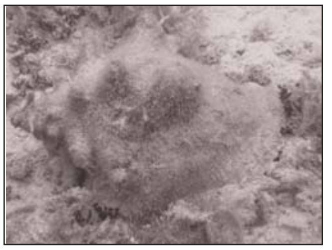
FEATURE:
FISHERIES MANAGEMENT

Impending Trade Suspensions of Caribbean Queen Conch under CITES: A Case Study on Fishery Impacts and Potential for Stock Recovery



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ABSTRACT: The Convention on International Trade in Endangered Species (CITES) Authority issued injunctions in 2003 and 2004 to halt export trade of Caribbean queen conch (*Strombus gigas*) from several countries and initiated reviews of a number of other conch-producing countries. The current regulatory framework for regional conch fisheries has obviously failed to protect stocks. I present a case study of the Belize conch fishery to examine fishing impacts, effectiveness of existing regulations, and potential for population recovery. Fishery-independent data from a no-take marine reserve indicated that unfished density and biomass were nearly an order of magnitude greater than in comparable fished areas. Size structure of the protected population showed that an average of 38% of the legal catch may consist of juvenile conch. The spawning potential ratio indicated that the fished stock is severely overexploited, and furthermore, the protected population has not compensated to make the local fishery sustainable. Under these conditions, a moratorium under CITES may be warranted. Until stock assessment models are refined, action should be taken to reduce juvenile fishing mortality, extend closed seasons, and enforce a network of functional no-take reserves in essential habitat.

INTRODUCTION

Queen conch (*Strombus gigas*) is a commercially-valuable marine gastropod that ranges throughout the Caribbean to Bermuda. It is the basis of a lucrative export market to the United States and Europe that was estimated at $60 million USD in 2001 (CITES 2003). Fishing pressure is intense and has led to significant declines in most populations over the past two decades. The conch fishery crashed in Florida and has not recovered to exploitable levels despite a 20-year fishing moratorium and an active reintroduction program (Glazer and Berg 1994). The status and trends of regional queen conch fisheries led to listing of the species on Appendix II of the Convention on International Trade in Endangered Species (CITES) in 1990. The International Union for the Conservation of Nature (IUCN) categorized the species as "commercially threatened" on the 1994 Red List (Groombridge 1994). More recently, the CITES Authority imposed a suspension of the export trade from the Dominican Republic, Honduras, and Haiti in 2003 based on evidence for declining stocks and the absence of an effective regulatory framework (Theile 2001; CITES 2003). In 2004, additional suspensions were implemented for Antigua and Barbuda, Barbados, Dominica, and Trinidad and Tobago. Fisheries in 13 other countries were categorized as "of possible concern."

Queen conch is harvested in over 25 Caribbean countries, but fishery regulations vary considerably (Berg and Olsen 1989; Chakalall and Cochrane 1997). For example, regulations may include shell size and/or meat weight limits (Bahamas, Bonaire, Puerto Rico and the U.S. Virgin Islands, St. Kitts and Nevis, St. Vincent and the Grenadines, Turks and Caicos Islands), closed season (Mexico, Puerto Rico and the U.S. Virgin Islands, Venezuela), and prohibition of fishing using scuba technology (Turks and Caicos Islands). Some countries (Bahamas, Dominica, Panama) have set landings or export quotas, but verification is difficult due to insufficient monitoring and reporting (CITES 2003). A few countries have no fishery regulations or management plans for this species.

Belize is one of 13 countries from which the CITES Authority has requested stock assessment and management plans. I used a long-term dataset on queen conch population fluctuation in a large, isolated no-take marine reserve in Belize to conduct a fishery-independent assessment of the potential productivity of the stock. These data were compared to equivalent data from adjacent fishing grounds to evaluate fishing impacts and the efficacy of the existing fishery regulations. Results from the Belize case study are discussed in relation to regional fishery management and whether intervention by CITES is warranted.

THE BELIZE QUEEN CONCH FISHERY

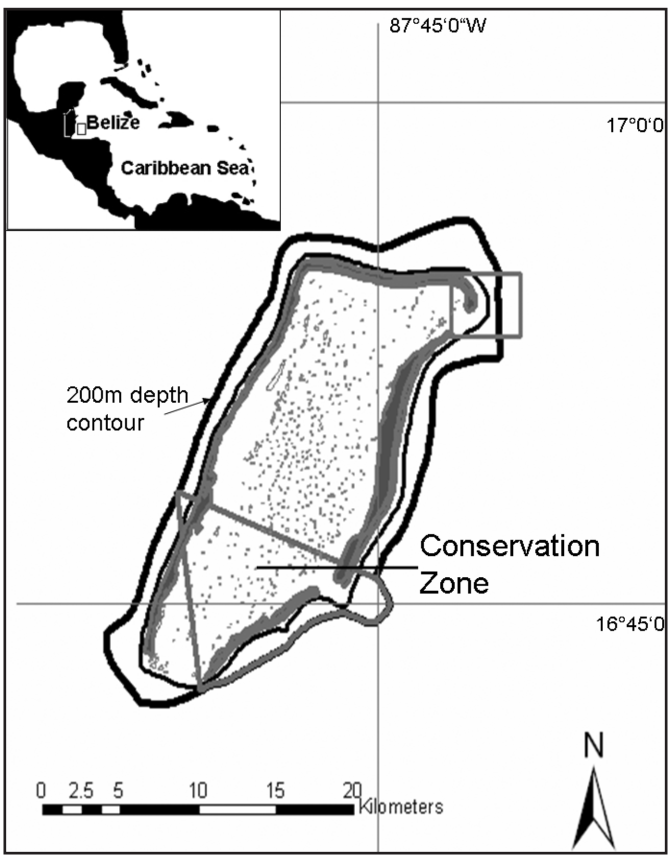
Belize is the seventh largest exporter of processed conch meat. The fishery regulations include a closed season from 1 July to 30 September, a minimum shell length of 17.8 cm or processed meat weight of 85 g, and prohibition of fishing using scuba equipment. The closed season was designated to encompass the reported peak period of reproductive activity during summer months. Commercial fishermen are issued licenses, but no limited entry system or individual catch quota has been established. Landings of conch and other commercial species are recorded as catch sold to exporters. There are few reliable estimates of the total landings that include catch sold in the legal local market, the illegal market for under-sized conch, and poaching by foreign fishers from neighboring countries (CITES 2003). Fishing is concentrated in relatively shallow water < 10 m deep in seagrass meadows, sand-algal flats, and near shallow coral reefs.

Maximum queen conch landings in Belize was reported as 1,200 metric tons (mt) in 1972, but landings declined rapidly after this period (CITES 2003; Camillo 2004). The mean annual catch reported by Belize fishery managers was about 200 mt between 1990 and 2004, but these figures were substantially higher that those verified by CITES. In response to the CITES notification, the Belize Fisheries Department set an export quota of 228 mt, plus a "local consumption" quota of 12 mt per year based on maximum sustainable yield (MSY) estimates (Anon. 2004). The Belize conch fishery was considered stable based on exports (Anon. 2004), even though landings are currently a fraction of the past maximum, fishing effort has clearly increased, and yield estimates are based on short time-series data (CFMC 1999; Camillo 2004).

FISHERY-INDEPENDENT SURVEYS AND ANALYSIS

Data were collected at Glover's Reef atoll, Belize, from 1997 to 2004. Preliminary sampling on east-west transects across the atoll indicated that primary conch habitat consisted of shallow (1-5 m) back reef and patch reef margins with clean sand substratum (spawning habitat), sparse seagrass, and abundant macroalgae Laurencia spp. (primary food source; Stoner 2003) (Figure 1). The soft silt substratum in the deeper lagoon and the dense coral cover on the forereef appeared to be unsuitable for conch. Glover's Reef was designated a marine protected area in 1993, but full-time enforcement was absent until 1998. Fishing is allowed in the General Use Zone (266 km2) and prohibited in the Conservation Zone (72.3 km^2).

Figure 1. Map of the Glover's Reef atoll, Belize, showing the no-take marine reserve (Conservation Zone). All other areas are fished (General Use Zone).



Queen conch were surveyed on a quarterly basis in the no-take Conservation Zone and the fished General Use Zone in a stratified random sampling design. Within each zone, sampling was conducted on 12 replicate 4 x 50 m belt transects (4 random transects at 3 general locations per zone) in seagrass/algal flats and on 5-m belt transects around the margins of 8 patch reefs. All conch were measured for total shell length (SL; to nearest 0.5 cm) from the tip of the spire to the siphonal groove. Adult conch have determinate shell growth in which lengthening ceases with the onset of sexual maturity as a flared shell lip develops (Egan 1985). The marginal shell lip continually thickens with age, but sexual maturity might be reached up to one year after the initial formation of the shell lip (Appeldoorn 1988). Thickness of the shell lip (LT; to nearest 1 mm) was measured and presence of a shell lip > 1 mm thick was taken as an indication of maturity. Reproductive activity was noted by the presence of egg masses or occurrence of mating or spawning.

For analysis, size classes were defined as: (1) juvenile recruit < 12 cm SL, (2) large juvenile > 12 cm SL without shell lip, (3) adult with flared shell lip. Fluctuations in density (log+1 transformed data) were analyzed using a doubly multivariate repeated measures analysis of variance (RMANOVA) with size classes and zones as between-subjects factors. Pillai's trace statistic was used to detect differences in density, and Bonferroni tests were used for post-hoc comparisons of factor levels. The error covariance matrix was inspected using Mauchley's test of sphericity, and homogeneity of error variances were checked using Levene's test of equal variances.

Change in exploitable adult biomass was assessed from individual adult weights calculated using shell morphometrics (Appeldoorn 1988):

$$\log(MW) = -1.357 + 2.571 \log(SL) + 0.135 \log(LT)$$

where MW: meat weight in g

SL: shell length in cm

LT: shell lip thickness in mm.

The trapezoidal rule of integration was used to compare the magnitude of biomass differences in the no-take and fished areas over the seven year survey period. Spawning stock biomass (SSB) within protected and fished areas was then calculated as (Ault et al. 1998):

$$SSB = \int_{L_M}^{L_\lambda} B(L|a,t)\,dL$$

where $B = \sum$ biomass at shell length $L|a,t$

$L_\lambda =$ maximum shell length with shell lip

$L_M =$ minimum shell length with shell lip.

The SSB estimates were used to calculate the reproductive potential for replenishing the stock and sustaining this fishery as the Spawning Potential Ratio (SPR; Goodyear 1993):

$$SPR = SSB_{fished}/SSB_{unfished}.$$

SPR was calculated on an annual basis from quarterly moving averages of biomass per unit area. The benchmark for the $SSB_{unfished}$ estimate was taken as the maximum annual biomass recorded in the no-take zone.

FISHERY IMPACTS

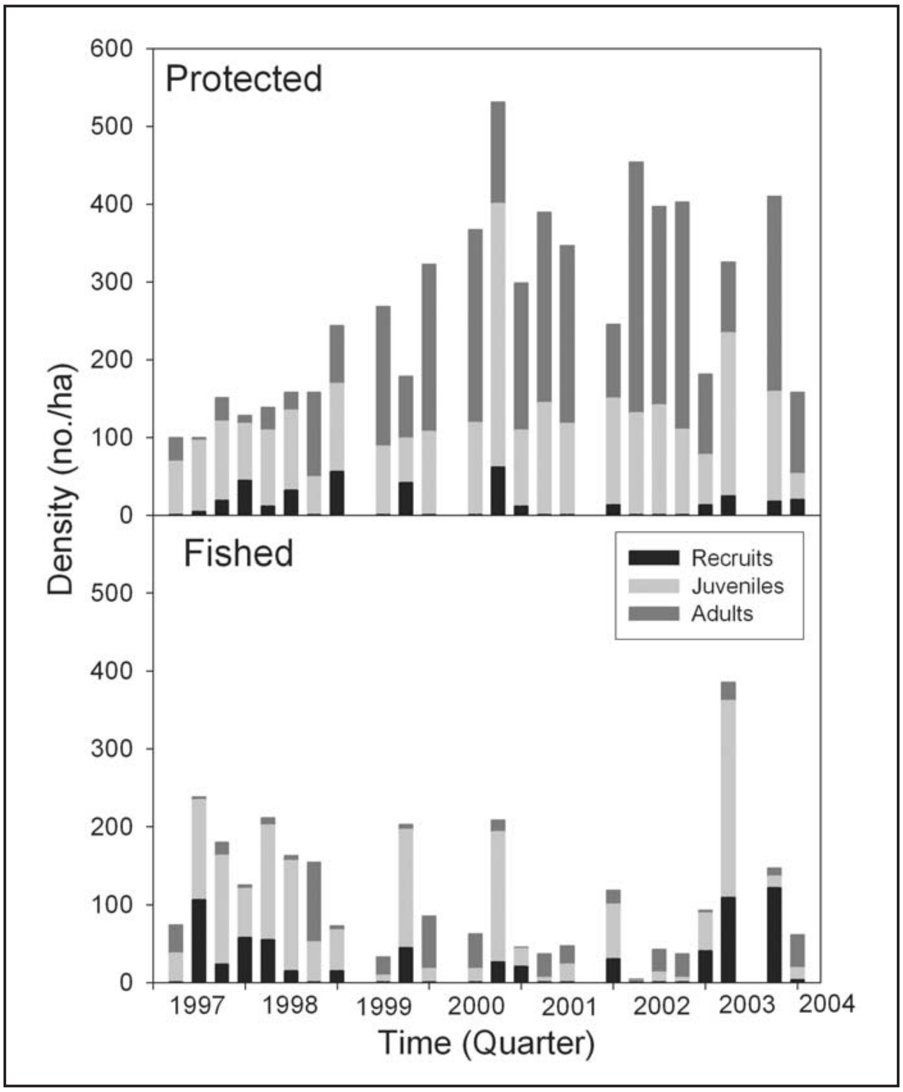
With the paucity of reliable catch and effort data, fishery-independent data from this no-take reserve with relatively consistent enforcement yielded valuable insights into fishing impacts and potential productivity. The density of adult conch in this population increased significantly since 1998 (Pillai's = 0.682, F = 3.543, $P < 0.0001$), primarily in the no-take zone (mean±SE: 240.3±50.6 per ha) compared to the fished zone (range from 10.9±5.9 in 1999 to 41.9±15.3 in 2000; Bonferroni $P < 0.0001$; Figure 2). The mean densities in the fished zone were well below levels at which depensation has been shown to occur in conch populations (Stoner and Ray-Culp 2000; Gascoigne and Lipcius 2004).

Occasional sharp declines in adult density occurred in the no-take zone in 2003 and 2004. Conch may undertake ontogenetic movement to deeper habitats with age (Stoner and Sandt 1992). However, extensive deep-water habitats for conch were lacking in this atoll, and no migrations were recorded during survey periods or during mark-recapture and telemetry experiments (Acosta 2002; Acosta et al. unpublished data). These declines instead qualitatively coincided with extended periods of no enforcement at the reserve (manager's log, Glover's Reef Research Station; A. Branson, pers. comm.), and as such, may be due to occasional poaching.

The density of large juveniles was greater in the no-take zone ($P = 0.02$), but the density of recruiting juveniles was similar in both areas ($P = 0.99$). One possible explanation for this discrepancy is that current fishery regulations allow fishing of all conch > 17.8 cm SL regardless of whether a shell lip is present. An average of 37.9% (range 0 to 92%) of the potential catch in the no-take zone in any given year consisted of juveniles (Figure 3).

There were no differences in the trends for individual adult weight, averaging

Figure 2. Summary of quarterly fluctuation in density of three age classes of queen conch in no-take and fished areas of Glover's Reef. Blank spaces represent missing surveys. Standard error estimation and statistical analysis are presented in text.



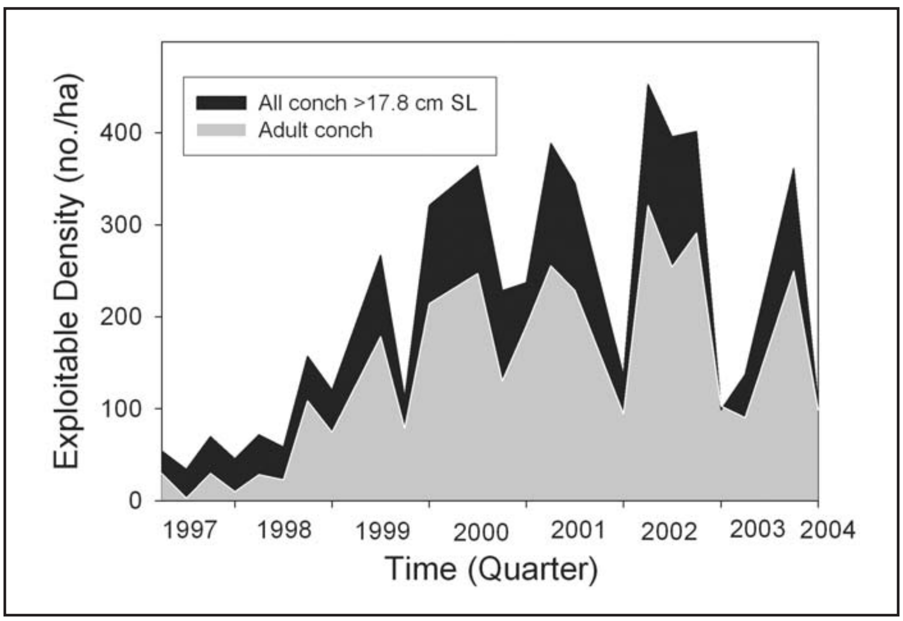


Figure 3. Density of adult queen conch with fully-formed shell lips, compared to density of all conch larger than the minimum fishable size (> 17.8 SL) in the protected population.

174.5±9.8 g in the no-take zone and 160±9.4 g in the fished area (Figure 4). Due to density changes, mean adult biomass increased in the no-take zone from 4.8±2.2 kg/ha in 1997 to 36.7±7.1 kg/ha in 2002 (Figure 4), whereas mean biomass in the fished zone ranged from 5.9±1.9 in 1998 to 1.7±0.7 kg/ha in 1999. Over time, therefore, exploitable biomass in the no-take zone (506 kg/ha) was approximately six times greater than in the fished area (85 kg/ha). Assuming similar productivity in fished and no-take habitats, the fishery may remove more than 80% of the exploitable adult biomass every year.

The SPR for the queen conch population at Glover's Reef increased from 0.13 in 1997 to a maximum level of 0.29 in 2000 (Figure 5). The point of overfishing is assumed to be 30% of the SPR as defined by Rosenberg et al. (1996). If we assume this is a self-recruiting population, it remained overexploited even with substantial increases in density and spawning stock biomass over 5 years. The population increase in the no-take zone (21% of the total area) has still not compensated for the intensity of fishing in exploited habitats. Finally, spawning activity was recorded as early as May and as late as November, compared to the designated closed season of July to September.

Figure 4. Mean individual biomass of adult queen conch (±1 SE; lower panel) and total spawning stock biomass (SSB; upper panel) in no-take (filled circles) and fished zones (open circles) at Glover's Reef, Belize.

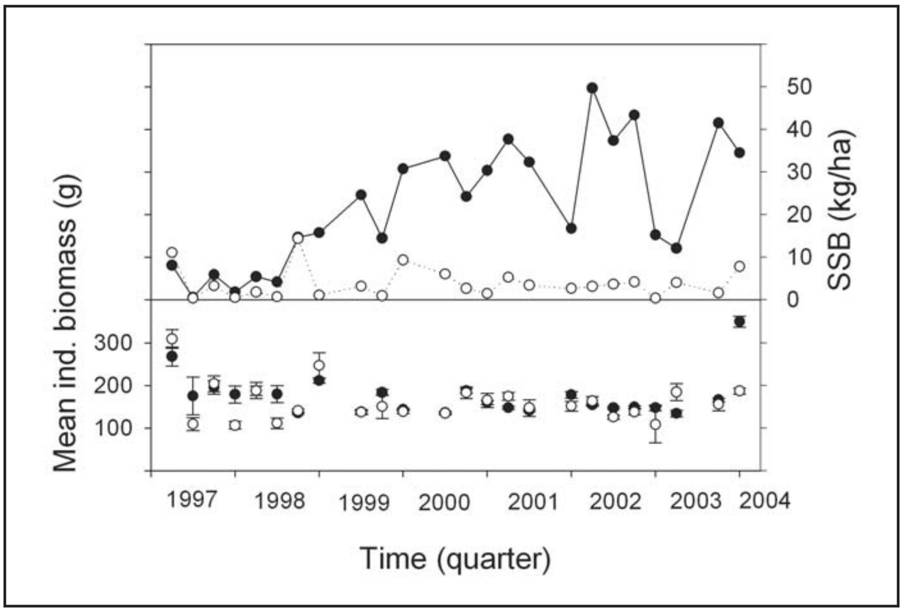
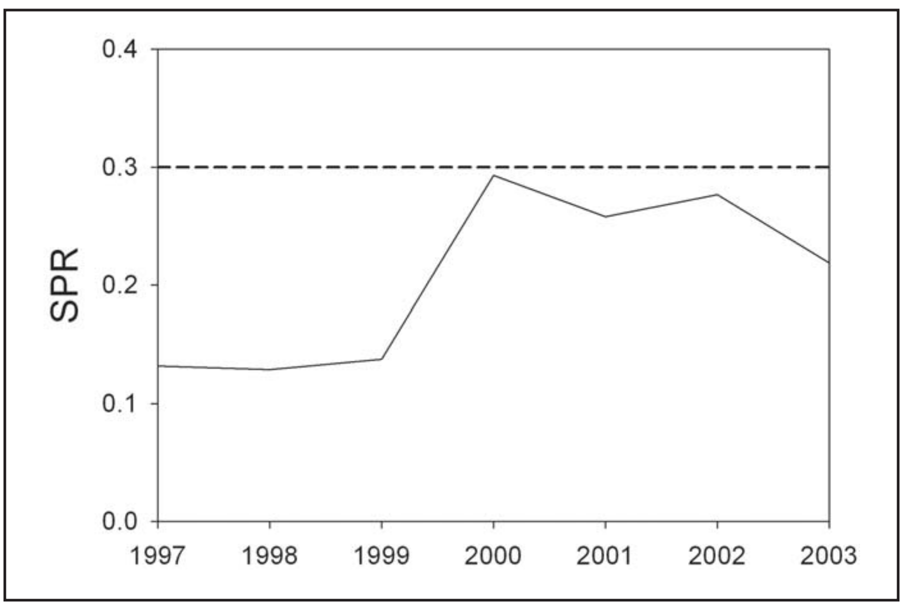


Figure 5. Spawning potential ratio (SPR) of the queen conch population at Glover's Reef, Belize. The point of overfishing is shown as 0.3 of the SPR (dashed line).



PRIORITIES FOR RECOVERY AND SUSTAINABILITY

The CITES Authority has requested assessments and management plans for queen conch from Belize and 12 other countries. Current problems with conch stock assessments discussed in a 1999 report included short catch-effort time series data and unreliable estimates of landings (CFMC 1999). Berg and Olsen (1989) showed that results of two MSY estimates for the Bahamas that differed by at least an order of magnitude.

A major problem is the legal standard for fishable conch based on shell length or meat weight set in 1978. Size at maturity in conch is highly variable, and the 17.8 cm SL size regulation provides for legal fishing of a substantial proportion of juveniles (Appeldoorn 1988). On average, almost 40% of the fishable conch population at Glover's Reef was immature. Equally ineffective is the alternative regulation for legal meat weight of 85 g. Estimated mean adult meat weight was twice this legal standard. Again, the regulation likely allows for legal fishing of juveniles. These results are consistent with previous studies (e.g., Gibson et al. 1983). The current practice of processing meat and discarding shells at sea facilitates transportation, but it makes limiting the catch to adults difficult to regulate. Currently, only Martinique and St. Vincent/Grenadines are reported to prohibit fishing of conch without flared shell lips (Chakalall and Cochrane 1997). Adaptive management options include requiring market delivery of conch in shells or substantially increasing the minimum size/weight regulation to encompass variability in maturity. Both options would decrease total landings initially but would likely increase yield per recruit (YPR) within a few years.

The Belize fishery closed season from July to September is based on early studies on the Florida conch population (D'Asaro

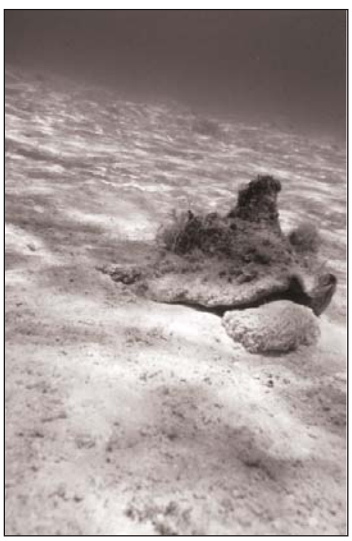
1965). The majority of spawning in most populations is concentrated in the summer months, but the breeding season in populations farther south in the Caribbean may be substantially longer, perhaps even year-round (see Stoner et al. 1992 for review). The actual breeding season at Glover's Reef is consistent with this latter pattern, extending from early May through late November. Reproductive output would likely increase with a longer closed season because adult conch may spawn multiple times during a breeding season. Additionally, an extended closure might allow more first-year breeders to reproduce (Gascoigne and Lipcius 2004), as opposed to the current fishery that imposes high mortality on older juveniles and first-year adults.

Overall density and biomass of conch at Glover's Reef have increased by nearly an order of magnitude, supporting predictions of a previous spatially-explicit population model for this particular reserve (Acosta 2002). Assuming that occasional poaching is not limiting the SPR to < 0.3, what increase in size of the no-fishing area would increase the SPR to a sustainable level? The predicted increase in conch abundance is approximately 50% if the no-fishing area is 31% of the total area (Acosta 2002), compared to the current 21%. This would potentially increase the SPR to well over 0.3 to compensate for current fishing levels. Studies in other Caribbean reserves showed similar increases in abundance (Stoner and Ray 1996; Béné and Tewfik 2003), whereas no population increases were apparent in others (Schweizer and Posada 2002; Torres and Sullivan-Sealy 2002). Differences in survey methods, length of time series, and the lack of information on enforcement and poaching are problematic for further comparisons.

Nevertheless, the theoretical foundation of the role of enforced no-take zones in fisheries management is well established (e.g., Guénette et al. 1998). For most sedentary species with high fishing mortality, no-take reserves with optimal configuration (size, shape, essential habitats) are expected to increase yield through increased reproduction and recruitment (Hastings and Botsford 1999). However, for the particular case of the Glover's Reef conch population, the protected area does not compensate for overfishing or depensation in the fished area. This may be due to any number of factors including insufficient habitat area under protection, insufficient self-recruitment, or poaching.

The response to the CITES notification by Belize fishery management was largely based on the reliance on eight marine reserves (several of which currently have little or no full-time enforcement) and the reported existence of a deep water stock of uncertain size (Anon. 2004). No changes in fishery regulations were proposed. In effect, future yield and sustainability of this conch fishery are based solely on the assumption that spawning stocks from these two sources will continue to supply adequate numbers of recruits to support current and future fishing levels. While there is a distinct possibility of self-recruitment within the Belize barrier reef ecosystem (Cowen et al. 2006), no reliable stock-recruitment models for queen conch have been developed.

Are stronger restrictions on Caribbean queen conch fisheries under CITES warranted? Closing export markets for conch would certainly impose significant economic hardships on the conch-producing countries (FAO 2004). In the case of Belize, this restriction would decrease their export fisheries market by more than 25%. The results reported here indicate that these stocks continue to be severely overcapitalized and that regional fishery management needs to be more adaptive to preclude CITES intervention. In addition to establishing and enforcing no-take reserves, immediate action can be taken to strengthen regulations to reduce juvenile fishing mortality and increase reproductive output.



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