Queen Conch Fishery Declines in the Turks and Caicos Islands

Determining the cause and finding solutions to restore Strombus gigas stocks

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Abstract

Queen conch (*Strombus gigas)* has been commercially fished in the Turks and Caicos Islands (TCI) for more than one hundred years (Clerveaux, 2000; P. Medley & Clerveaux, 1998); however, since 2009, harvests have declined dramatically and now measure only about half of traditional yields (Lockhart, 2011a). A review of historic data, peer-reviewed articles and a recent history of development in TCI suggests that human impacts from dredging have resulted in the destruction and sedimentation of critical conch habitats, which may have resulted in a permanent reduced carrying capacity for the species. Habitat loss is exacerbated by hurricane events (Lockhart, 2010; Pardee, 2008) and overfishing by as much as 800,000 pounds per year (Paul Medley, Wood, Clerveaux, & Salamanca, 2014).

The above factors combine with poor management practices. Fisheries management policy is based on a quota set against maximum sustained yield (MSY), rather than fixed effort, and regulation based on size and weight is biologically irrelevant ("Fisheries Protection Ordinance," 1997; Mueller & Stoner, 2013). As slow-moving organisms that sexually reproduce, the maintenance of adult densities of at least 47 mature individuals per hectare is essential for reproduction to take place (A. W. Stoner & Ray, 2000), but TCI has current measured densities of only 14 adults/ha (Paul Medley et al., 2014).

Political will for change remains elusive and is directed by private interests that benefit in the short-term from maintaining the status quo. With full awareness of declining stock characteristics, policy makers again set the export quota for 2014-15 at 500,000 pounds; however, unless policy is immediately adapted to existing conditions, stock collapse will be a likely outcome. An immediate closure of the fishery for a period of at least 4 years, coupled with revised legislation that recognizes biological requirements, including fixed effort harvesting and protection of critical habitats, may be the only means to rebuild diminished stocks for long-term sustainable use.

Introduction

Queen conch is a large (up to 30 cm in length), edible gastropod with a geographic range throughout the warm Western Atlantic. In TCI, queen conch is the second-leading fishery, with export values of approximately $3.5 million per year (Clerveaux, 2000). In 2009, recorded landings of conch plummeted from historic values, dating back to the 19th century, of approximately 1.5 - 2 million pounds per year, to 636,875 pounds (Lockhart, 2011a). Since that time, stocks have not rebounded.

The causes of conch stock declines have not been definitively determined; however, habitat loss related to events that took place prior to stock declines, including the landfall of two major hurricanes (Ike and Hannah) and the dredging of a mega-yacht marina and deep water channel (Olin et al., 2007), may be contributing factors. In addition, TCI has always managed the conch fishery based on an annual harvest quota, and evidence also suggests that conch may have been overfished for a period of several years. Permanent habitat degradation and loss, coupled with overfishing, may have created a perfect storm of conditions forcing conch stocks to the verge of collapse.

Complicated life histories and highly specialized niches have made queen conch vulnerable throughout its range. Where stocks have collapsed at other locations, they have not recovered to economic levels (Appledorn & Rodriguez, 1994; FAO, 2013). Because of the vulnerability of this species to fishing pressure, it has been listed in Appendix II of the Convention on International Trade in Endangered Species (CITES). Given the critical importance of the fishery in TCI, both economically and culturally, an urgent need exists to confirm the causes of stock declines and to implement revised appropriate management plans for the fishery, before stocks collapse beyond recoverable levels.

The following analysis explores historic and current research, statistics and published literature in order to determine the historic habitat range, maximum sustained yield and carrying

capacity for queen conch within the territorial waters of TCI. A further assessment of recent environmental impact and landing statistics aims to clarify habitat losses and fishing pressure. Finally, the causes of stock declines are identified, with recommendations for a revised stock management plan for the species.

Conch Biology

Figure 1 - Queen Conch *(Strombus gigas)*

The biology and life history of queen conch are complex. The species is a grazing animal that inhabits seagrass beds and areas where algae overgrow sand and rock bottom. As algae and seagrasses are photosynthetic and require light, depth limits their growth and therefore also limits conch habitat, which is generally restricted to a maximum of 30 meters of depth.

Conch reaches a maximum size prior to sexual maturity, which takes place at approximately 3-4 years (Hesse, 1975). Thereafter, growth is limited to an increase in shell thickness (A. Stoner, Mueller, Brown-Peterson, Davis, & Booker, 2012). Depending on environmental variables, the size of queen conch at maturity varies widely; therefore, size is not a good indicator of maturity.

Conch reproduces sexually with internal fertilization; thus, certain population densities must be maintained in order for slow-moving, mating adults to achieve successful reproduction. In a

recent study of conch in the Bahamas, no mating was observed in densities lower than 47 mature adults per hectare, and densities as high as 100 adults per hectare may be necessary to maintain stock levels (Allan W Stoner, Davis, & Booker, 2012). This is a result of a phenomenon known as the "allee" effect, which posits that a critical density is required for slow-moving species to find each other. Once the critical density is achieved, mating increases proportionately with density (A. W. Stoner & Ray, 2000).

Conch populations are also checked by predation. In spite of their thick shells, conch are vulnerable throughout all life phases. Significant predators include other gastropods *(Fasciolaria tulipa* and *Murex pomum),* cephalopods *(Octopus vulgaris)*, crustaceans *(Petrochirus diogenes, Dardanus venosus, Panulirus argus* and *Paguristes spp.),* sharks, rays *(Galeocerdo cuvieri, Aetobatis narinari* and *Dasyatis Americana)* and possibly other species (Randall, 1964).

Management Concerns

In order to be sustainable fisheries must conserve sufficient breeding stock to supply subsequent generations; therefore, various attributes regarding maturity must be understood in order to sustainably manage a species. Due to high phenotypic variation regarding size and weight in conch, other attributes must be used to definitively determine sexual maturity.

Mueller and Stoner found that shell thickness and gonadal maturity are significantly correlated, whereas shell length and gonadal maturity are not (Mueller & Stoner, 2013). Sexual maturity in females was evident in all individuals with shell thicknesses greater than or equal to 15 mm. For males sexual maturity was evident in all individuals with shell thicknesses greater than 10 mm (Mueller & Stoner, 2013).

Where stocks have been overfished, recovery efforts for collapsed stocks are confounded by evidence from recent genetic testing, which suggests that conch stocks are geographically isolated, with limited mobility of larvae from one population to another (Paris, Aldana-Aranda, Perez, & Kool,

2008). Stocks that are depleted are therefore not likely to benefit from recruitment due to migration. Studies on queen conch throughout its range have indicated that once collapsed, conch stocks are slow to recover, if recovery is even possible (Appledorn & Rodriguez, 1994; Chakalall & Cochrane, 1997).

Conch History and Management in TCI

Queen conch has been a culturally significant source of protein in TCI, since Lucayan Indians first settled the islands in the 10th Century C.E. Trade in conch between TCI and Haiti was first recorded in 1904 (434,000 conchs), and international export records have been kept since that time. In the early 1950's the introduction of refrigeration to TCI allowed for conch to be sold for frozen export to the United States. Frozen exports have increased steadily since that time and now account for all legal export. Once a primary local source of protein, demand is now driven by tourism and international markets. International demand has resulted in depletion of stocks throughout the specie's range; however, until 2009, conch stocks in TCI were believed to be replenished by unexploited deep-water stocks and were considered stable (Lockhart, 2011b; P. Medley & Clerveaux, 1998).

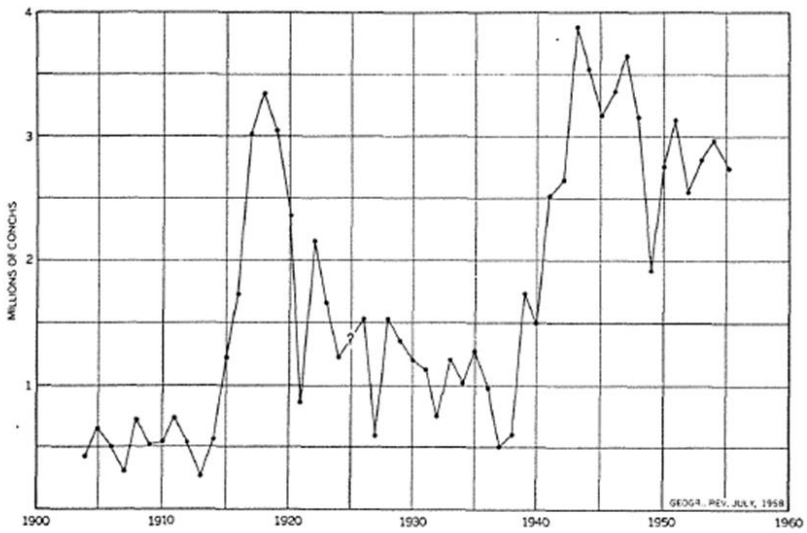

FIG. 5—Export of conchs from the Caicos Islands, 1904-1955.

Figure 2 - Recorded Exports of Queen Conch Since 1904 (Doran, 1958)

Historically, conch has been fished from areas of high stock densities that also function as spawning and nursery habitat (Doran, 1958; Hesse, 1975). These areas include areas off Six Hill Cays, Dove Cay and Ambergris Cay, near South Caicos, West Sand Spit, Molasses Reef and an area known as “the Shoe” off Providenciales. The critical spawning and nursery area within and adjacent to the Leeward Going Through Channel is not legally fished, as this area falls within the Princess Alexandra National Park (a no-take area).

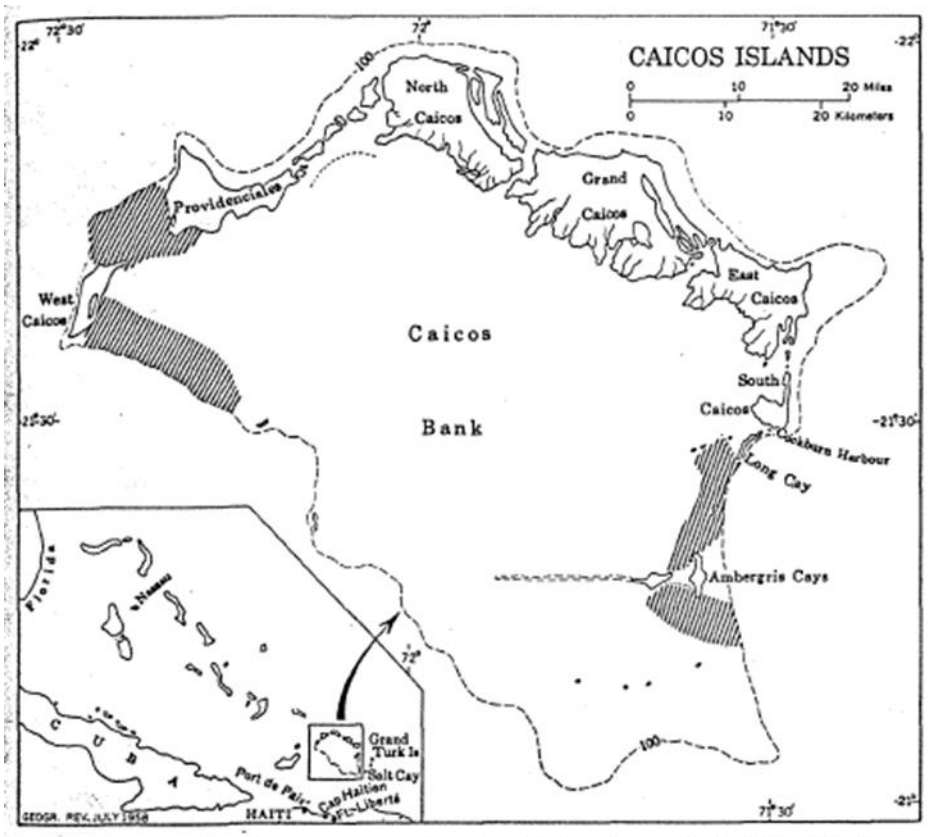

FIG. 1—The Caicos Islands, showing location of principal conch grounds (shaded) within the 100-fathom contour.

Figure 3 - Conch Fishing, Spawning and Nursery Areas (Doran, 1958)

In TCI conch is fished in an open fishery (unlimited licences), which is regulated by the establishment of an annual landing quota based on MSY, determined using a surplus model approach, which applies the following formula:

*MSY = 0.5*M*By (Lockhart, 2010; Paul Medley & Ninnes, 1999)*

By = virgin stock biomass, and M = mortality

A majority of time fishing for conch is spent searching for aggregations; therefore, catch per unit effort (CPUE) is inversely correlated to conch density and can be used to determine biomass. TCI has historically used a modified Schafer model (Paul Medley & Ninnes, 1999) to estimate a biomass dynamic model as follows:

$$B_{t+1} = B_1 - C_1 + rB_t(1 - B_t/K)$$

(Where B_t = biomass at time t, C_t = catch at time t, r is intrinsic rate of growth and K is carrying capacity)

Parmeter	Symbol	Value	Unit of measurement	Source
Intrinsic rate of growth	r	0.39	1/year	DECR (2009)
Carrying capacity	K	17,607,107	lb	DECR (2009)
Catchability coefficient	q	0.001152	1/boat/year	DECR (2009)
Unit cost of effort	cu	10,186	USD/boat/year	DECR Survey (2010)
Price of species	p	1.2	USD/lb	DECR (2010)
Fleet entry/exit parameter	θ	1.65E-05	boats/USD	
Average number of fishing days	f	24	days/year/boat	
daily catchability coefficient	q'	0.000048	1/boat/day	DECR (2009)

Name	Equation	Value	Unit of measurement
Biomass in bioeconomic equilibrium	Bebe=cu/pq	7,368,345	lb
Effort in bioeconomic equilibrium	Eebe = 2Emre	197	boats
Catch in bioeconomic equilibrium	$C_{ebe} = qE_{ebe}K(1-qE_{ebe}/r)$	1,671,068	lb
Effort in MSY	Emsy = r/2q	169	boats
MSY	Cmsy = Kr/4	1,716,693	lb
Effort in MEY	Emey = r/2q(1- cu/pqK)	98	boats
Catch in MEY	Cmey= qEmreK(1-qEmre/r)	1,416,046	lb
Biomass in MEY	Bmey=(1-qEmre/r)K	12,487,726	lb
Biomass en MSY	Bmsy=(1-qEmrs/r)K	8,803,554	lb

Figure 4 - Values for K, r, Biomass and other conch stock variables

In 1999, Medley and Ninnes theorized that K will fluctuate based on available food sources for conch, and populations that have been depleted by fishing will be less affected by available food; therefore, K will have little apparent fluctuation, and r will likely be the greatest source of fluctuation in the model (Paul Medley & Ninnes, 1999). They further posited that the main sources of stock variability are therefore related to changes in the physical environment, in addition to biological factors, such as relative numbers of spawning individuals. Depletion of stock therefore significantly affects r, as conch spawning is density dependent.

MSY has therefore been established on an annual basis, using the conch surplus model and based on the assumption that local consumption is approximately 320,000 pounds per year, as

determined in a 2003 study (Clerveaux & Lockhart, 2003). Local consumption cannot be quantified at processing plants because people fish for their own conch and fisherfolk sell product directly to restaurants, rather than to processing plants, which focus primarily on the export market. Until 2010, harvest quotas were set between 1.4 million and 1.8 million pounds annually; however, in 2009-2010, the reported catch was only 395,433 pounds, less than 25% of previous years' catch. In 2011, reported catch was only marginally better at 500,239 pounds. Catch levels for 2012 and 2013 levelled off at approximately 500,000 pounds. CPUE declined sharply and has continued to remain at low levels.

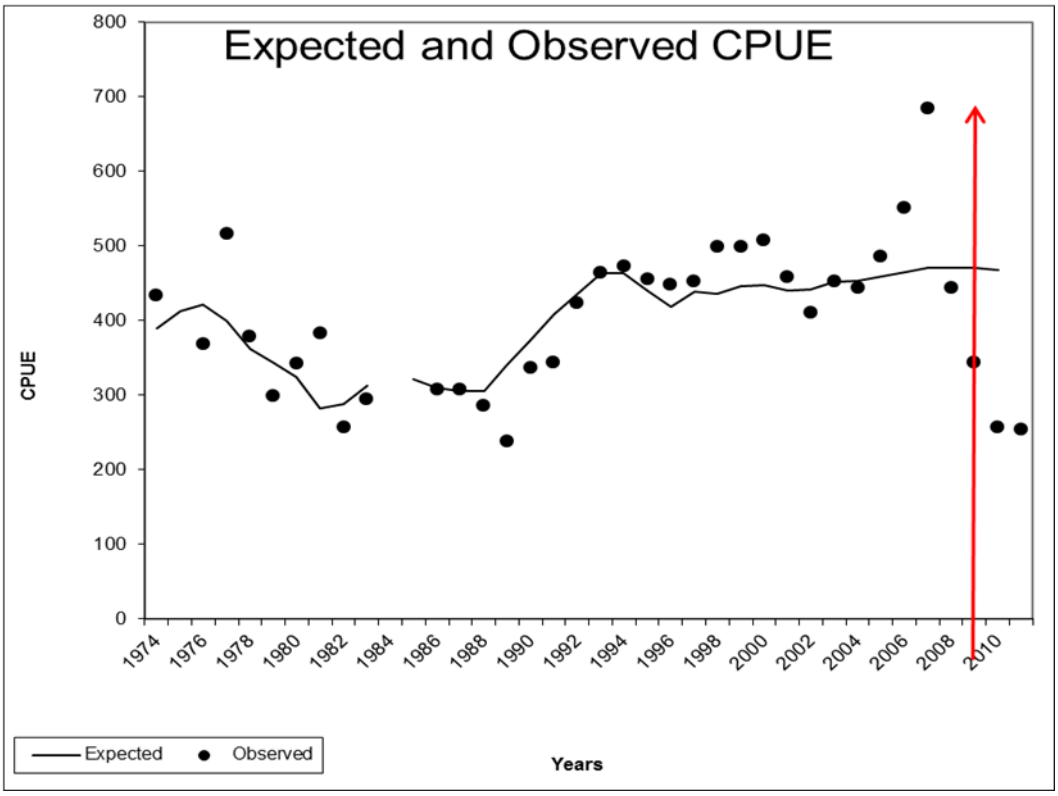

Figure 5 - Observed and Expected CPUE (Lockhart, 2010)

In response to declining stocks and to reassess stock characteristics, in 2013-14 the Department of Environment and Maritime Affairs (DEMA) conducted a visual survey stock assessment of conch populations (Paul Medley et al., 2014). The preliminary results of the survey indicate that young and old adult densities of conch are approximately 14 per hectare, considerably

lower than the minimum densities of 47 adult conch per hectare, required for mating to occur. Densities of juveniles are measurably higher, with densities of 172, 57 and 25 for 1, 2 and 3-year old juveniles, respectively. Currently sub-adults, young adults and old adults are fished. The significant decline in densities from small juveniles (172/ha) to large juveniles (25/ha) is indicative of natural mortality, including predation.

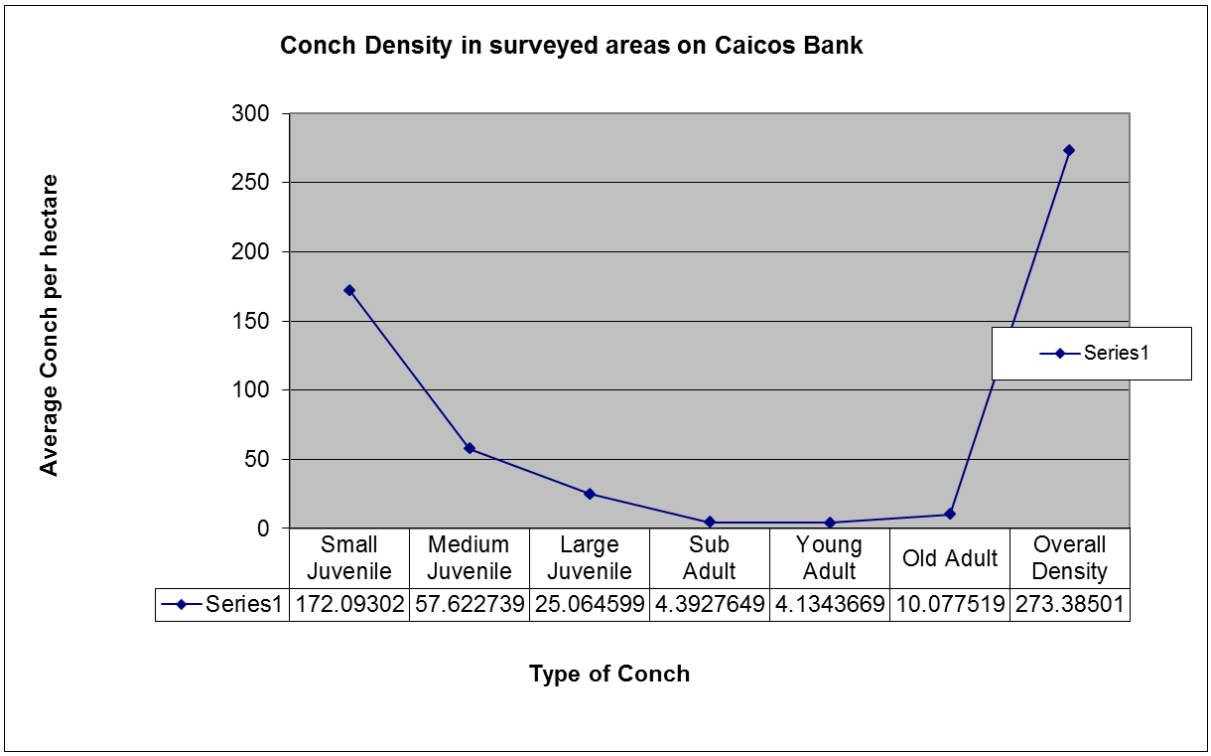

Figure 6 - Conch Densities in Surveyed Areas (Paul Medley et al., 2014)

In addition to the visual survey, the School for Field Studies (SFS) conducted a comprehensive local consumption study and determined that local consumption levels are actually approximately 600,000 pounds per year, almost twice the amount historically used to determine the harvest quota (Hind, 2014).

Factors Contributing to Stock Declines

In early 2008, the government of the Turks and Caicos Islands approved plans for the dredging of a deep-water channel and mega-yacht marina. In 2008 Marsha Pardee of Greenflash

Ltd., a leading TCI marine biologist, performed an assessment of queen conch in the area slated for dredging. The assessment revealed that the channel was a critical spawning, nursery and foraging area for conch and that densities of conch at this location were as high as 2,000 adults/ha, at least 10 times as high as in other known spawning and nursery habitats. The discrepancy may be attributable to the fact that, unlike other known spawning and nursery areas, this habitat falls within a protected area and is therefore a no-take area. It may also be attributable to larval recruitment from the nearby Conch Farm.

The study concluded that dredge and fill activities would have serious negative impacts, not only on the existing conch population, but also on the future potential recruitment for larvae and juveniles. Pardee warned that the changes in the ecological and physical dynamics of the area would result in long-term impacts on the conch stocks in TCI. (Pardee, 2008). Pardee's predictions were confirmed in a subsequent study in the same area that found that conch densities were reduced five-fold and that benthic cover had also changed significantly since the previous study with *Laurencia spp.*, a previously abundant and important species for larval recruitment, practically extirpated from the site (Pardee, 2014a).

The environmental impact assessment (EIA) for the dredging project estimated 18 acres of hard-bottom coral habitat, 231 acres of seagrass beds and 16 acres of sandy bottom would be directly affected by the proposed dredging (Olin et al., 2007). Recommendations made in the EIA to reduce environmental impact, including installation of turbidity curtains and transplantation of threatened organisms, were not undertaken (Pardee, 2014b).

In 2008, the channel was dredged using a cutter head dredge to deepen a naturally existing channel. An analysis of stored dredge material showed that much of the dredge material was in the silt/clay range. Dredge spoil from the dredge site was tested and compared it to sediments that collected during and after dredging at the Caicos Conch Farm (located approximately 1.4 miles to the south). The study concluded that the sediments came from the same source (i.e. dredge material)

(Woods & Zarillo, 2014). As silt remains in suspension more readily than sediments with larger grain sizes, it can travel further distances prior to settling. In the absence of turbidity curtains, fine silt sediments from dredging operations dispersed, smothering critical conch habitats within a several-mile radius of the dredge site.

Figure 7 - Leeward Going Through Channel (Woods & Zarillo, 2014)

Shortly after dredging was halted, in September 2008, Hurricanes Hannah and Ike made landfall in the Turks and Caicos Islands. Fine silt/clay sediments from dredging operations were again stirred up and redistributed. Fisherfolk reported that fine sediments, smothering conch populations, were distributed by the hurricanes across the fishing grounds (Lockhart, 2011a).

Regulation and the legislative and institutional framework for the management of conch stocks in TCI are also inadequate. Existing regulation allows for the following:

- A minimum shell length of 7 inches and a minimum meat weight of 8 ounces, after the removal of the digestive gland,

- A closed season (for export only) from 15 July to 15 October, and
- A prohibition on the use of artificial breathing apparatus (scuba and hookah) protects stocks not accessible via free diving ("Fisheries Protection Ordinance," 1997).

As conch is generally landed without the shell (the weight of the shell creates too large a load for small fishing vessels), regulation governing shell length is difficult to enforce. Furthermore, as Stoner et al determined, shell length is not related to sexual maturity or any other biologically relevant benchmark.

The impact of the closed season for export is also somewhat dubious, As conch spawning begins in early spring (March) and usually tapers off significantly by the end of July (Hesse, 1975). Furthermore, fishing for local consumption continues throughout the closed season; therefore, spawning adults are not protected.

The final factor affecting stock declines is probable overfishing. Since 2003, harvest quotas based on MSY were established with the assumption that local consumption amounted to approximately 320,000 lbs/year; however, the more-comprehensive 2014 SFS local consumption survey determined that local consumption is actually closer to 600,000 lbs/year. This discrepancy means that conch was overfished by at least 280,000 pounds per year during the period from 2003-2014. In addition, recent stock assessment from the conch visual survey indicates that a revised MSY is approximately 600,000 lbs/year (Paul Medley et al., 2014), a figure that matches local consumption. Assuming that MSY has been reduced to this level since 2009-10, perhaps due to the degradation of the critical spawning and nursery area at Leeward Going Through, one can also conclude that the approximate 500,000 lbs/year that has been harvested for export also represents an overfished quantity.

Political will remains a major impediment to meaningful reform of conch fisheries policy. One elected Member of Parliament is also a processing plant owner, who exports significant quantities of conch annually. In 2014, in spite of data supporting an export closure and possible complete closure of the fishery, government retained an export quota of 500,000 lbs. Coupled with

local consumption values of approximately 600,000 lbs., this quota will mean that conch will again be overfished in 2014-15 by at least 500,000 lbs.

Discussion

The decline of queen conch stocks in TCI is attributable to both manmade and natural variables, including the dredging of critical habitats, hurricanes, inadequate management and overfishing. The dredging of the Leeward Going Through channel, coupled with hurricane events, reduced critical nursery and spawning habitat. Reduced critical habitat probably lowered overall carrying capacity for conch in TCI.

Although carrying capacity has likely been reduced since 2008, fishing effort has not changed; therefore, overfishing has occurred. In addition, inaccurate estimates of local consumption resulted in miscalculations of MSY, contributing further to overfishing. As adult stocks have been fished out, adult densities have been reduced, and spawning and juvenile stocks to replace fished stocks have not been sufficient. Unless the following measures to reverse the above trends are not expeditiously implemented, continued stock declines and collapse are a likely outcome.

- In the short term, a complete closure on the fishery for a period of at least four years will allow existing juvenile stocks to reach sexual maturity. At the end of the four-year closure, another survey should be conducted to determine if adult densities have recovered to levels required to sustain reproduction (at least 47 adults per hectare). Closure should remain in place until such densities are achieved. Stocks should then be continuously monitored and fishing effort regulated to maintain required stock characteristics.
- The dredging of the Leeward Going Through channel resulted in the permanent degradation and loss of critical conch spawning and nursery areas and may have been the initial precipitator of stock declines. Remaining critical spawning and nursery habitats must be protected from ill-conceived development to prevent further loss of carrying capacity and stock declines (Pardee, 2014a).
- Biologically irrelevant regulation must also be corrected. Sexual maturity should be determined using shell lip thickness (a minimum shell thickness of 15 mm for harvest) and a closure on fishing during spawning season (March-July, inclusive) should be implemented. Conch should be landed whole in order to enforce revised regulation, which will also reduce effort, as fisherfolk will not be able to carry as many whole conch on small vessels (Anonymous, 2013; Mueller & Stoner, 2013).

The above measures will serve to regulate the fishery, based fixed-effort harvesting, rather than quotas based on MSY. If necessary, effort can be further controlled by introducing a policy to restrict the number of licences.

Conclusions

The queen conch fishery in TCI is at a critical juncture. The only known spawning and nursery habitat within a protected area has been severely degraded and is now functioning at 1/5 its original capacity. This circumstance has broad implications affecting overall recruitment and carrying capacity for the species. Other critical habitats have overall densities of adults that are 1/20th previous densities and are far below densities required for successful reproduction.

In order to avoid collapse, an immediate closure on the fishery, coupled with biologically relevant regulations, including protection for critical spawning and nursery habitats, fixed effort harvesting, spawning season closures, and restrictions on take, based on shell thickness rather than size, must be implemented. If such measures are adopted immediately, the fishery may be recoverable; however, with reduced recruitment and carrying capacity, yields will likely never again reach historic levels.

If current fishing practices continue, it is probable that conch stocks will collapse within 4 years, as juveniles reach harvestable size and are fished out, without reaching sufficient densities for spawning. TCI will then join other nations, including the United States, Haiti and the Dominican Republic, which have collapsed conch fisheries that appear to be non-recoverable.

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