Visual Assessment of Queen Conch (*Strombus gigas*) Stocks in the Turks and Caicos Islands: Cross-Checking Yield Estimates

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ABSTRACT

Once abundant throughout its' range, queen conch is currently threatened in many regions. In response to concerns that its' status is the result of overfishing, fisheries legislation has been enacted in many countries to help regulate harvest rates. To further ensure the sustainability of this important resource, queen conch was placed on Appendix II of the Convention on the International Trade of Endangered Species (CITES) in 1992. To satisfy CITES requirements, a modified version of the Schaefer model was used in the Turks and Caicos Islands during the 1993/1994 licensing year to model historical catch and effort data, estimate catch per unit effort (CPUE), and provide the basis for an annual Total Allowable Catch (TAC). However, since 1994 the model has consistently underestimated CPUE. To cross-check yield estimates derived from the modified Schaefer model, we conducted a visual assessment of queen conch stocks across the Caicos Bank. Surveys were carried out in traditionally fished areas using replicate belt transects at randomly selected sites. All queen conch encountered were enumerated and placed into size/age categories based on siphonal length and lip thickness. In total, 170 sites were surveyed between October 2000 and August 2001, and nearly 4000 queen conch enumerated. Our results indicate that the yield estimate derived using the modified Schaefer model is very close (i.e., within <1%) to those generated using the biomass estimate from our visual surveys, and within 10% of those estimated using the standard Schaefer and Fox surplus production models. As such, we conclude that the modified Schaefer model is producing reasonable yield estimates, but the catch and effort data need to be examined closely to determine why the model is underestimating CPUE.

KEY WORDS: Queen conch, visual assessment, maximum sustainable yield, Turks and Caicos Islands

Evaluación Visual de la Población del caracol (*Strombus gigas*) en las Islas Turcos y Caicos

RESUMEN

El caracol rosa, *Strombus gigas*, quien existiera en abundancia en todo su rango de distribución, se encuentra actualmente en peligro de extinción en muchas regiones. Como reacción a la preocupación de que este estado es a causa de la sobrepesca, se han desarrollado legislaciones pesqueras en muchos países para ayudar a regular la producción de caracol. Para poder asegurar la sostenibilidad de este importante recurso, la especie ha sido ubicada en el Apéndice II de la Convención Internacional para el Comercio de especies en peligro de extinción de la Flora y la Fauna Silvestre (CITES). Para satisfacer los requerimientos de esta Convención, se aplicó una versión modificada del Modelo de Schaefer en Turcos y Caicos en 1995 para modelar los datos históricos de captura y esfuerzo, estimar la captura por unidad de esfuerzo (c.p.u.e.) para el período 1996-2001, y aportar la base para determinar la Captura Total Permisible (TAC). Durante estos años, el modelo subestimó consistentemente la c.p.u.e., debido probablemente a que no tuvo en cuenta las capturas sin registrar destinadas al consumo doméstico. Con el objetivo de ofrecer un medio alterno para estimar la TAC, llevamos a cabo un censo de los stock de caracol en todo el Banco Caicos. Los ejemplares fueron evaluados visualmente en las áreas de pesca tradicionales usando transeptos rectos con réplica, en sitios seleccionados al azar. Los caracoles fueron contabilizados y colocados en categorías talla/edad, basándose en la longitud del sifón y grosor del labio. También fue caracterizado el habitat en cada transepto de acuerdo a la composición del sustrato. Se revisaron más de 200 localidades desde octubre del 2000 y se contabilizaron aproximadamente 3000 ejemplares. Se utilizarán estos resultados para validad los estimados del modelo y mejorar las técnicas actuales de evaluación del stock.

PALABRAS CLAVES: Caracol reina, *Strombus gigas*, Turks & Caicos

INTRODUCTION

Traditionally, queen conch (*Strombus gigas*) has supported local subsistence fisheries because they are relatively easy to catch and highly nutritious (Brownell and Stevely 1981, Nardi 1982). In the Turks and Caicos Islands (TCI), queen conch has been a dietary staple and the basis of a local commercial fishery for more than a century (Doran 1958, Sadler 1997). However, by the mid 1950s, rising economic value and increasing international demand encouraged an extensive commercial fishery to develop in the TCI.

Following a peak in the commercial harvest of queen conch in 1980 (ca. 1,150 MT), catch rates in the TCI began to decline, and it was hypothesized that this trend was the result of overfishing (Ninnes 1994). In an attempt to sustain local conch stocks, the TCI implemented a number of regulations including size restrictions (7" siphonal length or 8 oz meat weight), gear restrictions (e.g., SCUBA prohibited), a closed season for the commercial harvest (July 15 – October 15), and closed areas (e.g., East Harbour Lobster and Conch Reserve). In 1992, queen conch was also listed under Appendix II of the Convention on the International Trade of Endangered Species (CITES), in response to stock collapses and fishery closures in several areas throughout its' range (Mulliken 1996). Under the CITES agreement, signatory nations and countries that export queen conch to signatory nations, must report all international exports of queen conch and establish a management plan, such as annual export limits to avoid overharvesting. As such, an annual Total Allowable Catch (TAC) was instated in the TCI during the 1993/1994 licensing year to satisfy CITES requirements and help ensure the sustainability of local conch stocks.

To determine a TAC, the status of queen conch stocks was assessed in 1993 using a catch per unit effort (CPUE) time series going back to 1966. A modified version of the Schaefer (1954) model was filled to the time series data to estimate standing stock biomass and determine a TAC based on Maximum Sustainable Yield (MSY) (Medley and Ninnes 1999). However, since the TCI implemented the TAC in 1993/1994, the model has consistently underestimated CPUE (Caribbean Fisheries Management Council 1999), suggesting that it may not be accurately estimating the standing stock biomass. The objective of this study was therefore to conduct a visual assessment of queen conch stocks on the Caicos Bank to cross-check yield estimates derived from the modified Schaefer model with those generated using the standing stock biomass estimate from the visual surveys.

MATERIALS AND METHODS

Visual Stock Assessment

Historical landing records and surveys of TCI fishers indicated that most of the queen conch landed in the TCI are harvested from a fished area approximately 120,000 ha in size or about 1/6 of the Caicos Bank (Figure 1). Thus, we employed a stratified random sampling design that included only traditionally fished areas to conduct our visual assessment of the Bank.

Visual surveys were carried out from October 2000 to August 2001. Sites were randomly selected within fished areas using a remote sensing image (a Landsat 7 Thematic Mapper image) and Idrisi 32 (Clark Labs, Worcester, Massachusetts: USA). At each site, we ran three 3-m wide belt transects, for a total survey area of 90 m^2 per transect and 270 m^2 per site. Queen conch within the belt transects were enumerated and categorized by size/age based on siphonal length (SL), development of the shell lip, and the physical properties of the shell (Table 1). The abundance of queen conch in each size/age category was determined for each transect, and the mean abundance of each category calculated for each site. Mean abundances were then converted to densities (#/ ha) for each site.

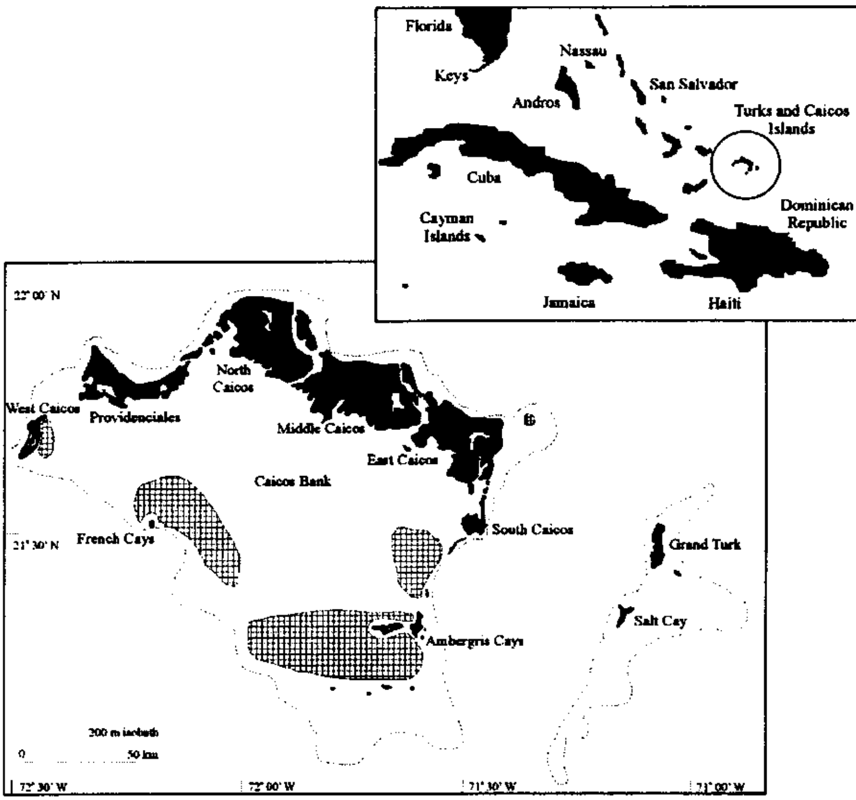

Figure 1. Location of the study area in the Turks and Caicos Islands. Hatched polygons are traditionally fished areas surveyed from October 2000 to August 2001.

Table 1. Size/age categories used during visual queen conch surveys on the Caicos Bank (from Tewfik and Béné 2000).

Category	Code	Description
Small Juvenile	SM	< 150 mm siphonal length, no shell lip
Medium Juvenile	ME	150 - 200 mm siphonal length, no shell lip
Large Juvenile	LG	> 200 mm siphonal length, no lip
Sub-adult	SA	Shell lip thickness < 4 mm
Young adult	YA	**Shell lip thickness > 4 mm, broad flaring shell lip, prominent spines, limited effects of bioerosion**
Old adult	OA	**Shell lip thickness >4 mm, worn, thick shell lip, worn spines, moderate to heavy effects of bioerosion**

Yield Estimates from Standing Stock Biomass

To estimate the standing stock biomass available for harvest, we determined the average landed meat weight of a total of 200 young (YA) and old adult (OA) conch collected from our surveys. The average meat weight was multiplied by the combined density estimate of young (YA) and old adult (OA) conch from our surveys to obtain a biomass per ha, which was then multiplied by the total fished area (120,000 ha) to obtain a standing stock biomass estimate.

Because we enumerated large juveniles (LG) and sub-adults (SA) as part of our visual surveys, we were also able to estimate the conch biomass available for exploitation the following year (i.e., recruitment yield). To do so, we determined the combined density of LG and SA in the fished area and employed this value in the following decay model:

$$N_2 = N_1 exp(-M(t_1-t_2))$$

where N_2 is the density at time t_2, N_1 is the density at time t_1, and M is natural mortality.

To determine yield estimate the standing stock biomass estimate obtained from the visual surveys was incorporated into the models presented by Garcia et al. (1989) as follows:

$$MSY_S = (BM)^2 / 2MB - Y_{avg}$$

$$MSY_F = MBexp((Y_{avg}/MB)-1)$$

where MSY_S and MSY_F are the maximum sustainable yields for the Schaefer and Fox versions of the model, respectively, B is the estimate of standing stock biomass, and M is the natural mortality rate. Since the TCI fishery is characterized by fluctuating landings, which may bias the yield estimate we replaced the current yield (Y_c) in both models with the mean landings for the past five years (Y_{avg}).

Yield Estimates from Surplus Production Models

Yield estimates were derived by fitting the standard Schaefer and Fox surplus production models to the CPUE time series using the linear catch-effort relationship as follows:

$$MSY_s = -a^2/(4b) \quad and \quad f_{msy} = -a/(2b)$$

$$MSY_f = -(1/d)exp(c-1) \quad and \quad f_{msy} = -1/d$$

where a and c are the slopes, and b and d are the intercepts of the regression lines (Garcia et al. 1989). We also determined a yield estimate by fitting the modified Schaefer model to the CPUE time series following the methodology of Medley and Ninnes (1999). In the modified Schaefer model, a variable recruitment index is used instead of a constant, intrinsic rate of increase (see Medley and Ninnes 1999 for additional details).

RESULTS

Standing Stock Biomass and Recruitment Yield

A total of 170 sites and about 4.6 ha of the Caicos Bank was surveyed during our visual assessment. The combined mean density of YA and OA from our surveys was 203 conch/ha, which using an average meat weight of 152 g per individual, produced a standing stock biomass of 3,703 MT available for harvest in traditionally fished areas on the Bank. In addition, based on a combined density of 87.5 conch/ha for LG and SA and a value of – 0.80 for $-M(t_1-t_2)$ within the region (A. Tewfik, pers. comm.), we estimated that 714 MT of conch would be recruited to the fishery next year.

Comparison of Yield Estimates

The yield estimates generated using the standing stock biomass estimate from the visual surveys and the models presented by Garcia et al. (1989) were 747 MT for the Schaefer formula and 743 MT for the Fox formula. The values for M used in the models were (M = 0.25) for the Schaefer model and (M = 0.23) for the Fox model. These values were chosen by determining which values produced yield estimates that equaled the yield estimate derived using the modified Schaefer model, since the Garcia et al. (1989) models we used assume that natural mortality is equal to fishing mortality.

From the CPUE data, the standard Schaefer and Fox surplus production models generated yield estimates of 822 MT and 802 MT, respectively. As in previous years, the modified Schaefer model fit the time series data reasonably well (Figure 2), however, the expected CPUE for 2000 was still below the observed CPUE (Figure 3). Nevertheless, the model produced a standing stock biomass estimate of 3941 MT with a yield estimate of 748 MT (Table 2).

CONCLUSIONS

The yield estimate derived using the modified Schaefer model is very close (i.e., within <1%) to those generated using the biomass estimate from our visual surveys, and within 10% of those estimated using the standard Schaefer and Fox surplus production models. In addition, the yield estimate from the modified Schaefer model was within 5% of the recruitment yield estimate using a decay model, while the standing stock biomass derived from the model was quite close (within 6%) to that estimated from our visual assessment. Taken together, these results suggest that the modified Schaefer model is doing a reasonable job estimating standing stock biomass and in turn, yield estimates that are the basis of the TAC in the TCI. Our results also suggest that differences between predicted and observed CPUE are more likely related to the way catch or effort are measured, rather than a problem with the modified Schaefer model. For instance, catches destined for local consumption are not accounted for which could result in the under- or overestimation of CPUE depending on trends in local consumption. Moreover, effort measured in boat days does not account for changes in the type of boat used or the number of fishers harvesting conch in each boat. As such, a more precise estimate of catch and effort could further improve the predictive power of the modified Schaefer model, and contribute to the continued sustainable harvest of queen conch in the TCI.

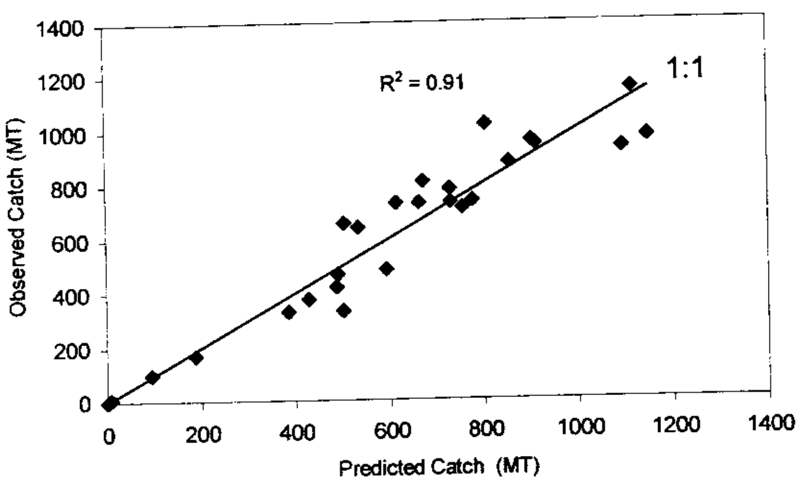

Figure 2. Relationship between observed catch and that predicted by the modified Schaefer model ($R^2 = 0.91$) from 1974 - 2000.

Table 2. Parameter estimates and 95% confidence intervals for the modified (variable-r) Schaefer model (see Medley and Ninnes 1999). Note: K = carrying capacity, r = fitted parameter multiplied by the average recruitment index, q = catchability, MSY = maximum sustainable yield, f_{msy} = effort at MSY, and F_{msy} = fishing mortality at MSY.

Estimate	Parameters	95 % Confidence Interval	
K (MT)	7187.19	6517.79	8062.16
r (year^{-1})	0.42	0.35	0.49
q (boat day^{-1})	4.31 X 10^{-05}	4.04 X 10^{-05}	4.48 X 10^{-05}
MSY (MT)	747.57	714.43	805.33
f_{msy} (boat days)	4828	4144	5787
F_{msy} (year^{-1})	0.23	0.18	0.30

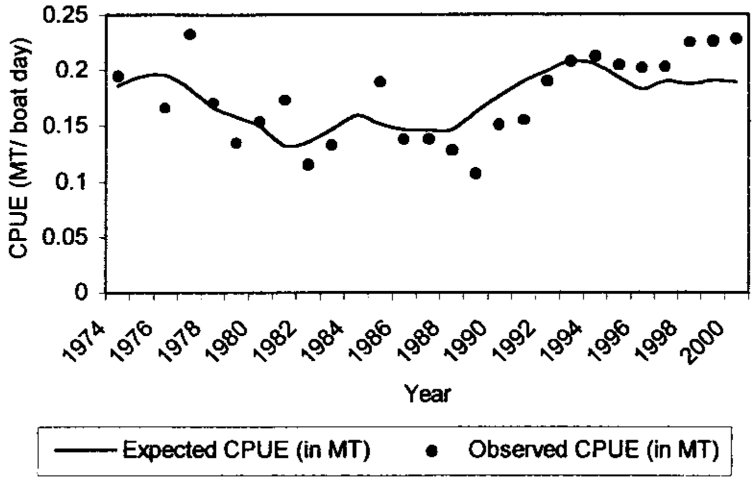

Figure 3. Observed CPUE (closed circles) versus that predicted by the modified Schaefer model (solid line) for 1974 - 2000.

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