cays (Stoner et al., 2011).

2.3. Survey vessels

Small powerboats (17-20 feet) were used to tow snorkelers in the shallow bank waters for observations on queen conch density and reproductive behavior (see below). Each boat was fitted with a Garmin GPS 441S unit. 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 Bight of Abaco followed the methods developed by Community Conch for earlier surveys in the Berry Islands (see Stoner et al., 2009). The use of similar protocols allows for direct comparison of data on conch density and reproductive behavior from earlier surveys.

Maps of each 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, 1673 m in the east-west dimension) and 310 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 one corner of the block 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.

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.
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 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.
e) Number of egg masses.

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. 2012a) that sexual maturity does not occur in the majority of queen conch until a minimum lip thickness of 10-15 mm

or greater is achieved. Therefore, where adult conch were abundant, random collections were made to measure for:

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.

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

The results were standardized to number of conch per hectare (10,000 m^2) for each age group in each of the two fishing grounds, and for comparison with earlier studies. 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) at each fishing ground.

2.5. Collections for gonad histology

Collections of "adult" conch with flared shell lips were made near Sandy Point to explore the relationship between reproductive maturity and shell lip thickness, a surrogate indicator of conch age. Methods for sampling the gonad tissues were similar to those used in an earlier study centered at Warderick Wells in the Exuma Cays Land and Sea Park (Stoner et al. 2011, 2012a). Before dissection, each conch was measured for shell length and shell lip thickness as described above. To extract the soft tissue from the shell, the spire was carefully broken from the shell and the entire soft body of the conch was extracted in one piece through the top of the shell. An effort was made to collect equal numbers of male (identified by the presence of a verge) and female conch over a range of shell lip thicknesses from 1 to 29 mm in six bins of 5 mm each (0-4, 5-9,10-14, etc). Fifty-seven queen conch (30 females, 27 males) were collected for this purpose. Thick shelled conch were relatively rare in the Bight of Abaco, and the thickest conch collected for histological study was a male 27 mm LT.

In brief, a 1-cm cube of gonad tissue was removed from the center of the gonad for histological evaluation and preserved in a 10% solution of buffered formalin. After fixation, the samples were transferred to ethanol and sent to Dr. Nancy Brown-Peterson (University of Southern Mississippi) for analysis. A detailed histological inspection of each sample was made to assess the stage of gonadal maturity and the percentage of gametogenic tissue. Each animal was given a score from 0 to 5 following procedures adapted from Delgado et al. (2004) to quantify maturity (Table 2). In addition, the percentage of ovarian or testicular tissue present was visually estimated using the following index (< 25%, 25-50%, 51-75%, and > 75%).

The entire histological section was then photographed for determination of a Gonadal Maturity Index (GMI) following a modification of procedures in Tomkiewicz et al (2011). The index ranges from 0 when only somatic (non-reproductive) cells are present to 1.0 when all of the germinal cells are spermatozoa in males or late

vitellogenic oocytes in females, and is weighted according to the proportions of cell types present. A detailed explanation for the GMI used for queen conch is provided in Stoner et al. (2012a), available online at www.communityconch.org/our-research/

RESULTS

3.1. Densities and depth distributions

3.1.1. Sandy Point

Densities of queen conch at Sandy Point were very low, with an average value of just 6.4 "adults"/ha overall and slightly higher values for subadults and juveniles (Table 3). "Adults" were highly dispersed and observed on 74.7% of the survey lines, but densities were very low with just one survey line yielding a density higher than 56 "adults"/ha, which is important in terms of fishery management criteria [i.e., this is the minimum threshold for mating (Stoner & Ray-Culp 2000); see Discussion]. The higher "adult" densities were found in the northwest portion of the site about 2 kilometers inland from the shelf drop off (Fig. 2).

Subadult densities were slightly higher than "adults", ranging from zero to 122/ha with an average of 10.1/ha. Subadults were observed on 63.2% of the transects and, therefore, were somewhat less dispersed than "adults". As always, juveniles were highly aggregated being observed in just 58.7% of the transects with just four survey lines yielding densities >100/ha. Seven locations yielded juvenile densities > 50/ha (Fig. 3). Densities of "adults", subadults, and juveniles all decreased with increasing depth zone.

3.1.2. More's Island

The average density of "adult" queen conch was about 50% higher at More's Island than at Sandy Point, but still very low (9.8/ha), and unlike Sandy Point, densities of subadults and juveniles were even lower (Table 3). "Adults" were observed on 71.4% of survey lines, but only six of the lines surveyed (5.2%) had densities higher than 56 adults/ha. The higher "adult" densities were also found at the northwest end of the More's Island study area about 2 to 4 kilometers from the shelf drop-off (Fig. 2).

As at Sandy Point, subadults were less dispersed than adults being observed on 61.7% of the transect lines. Subadult densities ranged from zero to 150/ha with an average of 7.8 subadults/ha (Fig. 3). Juveniles were highly aggregated, observed on 34.8 % of the transect lines, and three survey lines accounted for more than half of all juveniles observed and had densities >50/ha (Fig. 3). All of the density values decreased with increasing water depth.

3.2. Size data

3.2.1. Sandy Point

Queen conch found with flared shell lips were relatively small on the shallow bank portion of the Sandy Point fishing ground, averaging 187 mm shell length (Table

4). They were also very young with shell lips averaging 6 mm in thickness. Only 3 individuals (4.5%) had lip thickness ≥15 mm.

Twenty-five "adults" were collected and measured from one location on the bank edge about 4 km south of Gorda Cay (26° 03.00' N, 77° 28.84' W) (see section 3.3.1. below). These conch were both larger and thicker than others from the Sandy Point fishing ground (Table 4), and 19 of the 25 individuals measured had lip thickness ≥ 15 mm. However, this appeared to be an isolated group of conch, and similar thick-shelled conch were not found at any other location in both study areas. Overall, a relatively small proportion of flared-lip conch (23.9%) had lip thicknesses ≥15 mm (Fig. 4a), and this includes the older conch collected south of Gorda Cay.

3.2.2. More's Island

"Adult" conch in the More's Island survey area were slightly larger at 198 mm on average, than those from Sandy Point and just slightly thicker (9 mm) (Table 4). Only 9.9% of the 80 "adults" measured had lip thickness ≥ 15 mm (Fig. 4b), and the majority were young.

3.3. Reproductive behavior

3.3.1. Sandy Point

No reproductive behavior, either mating or egg-laying, was observed in any of the systematic towed surveys conducted at Sandy Point. However, egg laying was observed at one location at the bank edge south of Gorda Cay in 6 m depth (see above) on one date (22 June 2012). Two egg masses were observed at this site, but a search of the surrounding area in subsequent days revealed no additional mating or egg-laying. Twenty-five adult conch were collected from this site for the size analysis reported above, and some were sacrificed for reproductive histology.

3.3.2. More's Island

Only three mating pairs were observed during the More's Island survey (Table 5); this represents < 0.9% of the 677 conch with flared shell lips counted at this fishing ground. No egg masses or egg-laying females were observed.

3.4. Overall stock assessments

The total surface areas of fishing grounds surveyed along with the extrapolated numbers of adults and subadults are reported in Table 6. More than 62,000 ha (620 km^2) were surveyed with 1-km long tows, and the combined fishing grounds held approximately one-half million "adult" queen conch in June 2012. The larger survey area and slightly higher adult density at More's Island explains the higher estimated number of adults at that site.

Numbers of subadult conch were approximately equal at the two sites (Table 6), and totaled about one-half million. The slightly higher density of subadults at the smaller Sandy Point survey area (Table 3) accounts for the near equal numbers on the two fishing grounds.

3.5. Histological analysis of queen conch maturity and shell lip thickness[1]

Overall, females with lip thickness < 10 mm had little to no gonadal tissue present, and large amounts of ovarian tissue were not present in females until they reached a lip thickness of at least 15 mm (Table 7). All males with lip thickness <5 mm had little to no gonadal tissue present, but most had a high percentage of spermatogenic tissue in the testis by 15 mm LT (Table 7).

Females with lip thickness < 10 mm were not capable of spawning, although two of the 12 conch examined in this size range were in the early developing ovarian phase (Table 8, Fig. 5a). Females were 100% spawning capable at lip thickness ≥ 20 mm. One female in the 15-19 mm LT category was found in the regressing phase, characterized by reduced ovarian tissue and atretic vitellogenic oocytes, a phase generally seen at the end of the reproductive season.

All but one male with lip thickness < 5 mm had no germ tissue at all in the testis (Table 9, Fig. 5b). Among males in the 5-9 mm LT category, one was spawning capable and one was regressing, and all males ≥ 10 mm LT had developing gonads, were spawning capable or they were regressing. However, the majority of males were not spawning capable until they reached > 15 mm LT (Table 9). All of the regression-stage testis were observed in males with LT < 15 mm, suggesting that young males, although mature in some cases, may have a short reproductive season.

Gonadal Maturity Indices (GMI) provide another convenient way to show the state of reproductive readiness for each individual, and to compare results from the Bight of Abaco in 2012 with the earlier analysis of queen conch near Warderick Wells in the Exuma Cays (Stoner et al. 2012b). The plots (Fig. 6) clearly show that reproductive maturity in both females and males increased with shell lip thickness, and that the patterns were very similar at the two locations. No female conch with LT < 11 mm had significant reproductively maturity. Maturity as shown by GMI increased rapidly with LT > 11 mm, but the proportion of mature females was highly variable. The same pattern was true for males except that the threshold for elevated GMI was slightly lower than for females. These GMI data for Sandy Point, taken in combination with the percentage coverage of gamete tissue (Table 7) and reproductive phase data (Fig. 5) indicate that male and female conch < 10 mm lip thicknesses were, in general, not reproductively mature. It appears that conch of both sexes with lip thickness > 15 mm provided highest contribution to reproductive output and all conch ≥ 20 mm LT were spawning capable.

DISCUSSION

4.1. Population characteristics

Distributions of queen conch in the two study areas followed patterns previously observed in the Exuma Cays (Stoner 2003), the Berry Islands (Stoner et al.

[1] Example photographs for gonad tissues are available online: www.communityconch.org/our-research/

2009), and other fishing grounds in The Bahamas. Juvenile conch <10 cm SL were highly aggregated in a few shallow-water habitats characterized by sand and seagrass, while subadult individuals (>10 cm SL and without a flared shell lip) were more widely dispersed. Juveniles were especially abundant in certain areas where larval recruitment occurs on shallow sand bars, especially notable around the Sarah Wood shoal (north of Sandy Point) and Gorda Cay. Queen conch with flared shell lips were widely dispersed and most abundant in a zone 2-4 km inshore from the edge of the bank as is typical throughout The Bahamas.

Densities of subadults and adults were very low – just 6.4/ha on the Sandy Point fishing ground and 9.8/ha on the More's Island ground. This compares with an overall average of 118/ha of flared-lip conch in the core of the Berry Islands fishing ground observed in 2009 (Stoner et al. 2009), 117/ha in the Grassy Cays south of Abaco (Stoner and Davis, 2010) and 5.8 "adults"/ha on the shallow bank near LSI in 2011 (Stoner et al. 2012b). All of these grounds are considered to be overfished. The higher ratio of subadults to "adults" at the Sandy Point survey area (1.59) than at More's Island (0.80) suggests that Sandy Point may be more heavily overfished than More's Island. However, very low densities of subadult and juvenile conch observed at More's Island indicate that fishery recruitment is extremely low.

4.2. Reproductive biology – comparisons Abaco and Warderick Wells

The relationships between gonadal condition and shell lip thickness were very similar in queen conch collected near Sandy Point, Abaco, and in the marine protected area near Warderick Wells (WW), Exuma Cays. This was especially evident in the plots of GMI for the two locations, although some subtle differences did occur (Fig.6). For example, at WW, all females >15 mm LT were spawning-capable, while 100% spawning readiness in Abaco females did not occur until $\geq$ 20 mm LT. Also, ovarian development did not begin in WW females until > 10 mm LT, while a few Abaco females with LT < 5 mm showed some ovarian development (Fig 5). However, one regressing female with LT = 15 mm was found near Sandy Point, whereas no female conch in the regressing phase were found at WW, despite the fact that conch were collected somewhat later in the reproductive season (July) at WW than at Sandy Point (June).

Some small differences in reproductive development also occurred between the males collected at WW and near Sandy Point. One hundred percent of the Abaco males had >75% testicular tissue at sizes $\geq$ 20 mm LT (Table 7), whereas no WW males had this much testicular tissue until they reached LT > 35 mm. Similarly, 100% of Abaco males were spawning capable at sizes $\geq$ 20 mm LT (Fig. 5), whereas 100% spawning capability in male conch at WW was not achieved until $\geq$ 30 mm LT. The occurrence of regressing testes at Sandy Point among males with LT in the range of 5 to 14 mm indicates that these thin-shelled individuals had a short reproductive life in their first mating season. This contrasts with males at WW where no individual < 25 mm LT was observed in the regressing phase, and the reason for this difference is unknown. However, it is clear that at least some thin-lipped conch males were spent by mid-June in 2012. GMI plots for the two populations(Fig 6) are very similar,

suggesting that the tissues of male conch mature on the same schedule at WW and Sandy Point, and that very few males < 10 mm LT are engaged in reproduction. The earlier conclusion that queen conch in The Bahamas with lip thickness < 15 mm should not be harvested because they are not yet reproductively mature was borne out by this follow-up study in the Bight of Abaco. While it is clear that some males and females can engage in reproductive activity in early adulthood, the fact that some thin-lipped individuals have very short reproductive life in the first season provides more reason for a lip-thickness criterion for legal harvest.

4.3. Reproductive behavior and status of conch fishery in the Bight of Abaco

The general lack of queen conch reproduction observed in the Sandy Point and More's Island fishing grounds probably results from two key factors. First, densities of adults are well below the critical threshold of ~56 adults/ha determined earlier for queen conch in The Bahamas (Stoner & Ray-Culp 2000; Stoner et al. 2012c). This is the absolute minimum density of adults required for successful location of mates. Second, very few of the "adults" with flared shell lips were likely to be mature sexually. The recent histological studies of gonadal tissues from Warderick Wells (Stoner et al. 2011, 2012a) and Abaco (this study) show that very few conch with shell lips thinner than 15 mm are sexually mature. Only 3 of the 66 conch with flared lips measured on the shallow bank at Sandy Point had lip thickness ≥ 15 mm. Using a similar criterion, < 10% of the flared-lip conch at More's Island were likely to be mature. The small group of adults with thick lips found south of Gorda Cay, where two egg masses were observed, probably represents a small remnant population of older individuals.

Total numbers of conch on the two grounds were relatively small, with about 500,000 individuals legal for capture (i.e., with flared shell lip) at the combined fishing grounds. Local fishers claim that conch can be deeply buried in the sediment with only the dorsal-most spines showing, and this could result in undercounting in surveys. Aware of this possibility, we watched carefully for this kind of behavior. Only a few individuals buried in this form were observed and all were dead.

Three observations suggest that queen conch in the Bight of Abaco are severely overfished: (1) densities of flared-lip individuals are extremely low, well below the minimum threshold required for reproduction, (2) the age structure of the populations at both Sandy Point and More's Island is very young, with very few individuals ≥ 15 mm LT, and (3) only three mating pairs were observed among more than a thousand flared lip conch encountered during two weeks of survey work in the middle of the reproductive season. Additionally, it is clear that conch fishers in the Bight of Abaco have become dependent upon compressed air and deep-water populations of queen conch as adult conch are now relatively rare on the traditional shallow-bank grounds. We predict that the Sandy Point and More's Island conch fishing grounds are approaching collapse.

COMMUNITY INPUT

Input from several community members including former fishermen and island Administrator, Benjamin Pinder, Fisheries officer Jeremy Saunders, and former fishermen and fishing guide Paul Pinder was used to confirm the extent of the fishing ground area and identify any additional survey locations. A public meeting was held in Sandy Point on 27 June 2012, with the purpose of informing the community, particularly fishers, of the stock assessment, as well as to learn local opinions of the state of the conch fishery. Fifteen local fishers, several community members, and the Department of Marine Resources fisheries officer for Sandy Point attended this meeting. The key points for consideration from the interviews and public meeting are summarized here:

- Conch fishing has become more difficult with time. The numbers of conch have decreased, and adults are less accessible. In the past, conch washed up on the beach in Sandy Point.

- Many fishers now use hookah/compressed air and would be reluctant to give it up.

- Export is an important market for Sandy Point fishers. They believe most of the conch from Sandy Point is exported, and local demand is low.

- The price of conch is too low.

- The majority of fishers from Sandy Point are in favor of a closed season, but only if it was in August and September because lobster season is open during that time and demand for conch from tourists is low.

- The relationship among fishers in Sandy Point is generally good. A few fishers indicated that some might go as far as sharing fishing locations and collaborating to bring catch back to shore.

- Overall, fishers in Sandy Point acknowledge that better management is needed.

- More fishing is now taking place is deeper water (30'- 40') on the outer shelf, because that is where they are finding large conch. This was confirmed by both Sandy Point and More's Island fishers.

- Both Sandy Point and More's Island fishers believe that fishing pressure on conch has increased due to increased entry into the fishery, and because lobster catches have been poor in recent years, the number of months that fishers target conch has increased.

- Boats from More's Island fish the Berry Islands, Abacos, and Bimini. Catch from the More's Island fishing ground is taken to Potters Cay in quantities as much as 10,000/month (5,000 conch in the shell and 5,000 frozen).

- More's Island fishermen believe that stocks have been down in the past but are coming back now.

- There are several beliefs about conch behavior that should be noted:
    - Conch bury themselves in the sand even as adults
    - Conch emerge from the sand when it rains and when there's lightning

MANAGEMENT RECOMMENDATIONS

Given the extremely low densities and low total numbers of queen conch in the Bight of Abaco, and almost total absence of reproductive behavior, it is clear that a rebuilding program is needed for both the Sandy Point and More's Island fishing grounds. The following measures could be considered:

a) Partial or total closure of the fishing grounds until densities reach 100 adults/ha.
b) End the use of compressed air for conch fishing or at any depth out of lobster season.
c) Establish a total allowable catch at the fishing grounds and monitor it.
d) Institute a closed season for conch fishing.

A partial closure would allow rebuilding of queen conch stocks to densities adequate for reproduction in at least a portion of the formerly important fishing grounds. The density of 100 adults/ha was recommended in a 2012 Workshop of Queen Conch Experts as the minimum reference point for stable conch stocks (CFMC, 2012). A closed area would also provide the potential for a source of eggs and larvae to supply other populations in the Bight of Abaco.

Ending the use of compressed air for conch fishing would effectively protect any deep-water stocks that occur at the bank edge. Very few queen conch live deeper than 100 ft (30 m) depth and virtually all are vulnerable to capture when compressed air is used. Currently, deep-water conch (i.e., those in depths between 15 and 30 m) appear to be the last remaining conch populations in densities required for reproduction. Spatial closure of fishing grounds in the Bight should be considered in the context of a larger network of marine protected areas needed throughout The Bahamas.

The 2012 workshop of queen conch experts also concluded that an annual harvest rate of 8% of biomass would be precautionary. Based upon the stock assessment reported here (and using numbers of adults instead of total biomass) this would mean that not more than 41,000 adults should be harvested per year from the

Bight of Abaco. Current landings might be as high 120,000 individuals, or three times the sustainable level.

A closed season, if set in the warm summer months, could allow for mating and egg-laying. While local fishers showed willingness to consider a closed season for conch, the current standing stock of adult conch in the Bight of Abaco is so low that it is doubtful that the increased reproductive output in a closed season would increase local recruitment.

REFERENCES CITED

Caribbean Fisheries Management Council (CFMC). 2012. Recommendations of the Queen Conch Expert Workshop, Miami, United States of America, May 22-24. 2012. 5 p.

Delgado, G.A., C.T. Bartels, R.A. Glazer, N.J. Brown-Peterson and K.J. McCarthy. 2004. Translocation as a strategy to rehabilitate the queen conch (*Strombus gigas*) population in the Florida Keys. Fish. Bull. 102:278-288.

Stoner, A. and M. Davis. 2010. *Queen Conch Stock Assessment: Historical Fishing Grounds, Andros Island, Bahamas, June, 2010.* Technical report to The Nature Conservancy, Northern Caribbean Office, Nassau, The Bahamas. 15 p., plus electronic appendices.

Stoner, A.W. and M. Ray-Culp. 2000. Evidence for Allee effects in an over-harvested marine gastropod: density-dependent mating and egg production. Mar. Ecol. Prog. Ser. 202:297-
302.

Stoner, A.W., V.J. Sandt and I.F. Boidron-Metairon. 1992. Seasonality of reproductive activity and abundance of veligers in queen conch, *Strombus gigas*. Fish. Bull., U.S. 90:161-170.

Stoner, A., M. Davis and C. Booker. 2009. *Queen conch stock assessment: proposed MPA and fishing grounds, Berry Islands, Bahamas.* Technical report to the Department of Marine Resources, Nassau, The Bahamas. 49 p.

Stoner, A., M. Davis and C. Booker. 2011. *Surveys of queen conch populations and reproductive biology at Lee Stocking Island and the Exuma Cays Land and Sea Park, The Bahamas, June/July 2011.* Technical report to the Department of Marine Resources, Nassau, The Bahamas. 27 p.

Stoner, A.W., K.M. Mueller, N.J. Brown-Peterson, M.H. Davis, C.J. Booker. 2012a. Maturation and age in queen conch (*Strombus gigas*): urgent need for changes in harvest criteria. Fish. Res. 131:76-84.

Stoner, A.W., M.H. Davis, C.J. Booker. 2012b. Abundance and population structure of queen conch inside and outside a marine protected area: repeat surveys show significant declines. Mar. Ecol. Prog. Ser. 460:101-114.

Stoner, A.W., M.H. Davis, C. Booker. 2012c. Negative consequences of Allee effect are compounded by fishing pressure: comparison of queen conch reproduction in fishing grounds and a marine protected area. Bull. Mar. Sci. 88:89-104.

Tomkiewicz, J., T.M.N. Kofoed and J.S. Pederson. 2011. Assessment of testis development during induced spermatogenesis in the European eel, *Anguilla anguilla*. Mar. Coast. Fish. 3:106-118.

Table 1. Summary of the survey effort and queen conch counts conducted in the Bight of Abaco in June 2012.

Fishing ground	No. of tows	Dates surveyed (2012)	Depth range surveyed (m)	Water Temperature (°C)	No. adults counted	No. subadults counted	No. juveniles counted
Sandy Point	87	17-28 June	0.7 – 8.1	26.2 – 29.3	331	525	816
More's Island	115	20-26 June	0.6 – 6.1	25.9 – 27.6	677	540	366

Table 2. Index and definitions used to quantify gonadal maturity in queen conch (following Egan 1985).

Gonad condition	Score	Definition
No germ tissue	0	Holes in the gonadal area with some eipithelial tissue, but no germinal tissue
Immature	1	Oogonial nests in females, spermatogonial nests in males; no other germinal tissue present
Early developing	2	Only spermatogonia and spermatocytes in males; only primary growth and cortical alveolar oocytes in females
Late developing	3	All stages of spermatogenesis in males, including spermatozoa. No vas deferens present, or, if present, no spermatozoa in them. Early vitellogenic oocytes present in females, with a few vitellogenic oocytes. Conch in this phase are not capable of releasing gametes.
Spawning capable	4	All stages of spermatogenesis in males, with spermatozoa in the vas deferens. In females, late vitellogenic oocytes predominate. If oviducts are present, vitelogenic oocytes in oviducts. Conch in this phase are capable of releasing gametes.
Regressing	5	In males, lobules degenerating, atresia and resorption of all stages of spermatogenesis; macrophages and macrophage aggregates common. In females, oocyte atresia common, macrophage aggregates present. Conch in this phase are not capable of releasing gametes.

Table 3. Densities of adult and subadult queen conch in two fishing grounds in the Bight of Abaco in June 2012. Values for each depth zone are reported as mean and standard deviation for the numbers of individuals per hectare (no./10,000 m^2).

Depth zone	No. of tows	Adult density	Subadult density	Juvenile density
Sandy Point (overall)	87	6.4 ± 9.6	10.1 ± 18.9	15.7 ± 42.8
A: 0 to 2.5 m	25	7.2 ± 9.2	16.0 ± 25.3	28.3 ± 68.2
B: 2.5 to 5.0 m	58	6.3 ± 10.1	8.2 ± 15.7	11.2 ± 26.5
C: 5.0 to 10 m	4	1.7 ± 2.4	0 ± 0	0.4 ± 0.8
More's Island (overall)	115	9.8 ± 16.7	7.8 ± 20.6	5.3 ± 18.9
A: 0 to 2.5 m	21	11.8 ± 19.5	8.9 ± 17.2	9.1 ± 23.1
B: 2.5 to 5.0 m	87	9.8 ± 16.6	8.1 ± 22.1	4.7 ± 18.6
C: 5.0 to 10 m	7	2.4 ± 3.6	2.4 ± 4.9	1.2 ± 3.1

Table 4. Shell length and lip thickness data for adult queen conch collected from two fishing grounds in the Bight of Abaco in June 2012. Values for shell length and lip thickness are mean and standard deviation, followed by the total range (parentheses). Data are reported for conch dispersed over the shallow fishing grounds at each of the two sites and for one location near the bank edge south of Gorda Cay in the Sandy Point region where egg-laying behavior was observed.

Site	No. measured	Shell length (mm)	Lip thickness (mm)
Sandy Point			
bank	66	187 ± 19 (156-231)	6 ± 4 (1-20)
bank edge	25	226 ± 21 (189-260)	17 ± 6 (4-27)
More's Island			
bank	80	198 ± 24 (165-240)	9 ± 5 (1-21)

Table 5. Reproductive behavior observed in surveys for queen conch near More's Island, Abaco, June, 2012. No reproductive behavior was observed in the Sandy Point fishing ground.

Date	Depth (m)	Approx. location	Adult density (no./ha)	Number of mating pairs
21 June	2.2	26° 29' N, 77° 47' W	68.3	1
22 June	4.4	26° 25' N, 77° 44' W	16.7	1
22 June	4.8	26° 31' N, 77° 51' W	16.7	1

Table 6. Estimated total abundance of adult and subadult queen conch in the Bight of Abaco, June 2012.

Site	Area surveyed (ha)	No. of Adults	% of Adults	No. of Subadults	% of Subadults
Sandy Point	26,970	171,351	33.0	271,825	49.4
More's Island	35,650	347,710	67.0	278,789	50.6
Overall	62,620	519,061	100.0	550,614	100.0

Table 7. Percentage of gonadal tissue containing germ cells present in testes and ovaries by size class (mm lip thickness, LT) for male (M) and female (F) conch. Nd = no data.

LT (mm)	<25% gonadal tissue		25-50% gondal tissue		51-75% gonadal tissue		>75% gonadal tissue	
	M	F	M	F	M	F	M	F
<5	100	85.7	0	14.3	0	0	0	0
5-9	66.7	100	16.6	0	0	0	16.6	0
10-14	50	50	16.7	0	16.7	16.7	16.6	33.3
15-19	0	33.3	16.7	0	0	0	83.3	66.7
20-24	0	0	0	20	0	16.7	100	83.3
25-29	0	nd	0	nd	0	nd	100	nd

Table 8. Reproductive phases (%) present in ovaries by size class (mm lip thickness, LT) for female conch.

LT (mm)	*N*	No germ tissue	Immature	Early Developing	Developing	Spawning Capable	Regressing
<5	7	71.4	14.3	14.3	0	0	0
5-9	5	40	40	20	0	0	0
10-14	6	0	33.3	16.7	0	50	0
15-19	6	0	16.7	0	0	66.7	16.6
20-24	6	0	0	0	0	100	0

Table 9. Reproductive phases (%) present in testes by size class (mm lip thickness, LT) for male conch.

LT (mm)	N	No germ tissue	Immature	Early Developing	Developing	Spawning Capable	Regressing
<5	5	80	20	0	0	0	0
5-9	6	66.7	0	0	0	16.7	16.6
10-14	6	0	0	0	50	33.3	16.7
15-19	6	0	0	0	16.7	83.3	0
20-24	3	0	0	0	0	100	0
25-29	1	0	0	0	0	100	0

Figure 1. The Sandy Point and More's Island fishing ground study areas in the Bight of Abaco.

Figure 2. Spatial pattern of adult queen conch density over the Sandy Point and More's Island fishing grounds in the Bight of Abaco, June 2012.

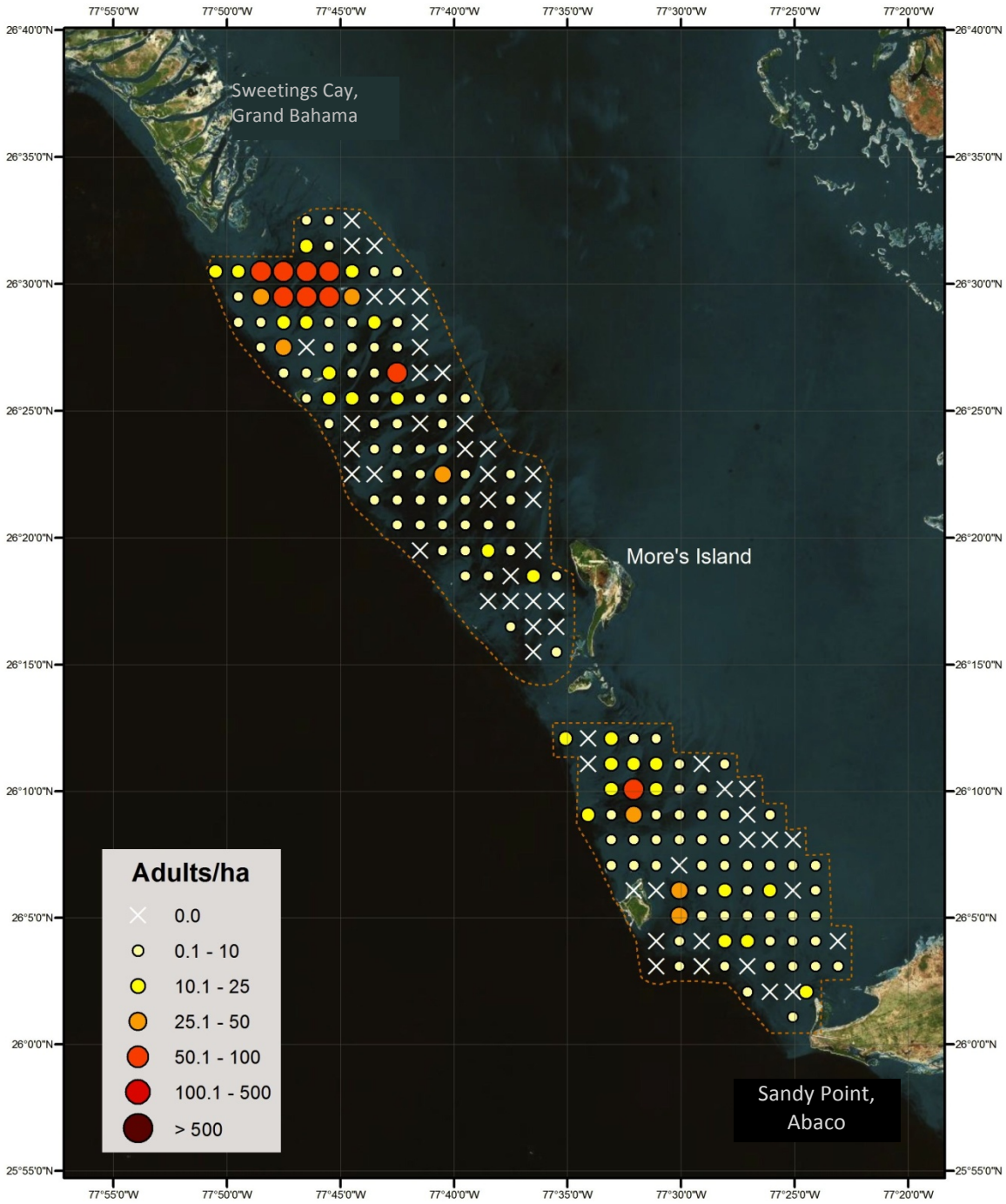


Figure 3. Spatial pattern of subadult and juvenile queen conch densities over the Sandy Point and More's Island fishing grounds in the Bight of Abaco, June 2012.

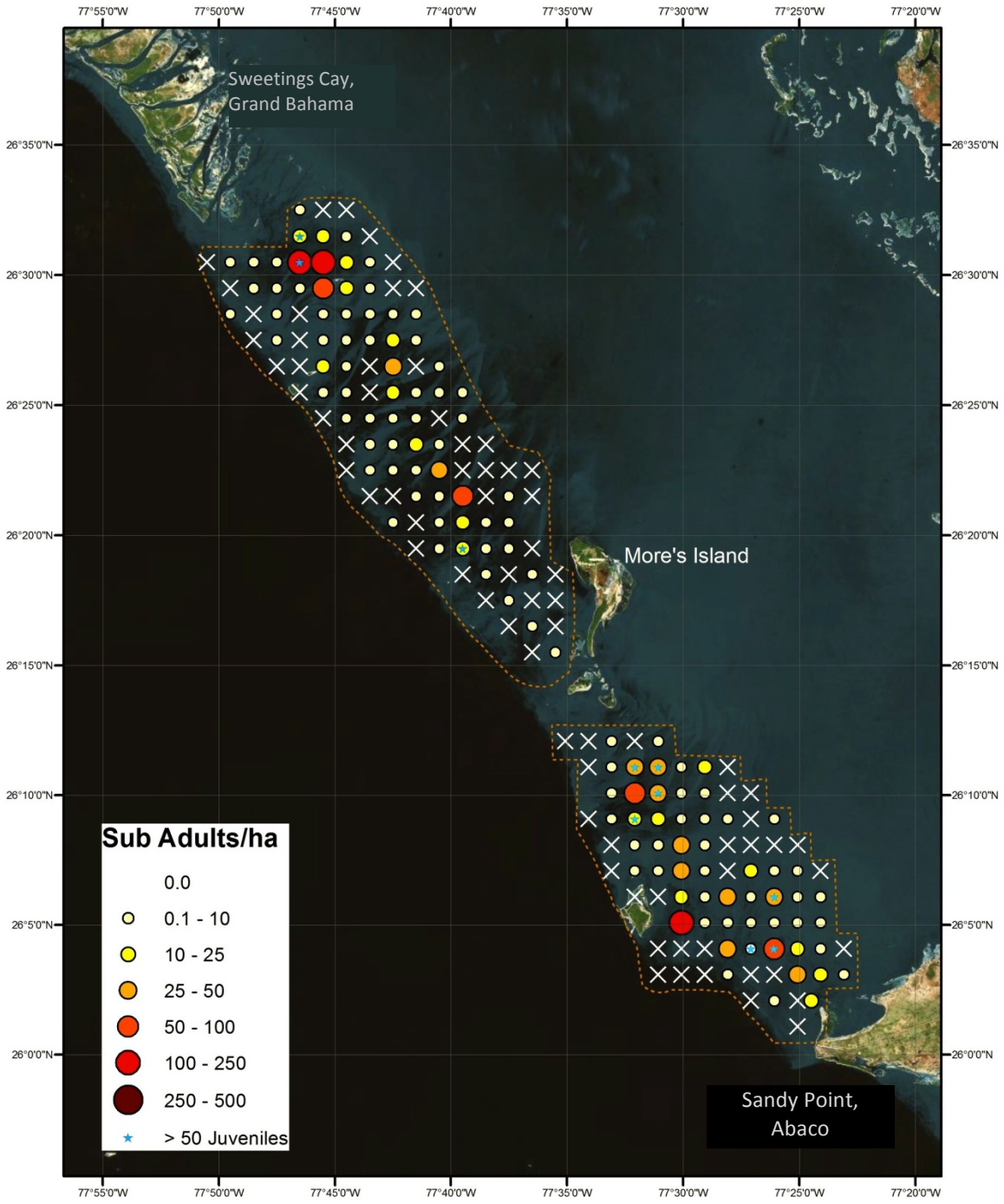


Figure 4. Frequency distribution of conch with flared shell lips at (a) Sandy Point and (b) More's Island fishing grounds in the Bight of Abaco, June 2012. The data for Sandy Point include 25 relatively thick-lipped individuals collected near the bank edge south of Gorda Cay.

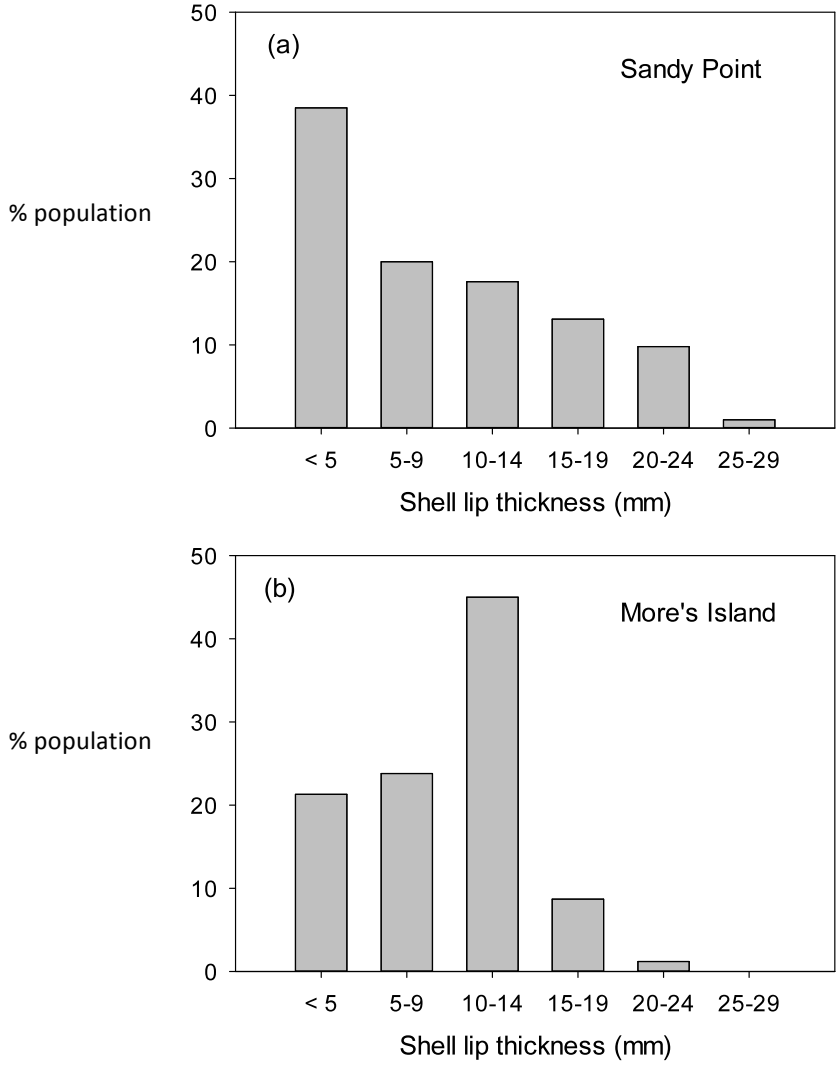
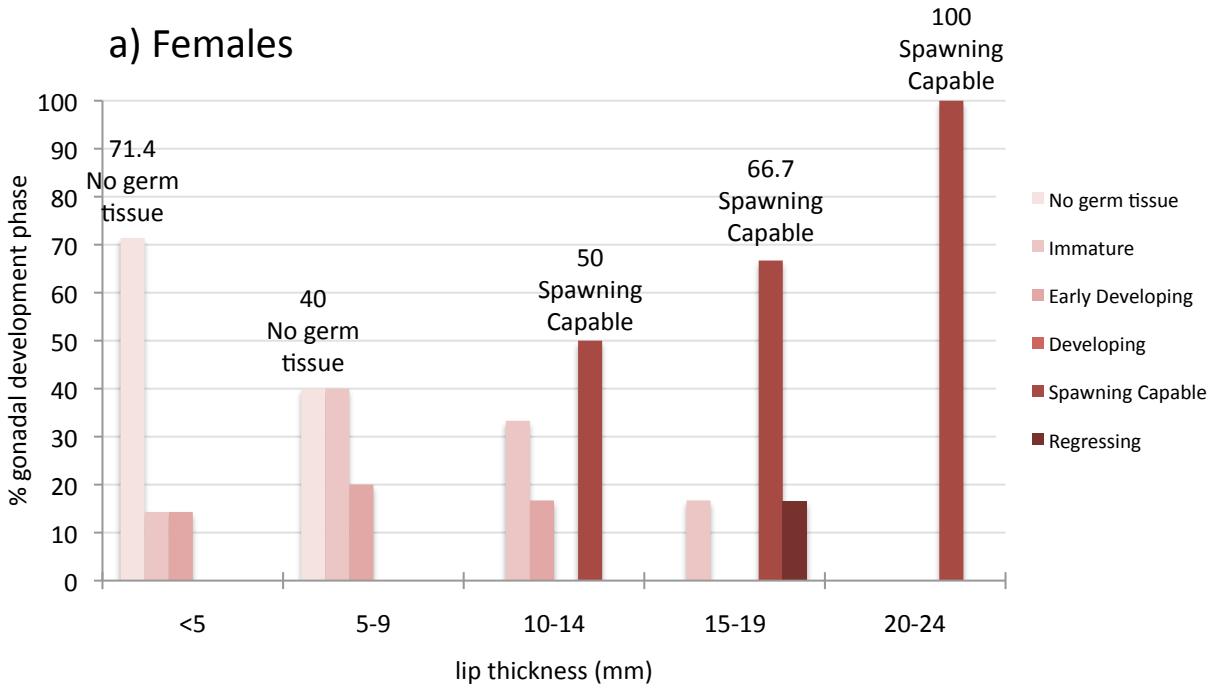


Figure 5. Gonad development in queen conch collected in the Bight of Abaco, June 2012. Data are shown for females (n = 30) and males (n = 27) in six classes based upon shell lip thickness.



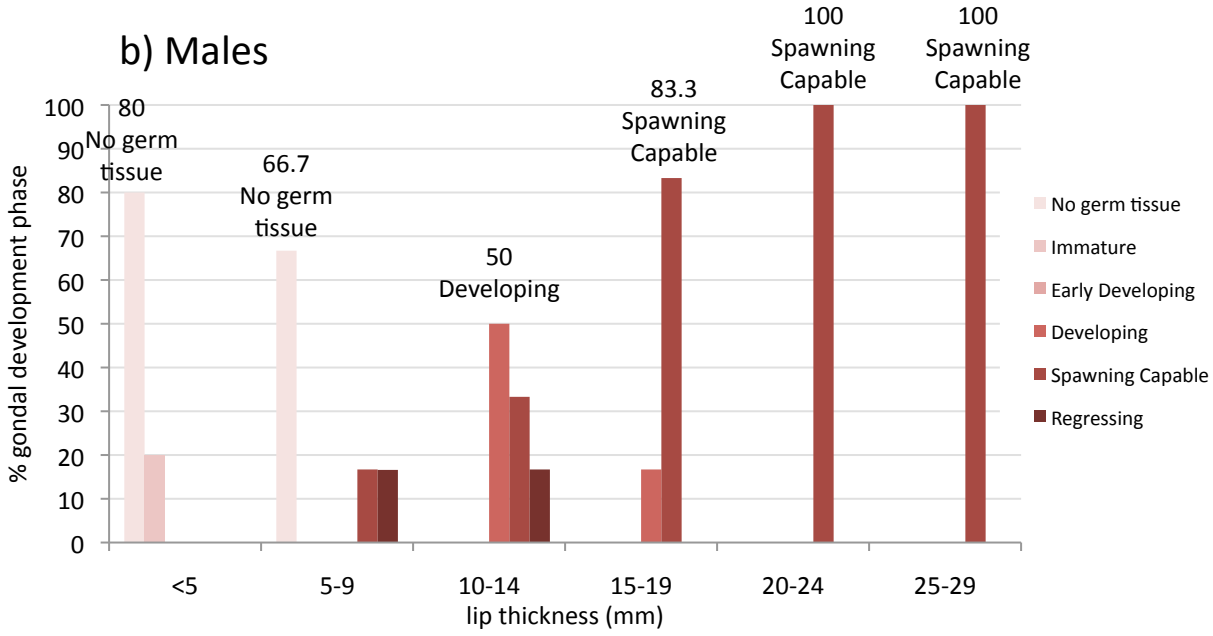


Figure 6. Gonadal maturity indices (GMI) for female and male queen conch collected near Warderick Wells, Exuma Cays (July 2011) and near Sandy Point in the Bight of Abaco (June 2012). The upper plot shows that no female conch with shell lip thickness (LT) < 11 mm was reproductively mature and that the proportion of mature females was highly variable but increases rapidly with LT after that. The same pattern is true for males except that the threshold for maturity was slightly lower (i.e., a few males showed developing maturity at 8 mm LT). The maturity schedules in Exuma and Abaco were very similar, with all of the points highly interspersed.