Conceptual Framework for Estimating Annual Quotas in Mexican Conch (Strombus gigas) Fisheries

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ABSTRACT

Catch records of the queen conch (Strombus gigas L) caught at three areas of south eastern Mexico (Alacran Reef, Cozumel and Chinchorro Bank) were examined under the context of pseudo-cohort analysis and an age structured simulation model. The goal of the study was to assess the queen conch stock in each exploitation zone. Queen conch densities, and population parameter values were compiled from published sources in order to apply the analytical methods mentioned above. Estimations of the stock biomass, current fishing mortality (F) and F at the maximum sustainable yield (FMSY) as extreme reference point, were made; this allowed to test the F and age of first catch required for the maximum biological yield, the maximum economic yield and the maximum social benefit as optimum harvesting strategies. Recommendations for the queen conch recovery and sustainable exploitation are provided.

KEY WORDS: Queen conch, stock assessment, bio-economic simulation, south eastern Mexico

INTRODUCTION

Queen conch stock is one of the most valuable fisheries resources of the Caribbean coral reefs. Unfortunately, it has been overfished throughout most of its distribution range and the stocks have usually been severely overexploited and in some cases the fishery has been pushed to local extinction as economic activity. Therefore, the goal of this paper is to analyze existing information available and to propose maximum allowable yields to restore or to avoid stock collapse of Mexican fisheries.

BACKGROUND

A workshop was held at Isla San Andrés, Colombia in November 2005, sponsored by the GCFI, was addressed to building a scientific consensus on regional queen conch management strategies; the main tasks assigned correspond to:

i) Compile queen conch morphometric relationships,
ii) Propose regional indices to follow-up possible trends in conch abundance, and
iii) To expand conceptual frameworks to estimate...
annual quotas based upon standing stock estimations, dynamic production models, age structured assessment, or use of FAO’s precautionary approach when no data are available.

Some of these accomplished tasks include information which is basic to carry on further stock assessments:

Population parameters — Information contained in the queen conch book edited by Appeldoorn and Rodríguez (1994) was compiled. Mean parameter values of the weight-length relationship and the operculum length-shell length (in cm and g) are the following:

Weight (W) - Length (L)

\[ W = a \times L^b \]

\[ a = 0.0167; \quad b = 2.93 \]

(Modified after Appeldoorn, 1994)

Operculum Length (OL) - Shell length (SL)

\[ OL = a + b \times SL \]

\[ a = -7.4; \quad b = 0.37 \]

(Herrera et al. 1994)

Operculum Width (OW) – Shell length (SL)

\[ OW = a + b \times SL \]

\[ a = -1.0; \quad b = 0.09 \]

(Herrera et al. 1994)

Mean values of the growth parameter values and natural mortality (M) recorded by several authors (Chávez and Arreguín-Sánchez 1994, Rathier, and Battaglia 1994, Jensen 1996, 1997) were used to obtain a mean value, which was used to analyze the stock dynamics. Total length and meat weight are the variables used for reference; length ranges from 20.7 to 38.9 cm and meat weight from 119 to 724 g. Mean natural mortality value \( M = 0.605 \), \( W_{\text{meat}} = 356 \) g and growth parameter \( K = 0.4146 \). These values were used to reconstruct age structure on fitting the FISMO simulation model (Chávez 2005).

TRENDS IN CONCH ABUNDANCE

Records of conch density from various sources and localities around the Caribbean were compiled from several sources, and graphically shown in Figure 1. There, it is evident that in ten out of the sixteen countries exploiting queen conch, densities are so low that are not enough to replace the stocks, where densities with 56 conchs per hectare are indicated by a horizontal line, showing the no-mating minimum densities found by Stoner and Ray-Culp (2000). Therefore, careful management practices should be applied there in order to allow restoration of the stocks and the fisheries in Bahamas, Virgin Islands, St. John, St. Thomas, Puerto Rico, St. Croix, Bermuda, Chinchorro Bank (Mexico), and Florida. Surveys recording queen conch densities have been made elsewhere in recent years; however, data included in Figure 1 give a general idea of the regional situation in the Caribbean. It is important to bear in mind that the over exploitation may change the picture, some times in very short time, as evidenced by Cozumel, which in Figure 1 appears as the most healthy stock; however, the intensity of exploitation lead to Mexican authorities to establish a ban to its capture, which has been applied for several years now.

According to the findings by Lugo-Fernández et al. 2001, Sale (2004), Delgado et al. (2005), and Thorrold SR (2006), there is diffuse drift of larval stages from the western Caribbean supplying the north western Caribbean, the Gulf of Mexico and the coasts of Florida (Chávez-Hidalgo et al. 2009); by analogy, it is expected that the east Caribbean stocks may play a similar role supplying the western Caribbean reef areas, otherwise dramatic extinctions in some low-density areas would have already occurred, but it is not the case.

Figure 1. Queen conch stock densities recorded at several localities of the Caribbean, showing densities ranked in order of abundance. The dotted line indicates the no-mating minimum density (56/hec.) recorded by Stoner and Ray-Culp (2000). Based on data compiled directly or from other authors (Alcolado 1976, Berg 1976, Weil and Laughlin 1984, Botero 1984, Ferrer and Hernández 1989, Chávez and Arreguín-Sánchez 1994, Friedlander et al. 1994, Glazer and Berg 1994, Rodríguez-Gil 1994, and Basurto et al. 2005), with modifications.

THE QUEEN CONCH IN MEXICO

In three areas in south eastern Mexico the queen conch fisheries have been established for long time, but over exploitation has forced the government to ban two of them. This paper examines the case of the stocks of Alacran reef (Figure 2a), Cozumel (Figure 2b) and Chinchorro Bank (Figure 2c).
biomass in each of the three places where there is a fishery or there was one before its closeness, in order to provide recommendations to advise on the optimum harvesting strategies to apply in each place; the first one Alacran reef, is on the northern Campeche Bank, and the other two, Cozumel and Chinchorro Bank, are on the Caribbean coast of Mexico.

**Alacran Reef**

Here, the catch was as high as 306 tons in 1979, decreasing to 10 tons in 1987 with a slight increase to 51 tons in 1990. The fishery was closed in 1994 (Rodríguez-Gil 1994) and it has been banned until present time. There are opinions stating that the stock is recovered, but unfortunately, poaching has been taking place in recent times and density surveys are too few to determine the stock biomass and the possibility of assigning allowable quotas.

A reconstruction of the fishery was made by applying a simulation model where a reference was made to the exploitation rate $E$ at the MSY level ($E_{MSY} = F_{MSY}/Z$) or limit reference point, as shown in Figure 3; in this figure, it is evident that in the last three years of catch records, the over exploitation exceeds the $E_{MSY}$ leading to an exhausted stock.

In the queen conch exploited at Alacran reef, catch records available (Figure 3) range from 1970 to 1986 with 50 and 51 tons respectively; catch reached a maximum of 306 tons in 1979 declining abruptly with a few temporary recoveries between 1979 and 1982 (Rodríguez-Gil 1994). Local authorities closed the fishery permanently since 1986.

According to our own evidence, the apparent recovery of the stock over time lead to the increase of an illegal fishery that has becoming a social problem and the fishing authorities have been coping with pressure by the fishermen claiming to open the fishery again as a mean to control poaching.

The use of the pseudo cohort analysis seems to be quite convenient when fishing effort data are absent, and estimations of conch density are a suitable option instead. Hence, a pseudo cohort analysis (Gulland 1983) was carried on and it was applied to the years when there are catch data available (1976 to 1990); the same method was applied to the conch stock of Martinique by Rathier and Battaglya (1994) and as they mention, it is based on the same two equations as cohort analysis, but different from these authors, age was used here instead lengths. Time units are years and the age of first catch used in these analyses is three years, corresponding to a total length of 21 cm. The catch number per age group in a given year is estimated using the age-length key, the growth parameters and the length-weight relationship. Thereafter, population abundance at each age is estimated using the catch equation. This method was applied to each year of catch data and results were integrated in Figure 4, showing that...
the MSY corresponds to the catch of 1981 and in 1987 the stock was fully collapsed. An extension of the use of the pseudo-cohort analysis, where estimates of the MSY expressed as fresh weight as well as meat weight under a wide series of conch densities is shown in Figure 6. It is hoped that this approach may serve as a basis for its application in other grounds where the queen conch is exploited. Here the MSY is not intended to be adopted as a target for the fishery; in an effort to ensure that many fisheries may be depleted as consequence of over exploitation; in recent literature, recommendations to adopt the criterion of 0.75FMSY, are more frequently seen.

Cozumel

In this island, the fishery took place on the northern shelf of the bank, where it has an extension big enough to hold a significant amount of conch to sustain the fishery (Figures 2b, 5a). Samplings carried-on by the Fisheries Institute of Mexico display a declining tendency, ranging from 0.0822 (conchs/m²) in 1995 to 0.0051 in 2005. Despite the high variability shown by the data, it is evident that a control of the access was required to avoid a collapse of the stock, which apparently occurred after 2005, leading to a closure of the fishery. Unfortunately, no catch data were available of this fishery and therefore it was not possible to carry-on an updated assessment of the stock to derive specific recommendations for its queen conch fishery management.

Chinchorro Bank

Catch data show a decline in densities, from 0.157 (conchs/m²) in 1989 to near zero ten years later and an apparent recovery in the last five years of the series (Figure 5b); however, the report by Basurto et al. (2005) does not explain why samplings made in the nineties covered all the lagoon reef in an area bigger than 300 km² and during the last five years they have been constrained the surveys to the reef edge in an area of only 25.1 km². This omission implies huge differences in stock size, being nearly tenfold larger in the nineties as compared to the current decade, where the over exploitation collapsed the population in the lagoon, limiting its distribution to the reef edge only, where a small stock persists in depths where free divers are not able to reach.

STOCK ABUNDANCE

On the basis of the reef areas of Alacran (Figure 2a), Cozumel (Figure 2b) and Chinchorro Bank (Figure 2c), stock sizes were inferred. Stock assessment was conducted based on historical catch records, population parameters, and the reef area, and the application of the pseudo-cohort analysis and with a simulation model (Chávez 2005). The latter reconstructs the age structure (for a detailed description of the method the reader should refer to the paper cited above and also in the paper by Chávez and Ley-Cooper (this volume). The FMSY value at an age of first catch of tc = 0.2 found was F = 0.2, the year when the maximum catch was recorded at the reef.

Parameter values are indicated above. The expression Maximum Sustainable Yield (MSY) is used here as the extreme reference point, not as a target of the fishery. References to stock density were used at each reef by considering that the reef size is constant, so catch records, when available, can be considered a good indication of stock density; as an example of the potential yield expressed as fresh and as meat volumes, Figure 6 was prepared, showing the relationship of maximum yield as a function of conch density. It is hoped that it can be used as a quick reference to other queen conch stocks along the Caribbean.

ASSESSMENTS USING AGE STRUCTURE

Records of Alacran reef include 17 years of catch data; no effort data are available. Therefore, application of the FISMO simulation model (Chávez 2005) suggests that the MSY level is 225 tons and obtained with the fishing effort applied in 1979 (Figure 3). A full knowledge of queen conch stock dynamics and other important processes ruling its dynamics may still be far from being reached. However, on the basis of data compiled from the literature, enough information is known nowadays to be able to assess the queen conch stocks to a level where it can be much more accurate than just a rough approach (Figure 7a, b). When costs and benefits of the activity are available, another optional target for managing the stock can be the maximum

![Figure 3. Catch records of queen conch of Alacran reef. Maximum potential yield evaluated with the aid of the FISMO simulation model (Chávez, 2005) corresponds to a catch of 225 tons. Horizontal dotted line indicates the exploitation rate (F/Z) at the maximum yield (FMSY/Z), or threshold of over exploitation. The thinner dotted line shows the exploitation rate estimated each year; therefore, each time this line is above the value defined by the FMSY/Z, is interpreted as a condition of an over exploited stock (after Beaver and Chávez 2007).](image-url)
economic yield ($F_{MEY}$), because implies the convenient option of exploiting the stocks below the limit attained at the $F_{MSY}$ and ensuring this way that fisheries being sustainable. In this regard, it may be considered that management regulation should impose quotas based on minimum densities as a reference, rather than quotas based on yields.

However, on the basis of the widespread areas occupied by the conch, many of them not accessible to fishers, there are many places beyond the fishing grounds, where the queen conch may find suitable conditions for reproduction, and this way the connectivity plays its role spreading offspring and replacing the stock in areas where conchs have been overexploited by fishermen. In order to protect the adult stock and to ensure that breeding zones remain inaccessible to fishers, conch exploitation in all the Caribbean should be made only by free diving.

By making reference to the Chinchorro Bank fishery, it is worth mentioning that the queen conch stock occupied all the lagoon area years ago, which is nearly eight times larger than the current edge of the Bank, where the samplings have been recently made. If the stock is allowed to be restored, then all the variables represented in Figure 7 A, B, could be multiplied by 12 and then is easy to perceive that in theory, the stock could allow the exploitation of nearly 60 tones, and the socio-economic benefits could sustain a much larger number of fishers that would significantly improve their living standards.

**CONCLUDING REMARKS**

Three conditions must be fulfilled in order to avoid further stock depletions, one, is not to lose control on the catch; banning has been an inconvenient at Alacran reef because it has stimulated illegal catch (Rodríguez-Gil Pers. comm.), especially through the last few years, when the stock apparently reached exploitable densities; the same process may occur in Cozumel. The second condition is to assess the stocks every year and to provide advice to fishing authorities before opening each fishing season so applying the principles of adaptive management. Finally, the third requirement is to carry-on capacity building; the San Andrés workshop gave a clear example in the sense that some scientific authorities are capable to do quite accurate assessments of the queen conch stocks, but the fishermen and some representatives of the fishing industry clearly showed that the fishing authorities lack of good advice so they may not be applying their management procedures on an informed basis and an evident misinformation on several avenues avoids the application of good management procedures, such that stocks do not fulfill the warranty of being exploited in a sustainable way.
Figure 6. Estimations of the queen conch potential yield based on the use of the pseudo-cohort analysis using as reference different densities. Yield is estimated in relation to the area of Alacran reef, with 26,400 Hectares, but it can be easily inferred to other areas by making reference to the reef area occupied by each stock.

Figure 7a. (left) Potential maximum biological yield ($Y_{MSY}$), as a function of the age of first catch and the fishing mortality at Chinchorro Bank. According to the last fifteen years of simulation, the Maximum Yield (7.5 tons) can be obtained at a fishing pressure of $F = 0.3$ and $tc = 3$ years old. This scenario would provide profits in a maximum of $110,000$ USD. However, the MEY would be obtained by reducing $F$ at $F_{MEY} = 0.25$ with nearly the same profits; here, the yield would also be the same as the one obtained under $Y_{MSY}$. Figure 7b. (right) Potential maximum economic indicators (B/C, number of fishers and number of boats) as a function of the age of first catch ($tc = 3$ years old) and the fishing mortality, which is different for each variable.
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LITERATURE CITED


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