Auto-ecology of the Queen Conch (*Strombus gigas* L. 1758) at Cabo Cruz, Eastern Cuba: Management and Sustainable Use Implications

Auto-ecología del Caracol Rosado (*Strombus gigas* L. 1758) en Cabo Cruz, Este de Cuba: Implicaciones para su Manejo y Uso Sostenible

Auto-écologie de Lambi (*Strombus gigas* L. 1758) à Cabo Cruz, à l’Est de Cuba: Implication pour la Gestion et l’Utilisation Durable

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ABSTRACT

In order to know the density and the population structure data at the Cabo Cruz were obtained that included three climatic periods (rainy, dry and cold front periods) at three zones: Farito, Guafe and Laguna, during 2010. Population density varied from 0.0247 ind/m² at Guafe in the rainy period, to 0.1767 ind/m² at Farito in the dry one. The highest density was detected at dry season (0.1395 ind/m²) and the lowest in the rainy one (0.0647 ind/m²). The siphonal length (SL) and the lip thickness (LT) of 1836 conchs were measured; the SL varied from 87 to 286 mm. An analysis of LT showed that 72.93 % of conchs had a completely formed lip, but they measured less than 200 mm SL, the minimal allowed fishing size in Cuba. Apparently, the conch population at Cabo Cruz is constituted by small conchs, with a gradual increase in weight and lip thickness, turning them into "dwarf" conchs. This fact was possibly density-dependent. Results are compared with data obtained at Banco Chinchorro, Mexico. We propose some alternative with precautionary focus to be included at the new revision of the Desembarco del Granma management plan, focused to conch and its sustainable use.

KEY WORDS: Cabo Cruz, Cobo, Cuba, distance sampling, population structure, *Strombus gigas*

INTRODUCTION

Queen conch (*Strombus gigas* Linneo 1758); is one of the most valuable fishing resource in the Caribbean Sea (de Jesús-Navarrete y Oliva-Rivera 1997). This is a mollusk with a lofty and esthetic and ecological value and it is widely distributed in the Caribbean: from south of Florida to Brazil (Abbott 1974). During the years, conch represented the second benthic fishery in economic importance in the Caribbean, only surpassed by the spiny lobster (*Panulirus argus* Latreille, 1804); even today it is a very important fishing resource for the region (Appeldoorn 1994, Theile 2001, Brito-Manzano et al. 2006).

At the regional level, a decrease of abundance and availability of this resource caused fundamentally by over-exploitation and habitat destruction has been recognized, and for that reason, queen conch has been included in the appendix II of the list of commercially threatened species (CITES) since 1992 (Stoner et al. 1992, Stoner et al. 1996, Glazer and Kidney 2004).

Although there are many studies on Strombus species in the Caribbean Sea, covering themes as biology and ecology and almost all conchs’ ontogenetic stages (Randall 1964, Appeldoorn 1990, Glazer and Berg 1992, Stoner et al. 1996, Basurto et al. 2005, Jared et al. 2006), the information related to Cuba is very scarce. For Cabo Cruz at the oriental region, the first conch research was conducted by Alcolado (1976) who studied the growth and shell morphologic variations among other biological aspects and also Quezada (2004) (Flora and fauna Conservation Enterprise of Cuba, Unpublished data) made the other conch population assessment in the Desembarco del Granma National Park. Afterwards, some evaluations with commercial purposes of conch exploitation were carried out (Formoso et al. 2001, Álvarez-Lemus y Formoso 2005).

The objective of this work was to determine the conch population density, distribution and structure, as well as shell size distribution and shell length-lip thickness relationships at the National Park Desembarco del Granma, in order to assess its management effectiveness and to determine the potential use of this fishery resource.

MATERIALS AND METHODS

Study Area

Cabo Cruz is located at the southeastern region of Cuba (19°50'14.1"N and 77°44'15.7"W) where the protected area Desembarco del Granma National Park occupies 32 576 ha (Figure 1). The sampling area was established within the reef lagoon, where the sandy bottom includes seagrass bed patches (*Thalassia testudinum* and *Syringodium filiforme*) and some
algae (Penicillus sp., Dyctiota sp., and Ceramium sp.) (Alcolado 1976). Sometimes certain turbidity associated to terrestrial drainage can be observed in the lagoon, but clear water conditions predominate. According to Alcolado (1976) this should be due to a great water exchange with the open sea. Lagoon depth varies from 0 to 6.0 m.

The study area was divided into three zones from East to West: Guafe, Farito, and Laguna. Three stations were sampled in each one.

**Sampling**

Three 100 x 4 m (400 m²) transects were sampled at each station. Transect length was measured with a graduated tape. To measure the perpendicular distance of each conch to the transect we used 1 m length PVC pipes. To evaluate conch population density, we used the Distance Sampling software, considering the perpendicular distance, using the cosine function and the normal expansion series (Buckland et al. 1993). The total density was the sum of the densities evaluated in each zone. Samplings included the main seasonal variations: rainy (March-June), dry (November-February) and cold front (July-October) periods (de Jesús-Navarrete et al. 1999).

At each station, the salinity of water column was measured with a precision of 0.1, using the portable refractometer RF20 model and the Practical Salinity scale. At each zone, a data logger HOBO (temperature & light) was programmed to take readings of temperature and light intensity each 30 minutes. The daily average of obtained data yielded the monthly average value of temperature registered.

The conchs were collected at each transect by free diving. All conchs within the transect area were collected. In the boat, the SL and LT were registered with a caliper with a precision of 0.1 mm. The organisms were separated in size class taking into consideration that the minimal allowable capture size in Cuba is 200 mm (SL) (Álvarez-Lemus and Formoso 2005). The utilized class sizes were: 0 (< 100 mm), I (100.1 - 150 mm), II (150.1 - 200 mm), and adults (> 200.1 mm). A parallel analysis was carried out using the LT and mature conchs were classified into three groups: Lip < 2 mm; 2.1 < lip > 5 mm and lip > 5 mm.

**Data Analysis**

The relation Variance/Average was used to determine the distribution type of the individuals according to the Poisson index (random: VMR = 1.0, aggregate: VMR > 1, uniform: VMR ≤ 1).

In order to compare the population density among zone and season, a bi-factorial Analysis of Variance (ANOVA) was used. Values of salinity and temperature were compared both spatially and temporally with a uni-factorial ANOVA, and the relationships between Biotic and abiotic factors were estimated with lineal regression analysis. In order to accomplish with homoscedasticity requirements, all data were transformed to log (x+1).

ANOVA results were followed by Scheffé test to achieve comparisons a posteriori. The correlation between LS and LT was calculated using the coefficient of determination ($r^2$). The statistical differences were considered with a 95% significance level (Zar 1999).

**RESULTS**

**Abiotic Variables**

The average water temperature was $28.8 \pm 1.8^\circ$C. A maximum of $30.82 \pm 0.26^\circ$C in rain season (August) and a minimum $26.00 \pm 1.26^\circ$C in cold fronts (December) were observed (Figure 2). Statistically significant differences among monthly temperatures were found ($p = 0.00$).

Salinity did not display substantial variations. The highest value occurred in the cold front period (35.4 ± 0.6 UPS) while the minimal one was registered in the rainy season (32.4 ± 0.98 UPS). No significant differences in salinity were detected neither among sites ($p = 0.298$), nor among stations ($p = 0.054$).

**Figure 2.** Monthly variation of water temperature at Cabo Cruz, Cuba.
Density

The conch distribution type in the study area was aggregated, both for all sampling sites and seasons. Density varied from 0.0247 ind/m$^2$ at Guafe in the rainy season to 0.1767 ind/m$^2$ at Farito in the dry season. The highest density registered during the sampling period occurred in the dry season (0.1395 ind/m$^2$), whereas the minimal value was in the rainy season (0.0647 ind/m$^2$). Spatially, Farito presented the highest density (0.1723, ind/m$^2$) while the minimal one was at Guafe (0.0511 ind/m$^2$) (Figure 3).

A total of 1,836 conchs were measured during the study period. The SL varied from 87 to 276 mm. Adults with SL higher than 200 mm constituted the 12.69 % of the sample, while sizes among 150 and 200 mm predominated (67.86%). The size frequency polygon showed a standard of 175.5 ± 26.4 mm (Figure 5).

We found a strong relationship between the temperatures behavior and the densities found at Cabo Cruz (r = 0.847306). This result has been documented for several papers at the Caribbean Sea (de Jesus-Navarrete and Valencia-Beltran 2003).

The analysis of variance evidenced that significant differences as individuals number for transect among sites, however it kept constant to crosswise of seasons (Table 1). The Scheffé test did not show significant differences of density between Farito and Laguna. However Guafe showed significant differences in comparison to Farito and Laguna (Figure 4).

**Table 1.** The ANOVA results by Zone and Season in Cabo Cruz.

<table>
<thead>
<tr>
<th>Variation Source</th>
<th>Sum of squares</th>
<th>Degrees of freedom</th>
<th>Squares means</th>
<th>F</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zone</td>
<td>17914.30</td>
<td>2</td>
<td>8957.15</td>
<td>19,2998</td>
<td><strong>0.0000</strong></td>
</tr>
<tr>
<td>Season</td>
<td>1706.96</td>
<td>2</td>
<td>853.48</td>
<td>1,8390</td>
<td>0.1664</td>
</tr>
<tr>
<td>Zone x Season</td>
<td>627.41</td>
<td>4</td>
<td>156.85</td>
<td>0.3380</td>
<td>0.8515</td>
</tr>
<tr>
<td>Error</td>
<td>33415.56</td>
<td>72</td>
<td>464.10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The size class distribution by site and season is given in Figure 6, where a predominance of the class II at all the seasons and zone was observed. It is very clear that there was a dominance of small individuals (87.31%, n = 1603).

An analysis of the relationship LS versus LT for the study area showed than some conchs had a completely formed lip but without having attained the length of 200 mm (Figure 7, Table 2).

**DISCUSSION**

**Density**

The study area is a reef lagoon protected from currents and waves of the open ocean by a reef crest 3 km long and 0 - 6 m deep, providing great stability to bottom sediments. The reef lagoon has an efficient water renewal with the ocean, and presents abundant patches of the seagrass *Thalassia testudinum* and of delicate turf algae on a sandy bottom. According to Alcolado (1976), these characteristics promote a favorable environment to conch development, so that it functions as a nursery area.

These environmental conditions and the legal protection of the park propitiate relatively high conch densities in the sampling zones. Farito had the highest density (0.1723 ind/m²) with a big proportion of adults (71.11%) with lip formed. At Farito there is a communication channel with the ocean, and this probably enables the access of adults during the reproductive season. This process has been well documented for the species (Laughlin and Weil 1985, Díaz-Avalos 1991, de Jesús-Navarrete et al. 1992, Domínguez-Viveros et al. 1999).

Laguna showed a very similar density to Farito (0.1271 ind/m²), and its bottom has sandy patches of *T. testudinum* as in Farito. It is possible that when adult conchs get into the reef lagoon they move to quieter sites as Laguna, where they find better conditions for reproductive activities.
Even when in this study we did not evaluate quantitatively the differences between the substrates, apparently the fact that in Farito the bottom is completely covered with a considerable density *T. testudinum*, could enable a high conch abundance in this site, and it is probably related to the existence of more available food for adults (Alcolado 1976, Stoner and Waite 1990, Sandt and Stoner 1993, de Jesús-Navarrete et al. 2003).

The lowest density was registered at Guafe (0.0511 ind/m²), which could be due to certain urban influence affecting conch distribution through some waste waters from Cabo Cruz town reaching the lagoon (Cala et al. 2005). This results in higher turbidity and sedimentation. We observed that conchs at Guafe were covered with a thin slime layer.

The total density reported for Cabo Cruz in this study (0.1108 ind/m²) was higher than Alcolado (1976) for the study area (0.0750 ind/m²). Also, it was considerably higher than in Pedro Bank in Jamaica (0.0513 ind/m²) (CITES 2003) and other sites in natural reserves in the Caribbean Sea (Table 3). Given, the relatively high conch population density, the National Park Desembarco del Granma can be considered an important reserve contributing to the down current larvae supply and recruitment.

The Population Structure According to Size

Conch size frequency reveals that population is mainly composed by juveniles (< 200 mm LS). However, many conchs had thick lips at only 150 mm siphonal length (Figure 7), even there were very small ones (e.g., LS < 100 mm) with very thick lips (e.g., GL > 7 mm). If we took the lip thickness as an indicator of sexual maturity, this case would indicate a smaller size for reproductive maturity. This implies that size is not enough to determine whether a conch is juvenile or adult. The presence of a well developed lip is the appropriate criterion for differentiating adult conchs. Conchs grow until getting sexually mature, after which only add material for the lip enlargement (Appeldoorn 1988, de Jesús-Navarrete et al. 1997). Those conchs with thick lips but small sizes have been reported in the Caribbean, and they are considered as dwarves or “samba” conch (Mitton et al. 1989, Clerveaux et al. 2005).

In Chinchorro Bank, Mexico, this effect was attributed to a fishing effect, produced by an artificial selection, fisherman take out the biggest conchs, because they represent more meat per conch. This affects the population because leads to smaller growth rates, with a detriment to long term of the biomass and the economic consequences. In general female conchs are a little bigger than males (Alcolado 1976, de Jesús-Navarrete 1997), if fishermen collect the highest sizes, then in a rather short time, the population can diminish its regular length and density, affecting the population size structure and at a critical point it could affect the reproductive encounter probability leading to an *Allee* effect (de Jesús-Navarrete 1997). But, what is happening in a non-exploited conch population with high density like Cabo Cruz?

Probably, the favorable biotic characteristics of the study area, like abundant seagrass and algae in the bottom, produce high food availability for conchs, and for this reason there are high abundances in the sampling area. It is possible that an increase in density coorelates to an individual competition for food, and they become dwarved conchs compared to other distribution areas of the species. This effect has been mentioned as “organism saturation” where conchs do not increase their length, but their weight, including a shell thickness (Bené and Tewfik 2003). The density-dependence has been perhaps the regulating mechanism within the population, comparatively; the population is of greater density than other populations were reported at the Caribbean Sea. Clearly, this hypothesis is difficult to prove with our data, but it suggests the necessity for more research on this issue in Cabo Cruz;

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**Table 3.** Queen Conch densities reported for several places in the Wider Caribbean.

<table>
<thead>
<tr>
<th>Location</th>
<th>Density ind/m²</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Caribe Colombiano</td>
<td>0.0004</td>
<td>Gomez-Campos et al. 2005</td>
</tr>
<tr>
<td>Chinchorro Bank, Mexico</td>
<td>0.0697</td>
<td>Basurto et al. 2005</td>
</tr>
<tr>
<td>Chinchorro Bank, Mexico</td>
<td>0.006</td>
<td>de Jesús-Navarrete et al. 2003</td>
</tr>
<tr>
<td>Punta Gavilán, Mexico</td>
<td>0.0052</td>
<td>de Jesús-Navarrete and Oliva-Rivera 1997</td>
</tr>
<tr>
<td>Florida Keys</td>
<td>0.047</td>
<td>Glazer and Anderson 1995</td>
</tr>
<tr>
<td>Puerto Rico</td>
<td>0.00081</td>
<td>Torres-Rosado 1987</td>
</tr>
<tr>
<td>Los Roques (Venezuela)</td>
<td>0.00016 (Ext. Zone)</td>
<td>Weil y Laughling 1984</td>
</tr>
<tr>
<td></td>
<td>0.00018 (Prot. Zone)</td>
<td></td>
</tr>
<tr>
<td>Turk and Caicos</td>
<td>0.0948</td>
<td>Hesse 1979</td>
</tr>
<tr>
<td>Cuba (Cabo Cruz)</td>
<td>0.075</td>
<td>Alcolado 1976</td>
</tr>
<tr>
<td>Jamaica</td>
<td>0.0513</td>
<td>CITES 2003</td>
</tr>
<tr>
<td>This Study</td>
<td>0.1108</td>
<td></td>
</tr>
</tbody>
</table>
The functional zonification of the area (to protect the reproductive stock; to guarantee the recruitment by generating more protection within areas with favorable environmental characteristics for the juvenile development, and finally; the implementation of a limited conch fishing zone to exploit the resource)

ii) The catch quote (according to the result of this study, 180 mm of siphonal length is adequate, considering the previous gonad study for demonstrating the sexual mature of the small conch) and,

iii) The prohibited use of the scuba dive for the conch fisheries

The second strategy must include directly:

i) The monitoring of the conch population in order to assessment of the important change at time; and finally,

ii) The monitoring of the habitat changes and Physical parameters.

We are considering, if necessary, to join together efforts to get to the Equilibrium model between over-protection and over-exploitation by the protected areas and fishing area respectively; that is: between the “dwarf” conch and the Allee effect, in order to accomplish the sustainable use of the resource.

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LITERATURE CITED


