Assessing Essential Queen Conch (*Strombus gigas*) Habitat in Eleuthera, The Bahamas: Population Declines Suggest the Urgent Need for Changes in Management

La Evaluación de Hábitat Esencial Caracol Reina en Eleuthera, Las Bahamas: Descensos de Población Sugieren la Necesidad Urgente de Cambios en la Gestión

L'Évaluation de L'Habitat Essentiel de Lambi de Eleuthera, Bahamas: Le Déclin des Populations Suggèrent le Besoin Urgent de Changements dans la Gestion

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ABSTRACT

Queen conch (*Strombus gigas*) are economically and culturally important throughout the greater Caribbean region. However, recent surveys have shown declines throughout their range. In The Bahamas, there exists one of the last viable conch fisheries, but overfishing and illegal juvenile harvest is observed throughout the family islands. In Eleuthera, many local residents rely on marine resources, particularly conch, for subsistence. Population declines may have devastating effects on an already impoverished part of the country. A marine protected area has been suggested for South Eleuthera, but without current information on conch populations and identification of essential habitat, ideal placement and effectiveness cannot be assessed. To determine the health of the local conch population, we performed surveys in two crucial habitats: shallow water habitat and deep water breeding grounds. Utilizing towed snorkel surveys, we obtained necessary baseline data in nearshore habitat with moderate fishing pressure; preliminary results show low numbers of conch, with a mean density of 18 conch/ha. The deep water surveys (performed on SCUBA) were compared to surveys from the 1990s, to determine if local waters are still used by conch for reproduction. Although mating and egg masses were identified in the deep water, the mean density of 11 adults/ha is significantly lower than previous population estimates, and below the threshold identified for a healthy breeding population. Coupled with midden surveys that show only 14% of locally harvested conch are adult, the data suggest a drastic decrease in the South Eleutheran conch population, a potential early sign of population collapse.

KEY WORDS: Conch, South Eleuthera, Bahamas

INTRODUCTION

Queen conch (*Strombus gigas*) has been an economically important and culturally valuable marine resource in the Caribbean since ancient times (Berg and Olson 1989). In The Bahamas, queen conch is the second biggest fishery. Marine fishery resources provide a substantial livelihood for residents of Eleuthera, a small family island of The Bahamas, particularly after tourism to Eleuthera drastically decreased, starting in the 1980s (Clark et al. 2005). Locally, small artisanal queen conch fisheries have historically been and still are an integral part of the culture and economy of South Eleuthera (Appeldoorn 1994). This reliance on marine resources, and in particular queen conch, is pronounced in the waters off Cape Eleuthera and the surrounding South Eleuthera area (Clark et al. 2005).

In recent decades, the health of the fishery has seen heavy depletion to the point of stock collapse in several areas, including Belize (Appeldoorn and Rolke 1996, Thiele 2005), Haiti (Wood 1995), and Florida (Berg and Glazer 1995). This low population density of *S. gigas* also been seen on several Bahamian islands, including Andros (Stoner 2010) and the Exuma Cays, an island chain close in vicinity and similar in bathymetry to South Eleuthera (Stoner et al. 2012a). Recent work suggests that a similar effect may be propagating through queen conch populations in South Eleuthera (Clark et al. 2005).

For the past 15 years, a Marine Protected Area has been suggested for the waters off of Cape Eleuthera, though little research has been conducted to confirm the effectiveness of the placement with the proposed boundaries. Also, previous work has shown that for MPAs to effectively protect queen conch, multiple life stages need to be considered (Stoner et al. 2012a).

Historically, the area of South Eleuthera contains multiple essential habitats for queen conch, and has supported local harvest for centuries, and a current assessment of the population is necessary to understand the current health of the population. the waters off Cape Eleuthera have been identified as an important nursery ground, providing essential habitat to juvenile conch, and are ideal for their shallow depths and seagrass beds (Danylchuk 2005). The deeper area south of the Cape has also been previously identified as important local breeding grounds (Stoner et al. 1998).

In order to determine the current health of the queen conch population in South Eleuthera, surveys were conducted in essential habitats, including the nearshore shallow waters off Cape Eleuthera, and the adjacent deep water habitat. Nearshore tows were conducted over two seasons, and deep water surveys were conducted in warmer summer months to search for positive signs of conch reproduction.

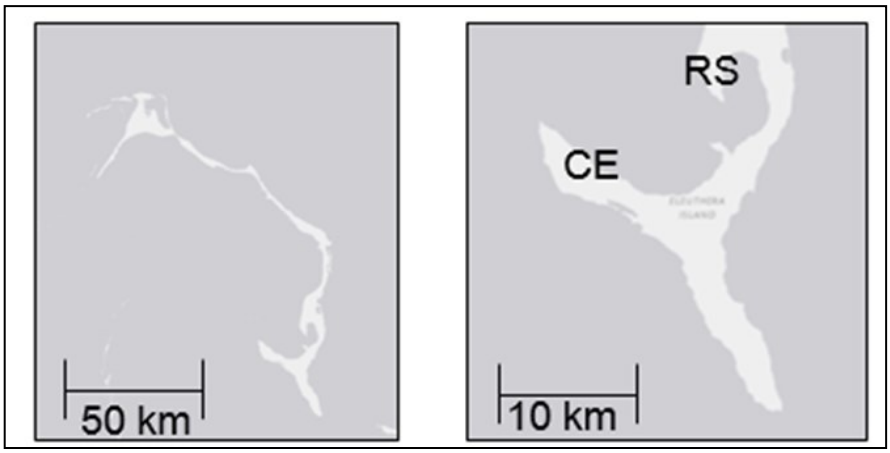

Figure 1. Map on left shows island of Eleuthera, The Bahamas; map on right is close-up of South Eleuthera, where shallow and deep water surveys were performed. Cape Eleuthera is denoted with "CE" and Rock Sound is denoted with "RS".

METHODS

Shallow Water Surveys

To assess the shallow water population of queen conch in South Eleuthera, shallow water snorkel tows were performed during the period of March - October, 2012. Transects were conducted at locations on the bank side of South Eleuthera, The Bahamas. The onshore bank located within the southern waters of Eleuthera is bounded by Cape Eleuthera to the west and south and Rock Sound to the east (Figure 1) A series of shallow sandbars constrict water flow onto the bank to the north. The bank is characterized by interspersed sand, coral rubble, seagrass, and macroalgae- dominated benthic types with scattered patch reefs less than 5 m deep.

A systematic sampling scheme was adopted to characterize queen conch populations in the area. GPS-guided transects were conducted at each 1 km^2 zone (Figure 2). Transects were 1,000 meters long and six meters wide (6,000 m^2 = 0.6 ha). Two snorkelers were towed behind a boat, noting observations of live adult, sub-adult, and juvenile conch. Values of the number of queen conch per tow were converted to number of individuals per hectare to allow direct comparison between zones. Several observations of benthic habitat within each zone were recorded to identify the dominant benthic feature to correlate conch densities with habitat preference. The depth soundings were taken via lead line at the start and end of each transect.

Deep Water Surveys

From June - July 2014, intensive dive surveys were performed to assess the breeding adult population of queen conch near Cape Eleuthera, concentrated between the Schooner Cays and the southeast tip of Eleuthera (Figure 2). Following the methodology of Stoner et al. (1998), surveys were conducted in 5 stratified depth zones: 0 - 5 m, 5 - 10 m, 10 - 15 m, 15 - 20 m, and 20 - 25 m. Transects in <10 m were performed as towed snorkel surveys, as visibility allowed for this method in place of diving. In depths >10 m, dive surveys were performed. Depth zones were concentrated in four perpendicular lines off the shore of South Eleuthera, to replicate previous surveys (Stoner et al. 1998) but the area was greatly increased after initial dives yielded few conch.

At each depth interval, a team of three divers (two surveyors and a safety diver) swam for a mean time of 22 minutes, holding a taut 8 m rope. These divers counted and recorded the number of conch beneath the line, noting also reproduction and egg masses. Divers drifted with current for a set time, and start and end locations were recorded. Mean swim distance was 359 m (SD = 141.7 m), with a mean sampling area of 2872 m^2 (0.28 ha) per dive. Conch densities were then calculated to show number per hectare. Mean density per depth zone was calculated using the replicates within that zone.

RESULTS

Shallow Water Surveys

During the period between March - October, 2012, fifty-seven 6,000 m^2 transects were conducted at locations on the bank side of Eleuthera. The total area covered by towed snorkel surveys was 342,000 m^2 (34.2 ha). Mean density of all age classes of conch was 55.1 conch per hectare. Mean adult, sub-adult and juvenile densities were 10.6, 31.0, and 13.5 conch per hectare, respectively. The greatest density of juvenile conch was seen in the shallow southern end of the sampled area, while the greatest density of adult conch was found in the northwest corner of the sampled area. Results from an ANOVA show a significant difference between density of conch per hectare by dominant benthic habitat type (Table 1), and a post hoc Tukey's test showed that densities of conch found in macroalgae and seagrass were higher than those found in sand ($p < 0.0001$), although densities in macroalgae and seagrass were not found to differ ($p = 0.330$).

Deep Water Surveys

In total, 39 transects were performed across the 5 depth zones (Table 2). Increased number of transects in deeper depths accounted for maximum bottom time on

dives >15 m. Unlike in previous surveys of this area, where conch were concentrated in the shallowest and deepest depth zones, (Stoner et al. 1998), the highest density of conch in 2014 was found within the 10 - 15m depth zone. A t-test performed between the mean densities per zone between 1993 and 2014 yielded a significant difference (p = 0.006), with declines seen at every depth (Figure 3). Seven instances of active breeding and one egg mass were noted from all the surveys.

DISCUSSION

In our shallow water surveys, the largest proportion of conch identified were immature individuals. While this supports evidence that the area is a nursery ground, it is also important to note that the highest density of individuals were classified as sub-adults, possessing a flared lip, but sexually immature. In The Bahamas, it is illegal to fish a conch without a fully formed flared lip; recent research by Stoner et al. (2012b), though, shows that even with a flared lip, queen conch may not have reproduced until they obtain a lip thickness of 10 mm (for males) and 15 mm (for females). So, although queen conch may be fished legally, they might still be immature, another potential reason for the perceived decline in queen conch populations in South Eleuthera. Fishing boats were observed on numerous sampling days within the sampled area (Claire Thomas, Cape Eleuthera Institute, personal observation), so harvest of legal-sized immature individuals was and is a likely occurrence in the area. Also, mean conch density differed by bottom type. The sample area, although containing macroalgae and seagrass beds, is dominated by sand, which yielded the lowest density of conch.

In previous work, Stoner and Ray-Culp (2000) found that densities of less than 47 adult queen conch per hectare resulted in no evidence of mating. In our shallow water study, only 9% of the sampled shallow water area had densities of adult conch > 47 per hectare. In our deep water surveys, the highest mean density found was 28 conch/ha, although active mating was observed (infrequently). Queen conch are sensitive to depensatory effects due to fishing, and efforts to revive significantly depleted populations have been ineffective, e.g., in the Florida Keys, where conch fishing has been banned since 1986 (Delgado et al. 2004). South Eleuthera is in danger of severely depleting conch resources to a level that would not only affect local stocks, but also regional abundance. With the decline we have seen in the past 20 years, it is unlikely that the current level of conch production can sustain fishing pressure and local demand.

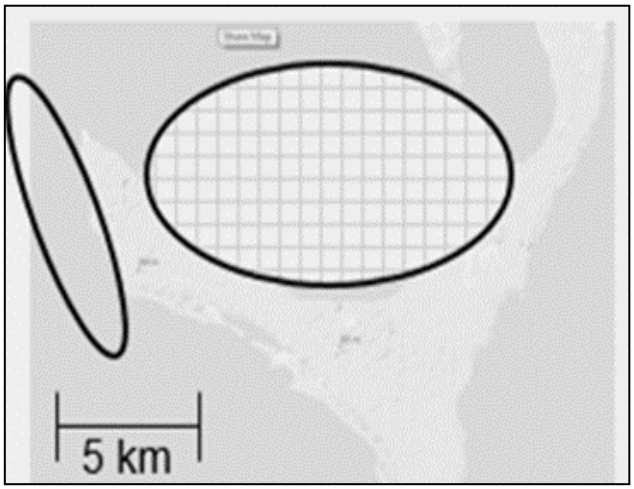

Figure 2. Map of South Eleuthera. Hatched oval denotes area for shallow water tows, second oval denotes dive survey sites.

Marine reserves provide positive population replenishing effects that include spillover, both regionally and immediately surrounding the reserve. Protecting an area in South Eleuthera could help create increased biomass of *S. gigas*, and an increase in larval spillover could eventually replenish deep water populations of breeding adults (Roberts and Polunin 1993). Marine reserves may positively affect conch populations, though special attention needs to be paid to ensure that multiple life stages of conch are protected, including the vulnerable juvenile stage (Stoner et al. 2012a).

Recent attention has been drawn to a proposed marine reserve in the Cape Eleuthera area to provide sanctuary for the intensely fished "holy trinity" of queen conch, spiny lobster, and grouper species (Danylchuk 2005); the proposed marine reserve has been suggested for the area north of Cape Eleuthera as part of a movement to preserve 50% of coastal habitat throughout the Bahamas by 2020. However, popular support for the reserve by residents of South Eleuthera has been lacking due to a strong economic

Table 1. Analysis of Variance (ANOVA) between density of conch per hectare and dominant benthic habitat type

Source	*Sum of Squares*	*df*	*MS*	*F*	*p*
Between	63778.109	2	31889.055	10.698	<0.0001
Within	83466.405	28	2980.943		
Total	147244.514	30			

Table 2. Summary statistics from conch breeding surveys conducted June-July 2014 in the waters off Cape Eleuthera. Totals for columns are bolded.

Depth Zone	Survey Method	No. of transects	Total no. of conch	Total area (m^2)	Conch/ha (SE) 2014	Conch/ha (SE) 1993
0-5 m	Tow	7	22	20866.8	10.57 (4)	228 (144)
5-10 m	Tow	6	12	18498.6	6.48 (5)	140 (76)
10-15 m	Dive	7	89	31397.6	28.34 (8)	75 (59)
15-20 m	Dive	9	8	23390.4	3.42 (2)	39 (36)
20-25 m	Dive	10	9	27477.2	3.28 (1)	92 (33)
TOTAL:		**39**	**138**	**121600.6**		

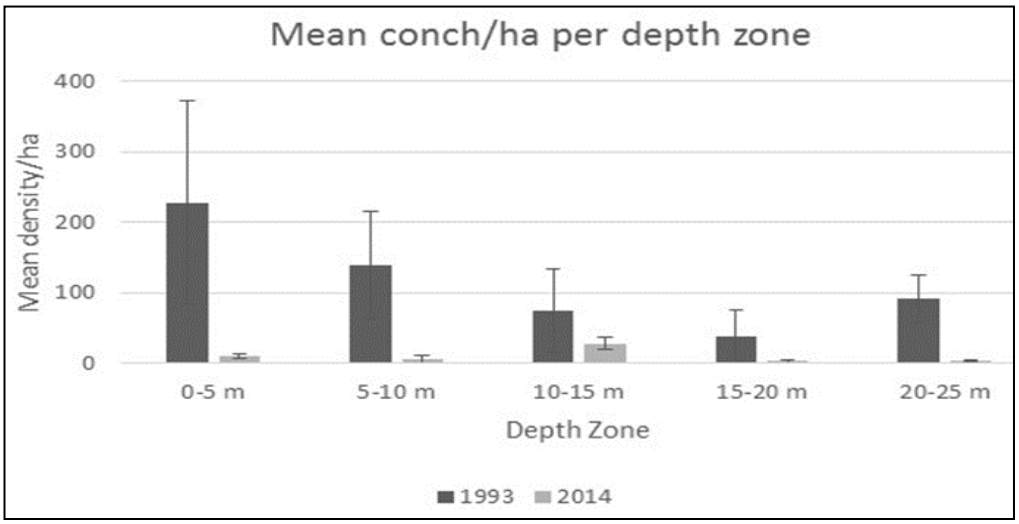

Figure 3. Bar graph showing the mean conch per hectare per depth zone in 1993 vs. 2014. A t-test showed a significant difference of means between years (p = 0.017)

reliance on marine food resources (Broad and Sanchirico 2008). In order to preserve queen conch resources in The Bahamas, closer attention must be paid to the balance of marine reserves and socioeconomic considerations of the population that uses its resources. This study reinforces the need for additional work to examine the regional significance of proposed reserves on nearby islands of The Bahamas. Our research also provides a baseline density of conch for the shallow waters off Cape Eleuthera, a measure which has been lacking, but more research in needed across other family islands to understand the regional health of this important resource

Results from our shallow water and deep water surveys suggest that protecting the waters off Cape Eleuthera would include protection of juvenile conch nurseries and adult breeding grounds. Including these essential habitats would be necessary to ensure success of an MPA. But, population numbers are low, and significant declines in the past 20 years in breeding adult populations suggests an urgent need for changes in management that can protect the resource, as current levels of fishing pressure with no changes in harvest regulation will lead to an inevitable collapse of the local conch population.

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