# The Study of the Populations of the Queen Conch (*Strombus gigas*) with Fisheries Management Implications in the Different Areas of the Archipielago of San Andrés and Providencia, Colombia

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ABSTRACT

This paper is a partial presentation of the results of a research program on the biology and fisheries of the queen conch (*Strombus gigas*) developed by INDERENA Colombia on San Andrés Islands during 1987 – 1988 with the collaboration of the Universidad del Valle and the Armada Nacional. The main objective was to benefit small-scale fishermen of the islands.

Information is included about the biology (ecology, feeding habitats, growth, and reproduction) of the queen conch in the different areas of the archipielago of San Andrés and Providencia.

Principal fishing areas, estimates of growth parameters by analysis of size frequency distributions, and analyses of the historical production on the islands are given from which an estimation of the resource potential is possible. With these results, an optimum point of exploitation (E) is calculated to optimize yield per recruit.

## INTRODUCTION

The queen conch (*Strombus gigas*) has been a mollusc of great importance as a seafood product for many years and a basic element in the diet of many inhabitants of the Gulf of Mexico and the Caribbean basin. As a result, there has been much research into their biology, growth, fishery, management, and aquaculture in the different zones of the Caribbean.

In respect to biology, there are studies about anatomy, larval development and metamorphosis, as well as sex determination, weight, size, juvenile growth, and analyses of stomach contents (Randall, 1964; Little, 1965; D'Asaro, 1965). Studies can also be found on habitat, reproduction, migratory patterns, and predators (Hesse, 1979; Berg, 1981; Jory and Iversen, 1983).

Alcolado (1976) has done important research on growth. He studied the differences in rhythm of growth in Cuba in relation to the environment. He also estimated the median growth rate, abundance of populations, and pattern of distribution. Wefer and Killingley (1980) indicate that the composition of stable isotopes in the conch can be used to estimate growth rates in the different stages of the life cycle.

There are also several fishing and population studies on different areas of the Caribbean which provide information about exportation to the United States from countries such as Belize, Honduras, and Colombia.

There is also data about small-scale fishing and industries actively involving fishermen of the region, especially during tag/recapture studies (Burnett-Herkes, 1981; Brownell and Stevely, 1981; Gibson *et al.*, 1983).

Wood and Olsen (1983) and Iversen *et al.* (1987) carried out studies on population dynamics in the Virgin Islands and the Bahamas, respectively, estimating growth through the analysis of size frequency distribution. They also estimated natural death and mortality by fishing. Combining this information on fishing and size, they analyzed yield per recruit.

As far as culture, restoration of a conch population, and resource management, Berg (1976), Brownell (1977), Sidall (1981), Davis and Hesse (1983), and Iversen (1983) investigated aspects of larval and juvenile culture-determined growth rates under laboratory conditions and developed hatchery techniques.

Appeldoorn and Ballantine (1983), Hensen (1983) and Weil and Laughlin (1984) refer to culture, its implication for the restoration of stock, and resource management in Puerto Rico, the Dutch Antilles, and the archipielago de Los Roques, (Venezuela) respectively.

In Colombia, there are few, although important, studies of conch. Duque (1974) refers to a biological and fishery study on the San Bernardo archipielago (Bolívar); later, Moncaleano (1976) analyzed fishing on the same archipielago.

García (1980) presents the queen conch as one of the most common species obtained through small-scale fishing in San Andrés and Providencia. Botero (1984) determined size and density of a population of *S. gigas* in Nenguange cove (Magdalena, Colombia); she also gave the distribution of individual size, sex ratio, spawning seasons, and size of egg mass.

Cantera and Contreras (1984) and Contreras and Cantera (1984) present the queen conch as a species appropriate for aquaculture and with potential as a food resource in San Andrés and Providencia, compiling and presenting information on the species throughout the Caribbean.

The purpose of the present study was to obtain data on *S. gigas* in various areas of the San Andrés and Providencia archipielago regarding its biology, distribution, potential of the resource, and fishing yield. This information is fundamental for a better understanding of the species in our territory and appropriate management of the resource in order to benefit the fishing community of the region.

## MATERIALS AND METHODS

Direct samples were taken during May, 1987 – April, 1988 in different areas of the San Andrés and Providencia archipielago; the Northern banks (Roncador, Serrana, Serranilla, and Quitasueño) and the Southern cays (Bolívar and Albuquerque). This region is Colombia's most distant offshore possession located between 78°28′ and to 82°0′ W and 11°30′ to 6°30′ N (Figure 1). The region is formed by atolls and islands of volcanic and coralline origin (von Prahl and Erhardt, 1985).

The Alisean winds blow mainly in an east-northeast direction; this greatly influences the marine currents of the region. It has also been determined that, as in the rest of the Caribbean, June and July represent the summer period, while February and March represent winter, and October represents a transition period. Superficial waters have a salinity of 36 ppt and a summer temperature of 29°C, and 35.9 ppt and 26°C in winter; intermediate waters have a salinity of 36.8 ppt and a temperature of 22 to 24°C (González, 1987).

Samples were obtained by skin and scuba diving at depths between 2 and 30 m, principally in the morning (8:00 a.m. to 1:00 p.m.).

A total of approximately 1000 specimens were processed and observations were made regarding biological type, ecology, feeding habitats, growth, and reproduction. Length of specimens was measured with a calibrator and weight taken with and without shell using a precision spring scale of ± 1.0 g. Data was treated according to the methodology of Alcolado (1976), Moncaleano (1976), Botero (1984) and Iversen *et al.* (1987).

Density was also determined on Roncador, Serrana, and Serranilla making crossections parallel to the coast 10 m long and 2 m wide covering an area of approximately 200 $m^2$.

To estimate growth parameters, length from tip to siphon channel was measured and the methods for analysis of size frequency data of Pauly (1983) were used. Also the ELEFAN-IBM software program (Gayanilo *et al.*, 1988) was used to estimate the von Bertalanffy equation, total mortality (Z), natural mortality (M), fishing mortality (F), and the exploitation rate (E).

## RESULTS

### Habitat

It was found that *S. gigas* prefers sandy bottoms and calcareous and coralline remains. In the shallow waters of the islands, the presence of juvenile forms due to the great quantity of calcium salts necessary for the development of the shell was observed. On the other hand, adult forms were found in deeper waters (as in Albuquerque).

In the area, at a depth of 8 meters, juveniles and preadults with a range in length (siphon channel-tip) of 10.0 – 16.0 cm are found, and at greater depths (18 – 25 m) adults are found ranging in length from 20.0 to 26.0 cm.

Although nocturnal immersions were not carried out, during the day, no specimens of less than 8.0 cm were found above the substratum at the various

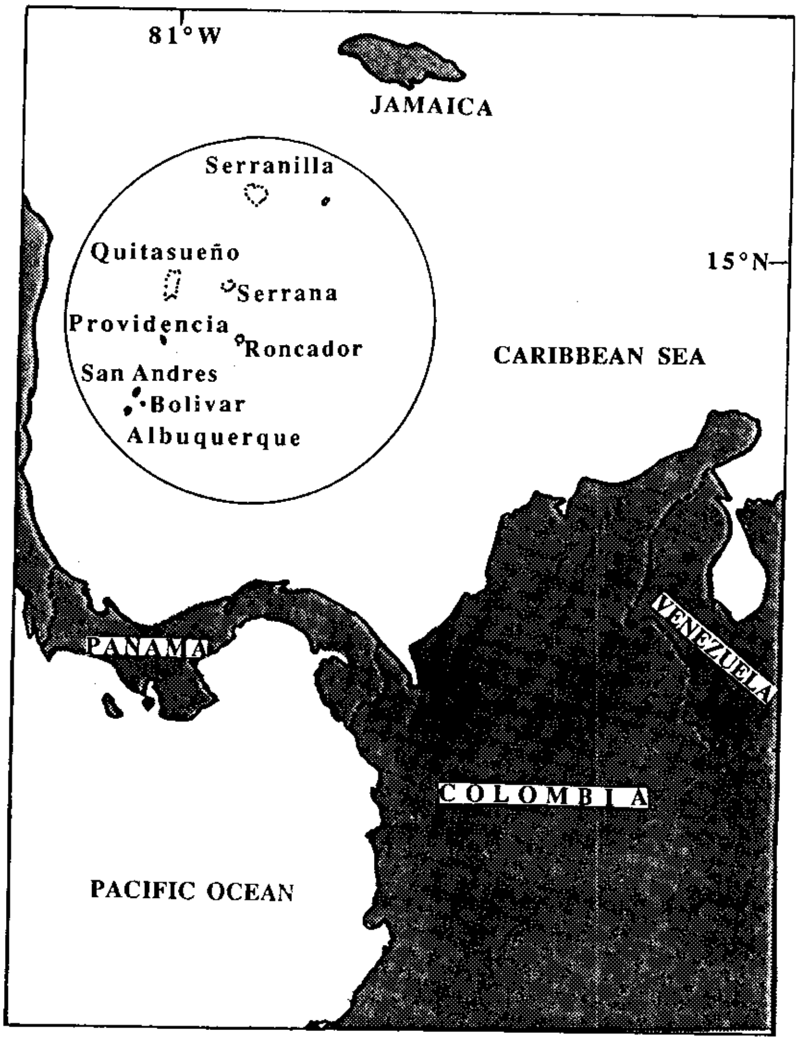


**Figure 1.** Areas of study on the archipielago of San Andrés and Providencia.

sampling sites; only one empty shell of 5.0 cm length from the tip to the siphon channel was found half-buried in the sand at a depth of approximately 5.0 cm.

The queen conch is also found near marine seagrass (*Thalassia testudinum* and *Syringodium filiforme*) in clear spaces of sand such as that found in the Serranilla bank. All of this information is similar to that reported by Randall (1964) in the Virgin Islands, Alcolado (1976) in Cuba, and Moncaleano (1976) in the San Bernardo archipielago of Colombia.

**Feeding Habits**

In the islands, *S. gigas* feed predominantly on epiphytic microalgaes that grow on the marine seagrass; this is possibly due to the fact that the microalgae have a much softer texture than the marine grasses, thus those are preferred by the queen conch. The conch also take in microalgae that live adhered to the sandy granules and from time to time to the leaves of *Thalassia*. The algae typically consumed by these gastropods are *Cladophora* sp., *Laurencia* sp., *Dictyota* sp., *Enteromorpha* sp., and *Dictyopteris* sp.

**Reproduction**

At the different sampling sites on the archipielago, intense reproductive activity such as copulation was observed on coralline sand bottoms near patches of dead coral at depths ranging from 20 to 30 m, and females spawning were observed on extensive sandy plains. Egg masses were found mostly half-covered by sand.

The reproductive season is long, beginning in mid-June on to October. During this time the coloring of the gonads changes from cream to an intense orange, and the size of the gonad increases proportionally in relation to body size.

**Predators**

The most frequent predators of *S. gigas* observed on the archipielago of San Andrés and Providencia are: *Fasciolaria tulipa* (Gastropoda), *Octopus vulgaris* (Cephalopoda), *Panulirus argus* (Crustacea), *Galeocerdo cuvieri*, *Aetobatus narinari* (Pisces), and *Caretta caretta* (Reptilia).

**Population Biology**

*Growth* – According to the exponential model, the length-weight relationship is represented in Equation 1.

$$W = \alpha * L^b \tag{1}$$

Weight (W) is proportional to a certain potential (b) of length (L) multiplied by a constant ($\alpha$). For this relationship, the length (tip-siphon channel) and the total weight of the animal were taken into account. The data were adjusted by means of a lineal regression given in Equation 2.

$$\text{Log } W = a + b \text{ Log } L \qquad (2)$$

In Table 1, the coefficients corresponding to the lineal regressions of each sampling are presented. Distribution of length frequencies obtained during the months of sampling are presented in Table 2.

ELEFAN I estimated the parameters K (growth constant), $L_\infty$ (asymptotic length), C (growth amplitude), WP (winter point) and ts (summer point) (Table 3) of the modified von Bertalanffy equation, expressing seasonal growth in length proposed by Pauly and Gaschautz (1979) (Equation 3).

$$Lt = L_\infty \left[ 1 - e^{-\left(K(t - to) + CK/2\pi \sin(2\pi(t-ts))\right)} \right] \qquad (3)$$
$$ts = WP + 0.5$$

Figure 2 shows the growth curve calculated from the analysis of length frequency data in the different areas of the archipielago of San Andrés and Providencia.

"to" was estimated using the Pauly (1983) equation (Equation 4), a gross estimate of this parameter.

$$\text{Log}(-to) = -0.3922 - 0.2752 \text{ Log } L_\infty - 1.038 \text{ Log } K \qquad (4)$$
$$to = -0.2195$$

Von Bertalanffy's growth Equation (5) for *Strombus gigas* obtained through our investigation is the following:

$$Lt = 32.94 \left[1 - e^{-\left(0.72(t-0.22) + 0.033 \sin(6.28(t-0.914))\right)}\right] \qquad (5)$$

*Density* – Counts of conch were made in Roncador, Serrana, and Serranilla banks (Table 4) where medium density was calculated.

*Estimates of Total Mortality (Z), by Fishing Mortality (F), and Natural Mortality (M)* – The different instantaneous rates of mortality were estimated: from the catch curve using the VBGF parameters previously calculated. In addition, exploitation rate was estimated (E = F/Z) (Table 5 and Figure 3).

*Probability of Capture* – Taking into account the classes of length analyzed, probability of capture was estimated for each length with percentages of 25%, 50%, and 75% (Table 6 and Figure 4).

*Recruitment Pattern* – The recruitment pattern was determined using projections from the length-frequency data and growth parameters for *S. gigas* from the area (Figure 5).

**Table 1.** Coefficients of lineal regression (length-weight) for *Strombus gigas* at the different sampling sites.

| Sites | a | b | $r^2$ | n |
|---|---|---|---|---|
| Roncador | -0.8457 | 3.0459 | 0.9299 | 214 |
| Serrana | -0.8034 | 3.0928 | 0.9937 | 216 |
| Serranilla | -0.4302 | 2.8296 | 0.9953 | 146 |
| Quitasueña | -0.9126 | 3.0619 | 0.9998 | 38 |
| Albuquerque | -0.7127 | 3.0209 | 0.9998 | 43 |
| Bolívar | -0.6559 | 2.9488 | 0.9964 | 98 |
| Providencia | -0.8673 | 3.1007 | 0.9995 | 83 |

**Table 3.** Growth parameters of *S.gigas* used in the von Bertalanffy equation.

| $L_\infty$ (cm) | K | C | WP | STARTING Length | STARTING Sample | Rn |
|---|---|---|---|---|---|---|
| 32.94 | 0.715 | 0.296 | 0.414 | 12.12 | 1 | 0.214 |

*Yield/Recruit and Biomass/Recruit* – Levels of exploitation (E) were estimated using yield/recruit relative (Y′/R) and biomass/recruit relative (B′/R). This analysis was carried out using the probabilities of capture that change gradually (Table 7 and Figure 6).

## DISCUSSION AND CONCLUSIONS

The reproductive season of the *S. gigas* occurs during mid-June to October in the different areas of the archipielago of San Andrés and Providencia. This represents the summer season in the area and the water temperature rise (González, 1987).

As in other areas of the Caribbean, when the water temperature rises, reproductive peaks appear for conch (Brownell, 1977; Botero, 1984; Weil and Laughlin, 1984; Appeldoorn, 1985; Iverson *et al.*, 1987).

### Growth

Regression coefficients are not significantly different from 3.0. As a result, the special von Bertalanffy equation can be used by pooling all sites and all months sampled.

The growth parameters $L_\infty$ (32.94 cm) and K (0.715), estimated for conch in the San Andrés Islands, show values near to those reported for Cuba (Alcolado, 1976) and Los Roques, Venezuela (Weil and Laughlin, 1984).

The values of the winter point (WP) 0.414 and the amplitude of growth (C)

**Table 2.** Size frequency distribution of *Strombus gigas*.

| ML/DATE | 5/15/87 | 6/15/87 | 7/15/87 | 8/15/87 | 9/15/87 | 10/15/87 | 3/15/88 | 3/15/88 |
|---|---|---|---|---|---|---|---|---|
| 8.5 | 3 | | | 1 | | | | |
| 9.5 | 1 | | | 0 | | | | |
| 10.5 | 0 | 2 | | 0 | | | | |
| 11.5 | 2 | 1 | | 0 | 1 | | | |
| 12.5 | 7 | 3 | | 0 | 0 | | | 1 |
| 13.5 | 7 | 3 | 3 | 1 | 0 | | | 3 |
| 14.5 | 3 | 1 | 0 | 5 | 0 | | | 2 |
| 15.5 | 1 | 2 | 1 | 3 | 0 | | | 0 |
| 16.5 | 2 | 4 | 1 | 3 | 0 | 2 | 4 | 0 |
| 17.5 | 6 | 5 | 4 | 2 | 0 | 3 | 8 | 0 |
| 18.5 | 7 | 14 | 7 | 19 | 2 | 11 | 13 | 0 |
| 19.5 | 8 | 14 | 7 | 20 | 4 | 12 | 18 | 0 |
| 20.5 | 12 | 16 | 11 | 23 | 8 | 11 | 19 | 1 |
| 21.5 | 13 | 12 | 15 | 29 | 19 | 21 | 10 | 0 |
| 22.5 | 18 | 7 | 26 | 24 | 23 | 16 | 6 | 4 |
| 23.5 | 18 | 9 | 15 | 23 | 22 | 14 | 5 | 2 |
| 24.5 | 15 | 6 | 13 | 19 | 18 | 8 | | 5 |
| 25.5 | 10 | 3 | 7 | 5 | 11 | 5 | | 2 |
| 26.5 | 5 | 0 | 3 | 7 | 2 | 1 | | 3 |
| 27.5 | 1 | 1 | 1 | 1 | 1 | 1 | | 2 |
| 28.5 | | | 4 | 2 | | 0 | | 2 |
| 29.5 | | | | | | 1 | | |
| SUM | 139 | 103 | 118 | 187 | 111 | 106 | 83 | 27 |
| "rf" | 4.1 | 29.6 | 15.7 | 3.8 | 22.6 | 119.5 | 40.3 | 117.9 |
| n = | 874.00 | | | | | | | |

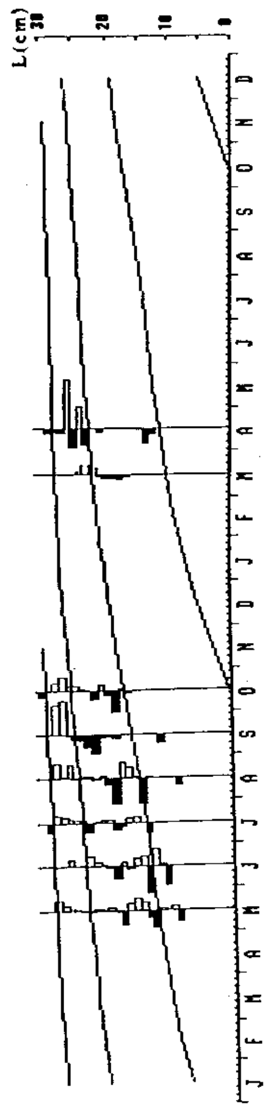


**Figure 2.** Von Bertalanffy growth curve for the *Strombus gigas* in San Andrés and Providencia.

**Table 4.** Average number and density of conchs.

| Location | Date | No. of Conch (Average) | D = No. of Ind. / 200m | Depth (m) |
|---|---|---|---|---|
| Roncador | 25-05-87 | 17 | 0.085 | 10 |
| | 30-06-87 | 18 | 0.09 | 12-15 |
| | 03-08-87 | 19 | 0.095 | 12-13 |
| Serrana | 02-06-87 | 25 | 0.125 | 16 |
| | 29-08-87 | 12 | 0.06 | 10 |
| Serranilla | 04-08-87 | 16 | 0.08 | 13 |

**Table 5.** Rates of total mortality (Z), by fishing mortality (F), natural mortality (M), and exploitation rate (E) for *Strombus gigas* in San Andrés and Providencia.

| Z | M | F | E=F/Z |
|---|---|---|---|
| 5.263 | 1.397 | 3.866 | 0.735 |

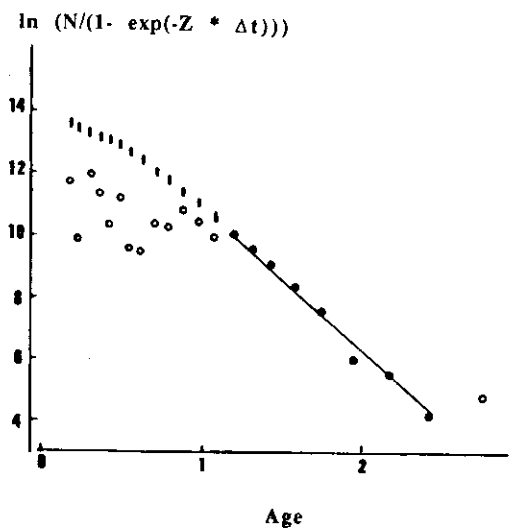


**Figure 3.** Catch curve of queen conch in the study area.

**Table 6.** Probability of capture of *Strombus gigas* based on size type.

| Mid-length(cm) | Prob. Selection | Smooth Prob. |
|---|---|---|
| 8.500 | 0.0127 | 0.01331 |
| 9.500 | 0.0324 | 0.03356 |
| 10.500 | 0.0800 | 0.08209 |
| 11.500 | 0.1843 | 0.18717 |
| 12.500 | 0.3699 | 0.37223 |
| 13.500 | 0.6040 | 0.60424 |
| 14.500 | 0.7985 | 0.79722 |
| 15.500 | 0.9115 | 0.91010 |
| 16.500 | 0.9640 | 0.96305 |
| 17.500 | 0.9858 | 0.98532 |
| 18.500 | 0.9945 | 0.99425 |
| 19.500 | 0.9979 | 0.99776 |
| 20.500 | 0.9992 | 0.99913 |
| 21.500 | 0.9997 | 0.99966 |
| 22.500 | 0.9999 | 0.99987 |
| 23.500 | 0.9999 | 0.99995 |
| 24.500 | 1.0000 | 0.99998 |
| 25.500 | 1.0000 | 0.99999 |
| 26.500 | 1.0000 | 1.00000 |

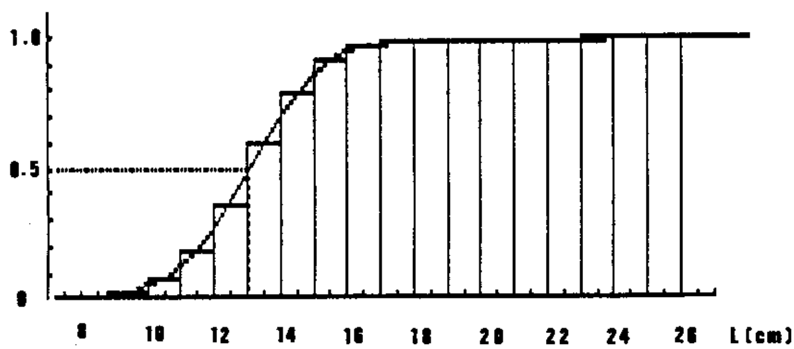


**Figure 4.** Percentage of selection according to animal length. Showing L-25% = 11.891 cm, L-50% = 13.053 cm, L-75% = 14.214 cm, and a slope = 0.9458.

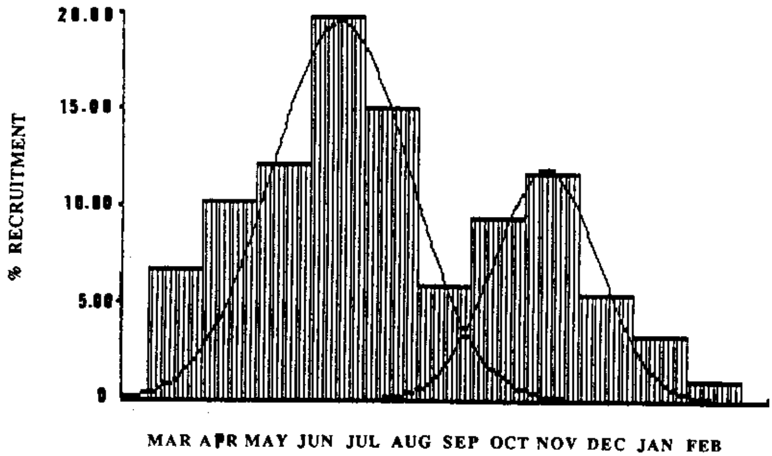


**Figure 5.** Recruitment pattern.

0.296 are not too high. WP (0.414) occurs during the first quarter of the year and indicates the beginning of the growth oscillations right after the recruitment. The value of the parameter C (0.296) and the difference between the highest and lowest mean monthly temperatures to which the gastropod was exposed ($\Delta T$ = 2.65) make sure that $\Delta t$ values of 2 to 3 °C gives C values of 0.18 to 0.35.

The slight seasonal fluctuations of temperature (or of correlated parameters C and WP) such as occur in the tropics are sufficient to generate seasonally oscillating growth curves (Pauly, 1982).

**Density**

The mean density in the area (0.09 conch/m$^2$) is low compared with the extended archipielago (55 km$^2$). Serrana bank presents the highest density of the area (0.1 conch/m$^2$). In May, Roncador bank density (0.09 conch/m$^2$) is similar to the density reported by Botero (1984) in the same month in Nenguange cove, Magdalena-Colombia.

First the densities of the conch in San Andrés Islands are similar to those obtained by Hesse (1979) (0.093 conch/m$^2$, Turks and Caicos) and Weil and Laughlin (1984) (0.08 conch/m$^2$ overfished zone, Los Roques-Venezuela).

Second our densities are lower than those given by Alcolado (1976) (0.5 conch/m$^2$ Diego Perez-Cuba), Weil and Laughlin (1984) (0.455 conch/m$^2$ protected zone, Los Roques-Venezuela) and Iversen *et al.* (1987) (0.303

**Table 7.** Y′/R and B′/R analysis by the probability of capture. $L_\infty$ =32.94 and M/K = 1.9538.

| E | Y′/R | B′/R |
|---|---|---|
| 0.05 | 0.0030739 | 0.925824 |
| 0.10 | 0.0059831 | 0.853361 |
| 0.15 | 0.0087186 | 0.782690 |
| 0.20 | 0.0112704 | 0.713894 |
| 0.25 | 0.0136274 | 0.647062 |
| 0.30 | 0.0157773 | 0.582286 |
| 0.35 | 0.0177055 | 0.519671 |
| 0.40 | 0.0193954 | 0.459326 |
| 0.45 | 0.0208270 | 0.401371 |
| 0.50 | 0.0219760 | 0.345939 |
| 0.55 | 0.0228119 | 0.293182 |
| 0.60 | 0.0232956 | 0.243273 |
| 0.65 | 0.0233748 | 0.196424 |
| 0.70 | 0.0229775 | 0.152889 |
| 0.75 | 0.0220005 | 0.113048 |
| 0.80 | 0.0202913 | 0.077374 |
| 0.85 | 0.0176172 | 0.046642 |
| 0.90 | 0.0136226 | 0.022078 |
| 0.95 | 0.0078045 | 0.005661 |
| 1.00 | 0.0000067 | 0.000000 |

$E_{max}$ : 0.6333
$E_{0.1}$ : 0.6224
$E_{0.5}$ : 0.3661

conch/m$^2$, Bahamas).

And finally our densities are higher than those calculated from February to March (0.03 conch/m$^2$) in Nenguange cove, Colombia (Botero, 1984) because this time period represents the winter season with high tides so the queen conch usually burrowed in sand. Densities are also higher then in Cabo Cruz, Cuba (0.065 conch/m$^2$; Alcolado, 1976) where optimum substratum and fragile algae were not available.

**Mortality**

Total Mortality (Z = 5.263) for queen conch in the archipielago of San Andrés and Providencia is high as found by Sparre *et al.* (1989), when we have Z > 2 the fishery resource suffers a heavy exploitation and total mortality values are high.

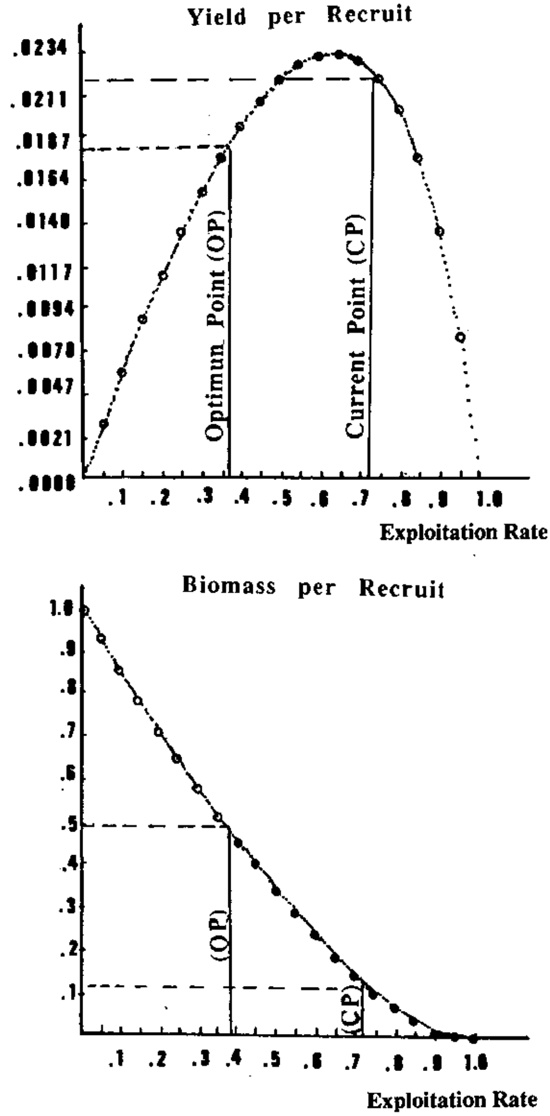


**Figure 6.** Curves of relative yield per recruit and relative biomass per recruit using probabilities of capture.

Also fishing mortality (F = 3.866) is above natural mortality (M = 1.397) so the exploitation rate (E = 0.735) is higher than the optimum exploitation level (E = 0.5).

The natural mortality rate is similar to those given for Cuba (1.06 – 1.90) and Los Roques, Venezuela (1.3) (Alcolado, 1976; Weil and Laughlin, 1984).

Total mortality and fishing mortality are higher in this study than values obtained by Berg (1976) for Puerto Rico (Z = 3.0), Iversen (1983) for the Bahamas (Z = 2.41 – 3.91), Wood and Olsen (1983) for the Virgin Islands (Z = 0.22 – 1.80; F = 1.69) and Muñoz *et al.* (1987) for Cuba (Z = 1.82).

Our Z estimate is lower than the values of Z = 7.39 and Z = 8.62 reported from Puerto Rico by Appeldoorn and Ballantine (1983) and Appeldoorn (1985) respectively.

With the value obtained from E = 0.735, it can be deduced that the fishing effort should not be increased because the optimum level has been reached and passed, and as a result the resource would collapse.

**Probability of Capture**

The probability of capture over different length classes in this study gives an $L_{50}$ or $L_c$ (length at first capture) of 13.053 cm, which is an inadequate minimum length because the queen conch has not yet reached sexual maturity. Also the catch curve shows that the relative age of the *S. gigas* catch by fishing is 1.18 to 2.34 years.

It is known that *S. gigas* reaches its sexual maturity at 3.0 to 3.5 years with a shell length above 22 cm (Randall, 1964; Berg, 1976; Gibson *et al.*, 1983; Wilkins *et al.*, 1987).

**Recruitment Pattern**

The Recruitment Pattern for queen conch in San Andrés Islands gives two normal distributions per year. The first component, with 61.99% of recruitment, peaks in June. The second component, with 28.5% of recruitment, peaks in October. The peaks of recruitment coincide with the reproductive season for conch in the area.

**Yield/Recruit and Biomass/Recruit**

The optimum point (OP) ($E_{0.5}$ = 0.3661) is exceeded largely because the current point (CP) (E = 0.735) is higher than $E_{max}$ (0.633). The current point results in a biomass (0.13) that is 37% below the value of the biomass at the optimum point (0.5).

The value Y/R in the current point is 10% above the Y/R of the optimum point which is not good because the maximum sustainable yield has to be below the optimum point (Y′/R = 0.017) to assure survival of the species and success of the fishery resource.

All these parameters indicate that the conch resource is fragile and requires rational management as well as managing minimum increases in fishing pressure.

We recommend that more population dynamics studies involving tag/recapture as well as studies on culture for stocking to be conducted. Results from these studies will give a greater degree of assurance in the current estimates of growth and population parameters.

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LITERATURE CITED

Alcolado, P.M. 1976. Crecimiento, variaciones morfológicas de la concha y algunos datos biológicos del cobo *Strombus gigas* L. (Mollusca, Mesogastropoda). *Acad. Cienc. Cuba Ser. Oceano.* **34**: 36 pp.

Appeldoorn, R.S. 1985. Growth, mortality and dispersion of juvenile laboratory-reared conchs, *Strombus gigas* and *S. costatus*, released at an offshore site. *Bull. Mar. Sci.* **37**:785-793.

Appeldoorn, R.S. and D.L. Ballantine. 1983. Field release of cultured queen conchs in Puerto Rico: implications for stock restoration. *Proc. Gulf Carib. Fish. Inst.* **35**:89-98.

Berg, C.J., Jr. 1981. Conch biology. Pages 9-12 *in* C.J. Berg, Jr., ed. *Proceedings of the Queen Conch Fisheries and Mariculture Meeting.* Wallace Groves Aquaculture Foundation.

Berg, C.J., Jr. 1976. Growth of the queen conch *Strombus gigas*, with a discussion of the practically of its mariculture. *Mar. Biol.* **34**:191-199.

Botero, L. 1984. Observaciones sobre una Poblacón de *Strombus gigas* L. en la ensenada de Nenguange, Caribe Colombiano. *An. Inst. Inv. Mar. Punta de Betín* No. **14**:47-65.

Brownell, W.N. 1977. Reproduction, laboratory culture and growth of *Strombus gigas*, *S. costatus* and *S. puglilis* in Los Roques Venezuela. *Bull Mar. Sci.* **27**:668-680.

Brownell, W.N. and J.M. Stevely. 1981. The biology fisheries and management of the queen conch, *Strombus gigas*. *Mar. Fish Rev.* **43**(7): 12 pp.

Burnett-Herkes, J. 1981. Management and replenishment of conch. Pages 29-40 *in* C.J. Berg, Jr., ed. *Proceedings of the Queen Conch Fisheries and Mariculture Meeting*. Wallace Groves Aquaculture Foundation.

Cantera, J.R. and R. Contreras. 1984. Potencialidad del uso de *Strombus gigas* como Recurso Alimentario en el archipiélago de San Andrés y Providencia. *Memorias del I Seminario. Taller sobre Tecnologías Nativas y Apropiadas*. FIPMA. San Andrés. En prensa.

Contreras, R. and J.R Cantera. 1984. Especies Potencialmente Aprovechables en Acuacultura en el archipiélago de San Andrés y Providencia. *Memorias del I Seminario. Taller sobre Tecnologías Nativas y Apropiadas*. FIPMA. San Andrés. En prensa.

D'Asaro, C.N. 1965. Organogenesis, development and metamorphosis in the queen conch, *Strombus gigas*, with notes on breeding habitats. *Bull Mar. Sci.* **15**:359-416.

Davis, M. and C. Hesse. 1983. Third World level conch mariculture in the Turks and Caicos Islands. *Proc. Gulf Carib. Fish Inst.* **35**:73-82.

Duque, F. 1974. Estudio Biológico-Pesquero de *Strombus gigas* en el archipiélago de San Bernardo. Tesis Profesional. Univ. de Bogotá Jorge Tadeo Lozano. 75 pp.

García, V.M. 1980. Diagnóstico preliminar de la Pesca Artesanal del archipiélago de San Andrés y Providencia. INDERENA. *Rev. Divul. Pes.* **22**(1): 39 pp.

Gayanilo, F.C. Jr., M. Soriano, and D. Pauly, 1988. *A Draft Guide to the Complete ELEFAN. ICLARM Software* **2**. 65 pp.

Gibson, J., S. Stradisne and K. Gonzáles. 1983. The status of the conch industry of Belize. *Proc. Gulf Carib. Fish. Inst.* **35**:99-107.

González, G.E. 1987. Oceanografía física descriptiva del archipiélago de San Andrés y Providencia con base en el Análisis de los Cruceros Oceano IV a IX. *Bol. Cient. CIOH.* No.7: 73-100.

Hensen, R.R. 1983. Queen conch management and culture in the Netherlands Antilles. *Proc.Gulf Carib. Fish. Inst.* **35**:53-56.

Hesse, K.O. 1979. Movement and migration of the queen conch *Strombus gigas* in the Turks and Caicos Islands. *Bull. Mar. Sci.* **29**:303-311.

Iversen, E.S. 1983. Feasibility of increasing Bahamian conch production by mariculture. *Proc.Gulf Carib. Fish. Inst.* **35**:87-89.

Iversen, E.S., E.S. Rutherford, S.P. Bannerot, and D.E. Jory. 1987. Biological data on Berry Islands (Bahamas) queen conch *Strombus gigas* with mariculture and fisheries management implications. *Fish Bull.* **85**(2): 299-310.

Jory, D.E. and E.S. Iversen. 1983. Queen predators. *Proc. Gulf Carib. Fish. Inst.* **35**:108-111.

Little, C. 1965. Notes on the anatomy of the queen conch *Strombus gigas*. *Bull. Mar. Sci.* **15**:338-358.

Moncaleano, A. 1976. Delineamientos Estadísticos para la Evaluación del stock y la actividad pesquera sobre el caracol de pala *Strombus gigas* en el archipiélago de San Bernardo, Mar Caribe, Colombia. INDERENA. *Rev. Divulg. Pes.* **13**(4-5): 14 pp.

Muñoz, L., P. Alcolado, I. Fraga, and D. Llorente. 1987. Status of population and fisheries of *Strombus gigas* in Cuba with same results of juvenile rearing in pens. *Proc. Gulf Carib. Fish. Inst.* **38**:353-361.

Pauly, D. 1983. Algunos Métodos simples para la Evaluación de Recursos Pesqueros Tropicales. *FAO. Doc. Tec. Pesca* **234**: 49 pp.

Pauly, D. 1982. Studying single species dynamics in a tropical multispecies context. Pages 33-70 *in* D. Pauly and G.I. Murphy, eds. *Theory and Management of Tropical Fisheries ICLARM. Conference Proceedings* **9**, 360 pp.

Pauly, D. and G. Gaschautz. 1979. A simple method for fitting oscillating length growth data, with a program for pocket calculators. I.E.S.C.M. 1979/G: 24 Demersal Fish Cttee: 26 pp.

Randall, J.E. 1964. Contributions to the biology of the queen conch *Strombus gigas*. *Bull. Mar. Sci.*, **14**:243-295.

Sidall, S.E. 1981. Larviculture. Pages 13-23. *in* C.J. Berg, Jr., ed. *Proceedings of the Queen Conch Fisheries and Mariculture Meeting*. Wallace Groves Aquaculture Foundation.

Sparre, P., E. Ursin, and S.C. Venema. 1989. Introduction to tropical fish stock assessment. Part I. Manual. *FAO Fisheries Technical Paper* No. 306.1 Rome FAO: 337 pp.

von Prahl, H. and H. Erhardt, ed. 1985. *Colombia, Corales y Arrecifes Coralinos*. FEN Colombia, editorial Presencia Ltda, Bogotá: 295 pp.

Wefer, G. and J.S. Killingley. 1980. Growth histories of Strombid snails from Bermuda recorded in their 0-18 and 0-13 profiles. *Mar. Biol.* **60**: 129-135.

Weil, E.M. and R.G. Laughlin. 1984. Biology, population dynamics and reproduction for the queen conch *Strombus gigas* L. in the archipielago de Los Roques National Park. *J. Shellfish Res.*, **4** (1):45-62.

Wilkins, R.M., M.H. Goodwin, and D.M. Reid. 1987. Research applied to conch resource management in St. Kitts/Nevis. *Proc. Gulf Carib. Fish. Inst.* **38**:370-375.

Wood, R.S. and D.A. Olsen. 1983. Application of biological knowledge to the management of the Virgin Islands conch fishery. *Proc. Gulf Carib. Fish. Inst.* **35**:112-121.