Parametros de Crecimiento, Mortalidad y el Estado de la Pesqueria Basados en la Distribucion de los Grosores de Labio de una Poblacion Adulta de Caracol Blanco *Strombus costatus* Gmelim en la Costa de Yucatán, México

Growth, Mortality and Status of the Fishery in an Adult Population of the milk Conch *Strombus costatus* Gmelin on the Yucatan Coast, Mexico

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ABSTRACT

A study was carried out on the growth and mortality of an adult population of the milk conch, based on lip-thickness frequency data analyzed using ELEFAN. An interval width of 2 mm was used in the analysis; growth parameters were determined using the von Bertalanffy incorporating seasonal growth oscillations. Growth parameters from ELEFAN I were K = 0.29 yr^{-1}, L = 43.76 mm, WP = 0.11 yr^{-1} and C = 0.6. Wetherall's method yielded L = 30.59 mm and Z/K = 1.66. Total mortality estimated by catch curve analysis was Z = 0.89 yr^{-1}. Natural mortality (M) was estimated using the empirical formula of Hoenig as 0.4 and 0.7 yr^{-1}, based on the ELEFAN I and Wetherall results, respectively. Subtracting M from Z, corresponding values were calculated for fishing mortality (F =0.49 and 0.19 yr^{-1}) and exploitation rate (E = 0.55 and 0.21), respectively. The annual recruitment pattern was unimodal but skewed to the right.

KEY WORDS: Lip-thickness, *Strombus costatus*, growth, mortality, exploitation rate.

INTRODUCTION

Importance, Distribution, Habitat and Status of the Fishery

The marine conch represents a natural resource of considerable importance both economically and for its wide consumption in theCaribbean region where the Queen conch *Strombus gigas* (Linnaeus) and the milk conch *Strombus costatus* (Gmelin) are distinguished in the fishery (Randall, 1964; Gulland, 1971; Berg, 1976; Brownell and Stevely, 1981; Darcy, 1981). The geographic distribution of *Strombus costatus* practically covers all of the Caribbean region from Florida to Venezuela (Morris, 1975; Linder, 1977). In Mexico, this species is found along the coast of the Yucatan Peninsula (SEPESCA, 1987) (Figure 1).

Strombus costatus is a species of the family Strombidae and commonly inhabits sandy sea floor with marine seagrasses such as:*Thalassia testudinum, Cymodea manatorum* and *Syringodium filiforme* (Roberson, 1961; Randall, 1964; Alcolado, 1976). However, they are frequently seen in sandy areas where there is no seagrass in the reproduction season and the depth varies from a few centimeters to meters depending on the area (Randall, 1964; Stradine, 1984). Fishing for this resource is done by SCUBA diving and skin diving. Thus due to the high demand, divers have exhausted the shallow areas and presently the fishery has been reduced due to overexploitation in the Caribbean countries (Berg, 1976; Brownell, 1977; Hesse and Hesse, 1977; Siddall, 1983).

In Mexico there has also been a reduction of this natural resource. Due to this situation and the danger of extinction of this species, the fishery department has closed this fishery (De la Torre, 1982; Arreguin *et al.*, 1987; SEPESCA, 1987). The efforts to rebuild conch resources have been focused mainly on the aquaculture of the species *S. gigas* and *S. costatus* (Martinez and Morales, 1979; Ogawa and Coral, 1985; Aldana and Rodríguez, 1986; Rodríguez, 1986; Aldana and Torrentera, 1987; Rodríguez, 1996).

Studies on the population dynamics of conch have not been carried out on the Mexican coast of Yucatan. It is well known that a study on the dynamics of exploited population and the knowledge and characterization of individual growth is of utmost importance, since this process together with the survival determines the magnitude of the resource. In this sense, it is evident that obtaining detailed knowledge of the growth model of a species, that a more accurate estimation will be obtained of the population size and its exploitation availability or at least with known variable limits.

In this particular manner and acknowledging that this type of information is of importance for the understanding and management of fishery resources, this present project has, as its main objective, the acquisition of information on growth, mortality parameters and the state of the fishery of this important malacological resource, an adult population of milk conch, *S. costatus*, in the Yucatan Peninsula, based on lip-thickness frequency data analyzed using ELEFAN.

MATERIALS AND METHODS

Study Area

The study area was located 20 km west of Dzilam de Bravo between parallels 21°N and 22°N and meridians 89°W and 88°W (Figure 2). The depth was uniform and consisted of a sandy plain with patches of macroalgae.

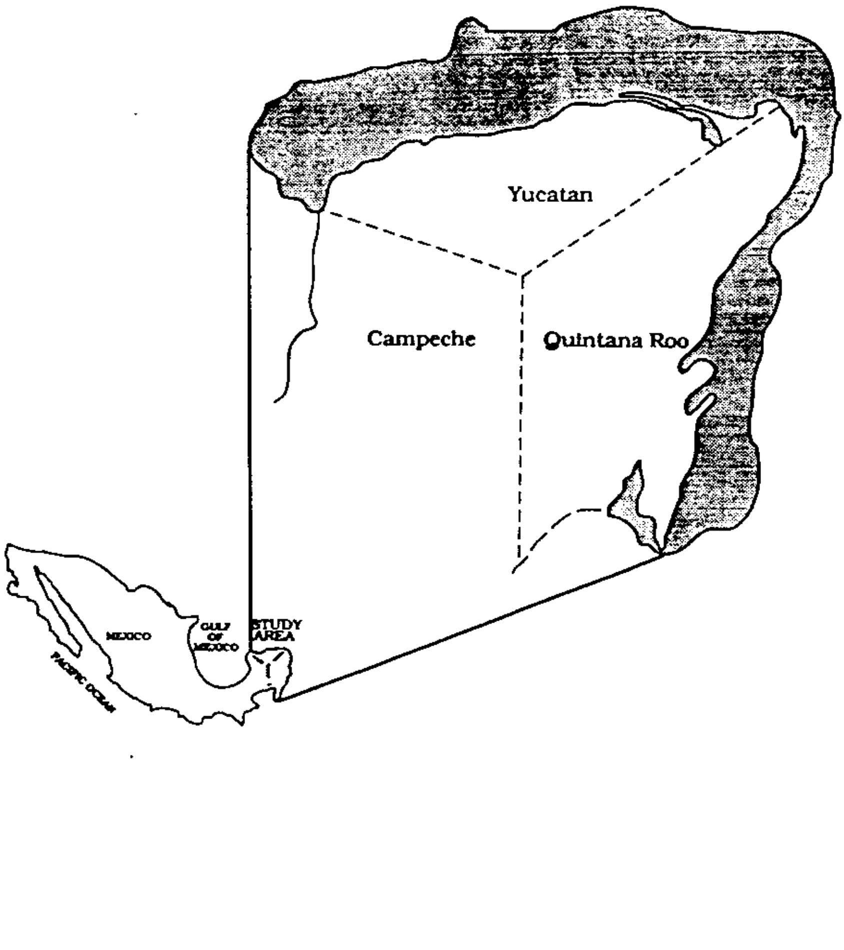

Figure 1. Distribution of milk conch, *Strombus costatus*, in the Yucatan Peninsula.

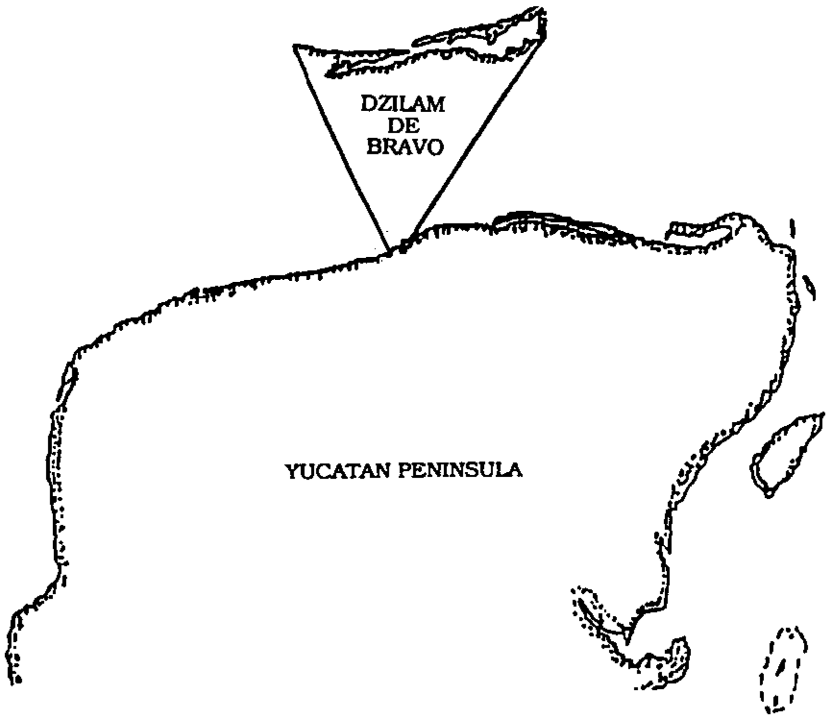

Figure 2. Study area of the milk conch, *Strombus costatus*, at Dzilam de Bravo, located between parallels 21°N and 22°N and meridian 89°W and 88°W.

Sampling

Six monthly samples were taken during the last two days of each month during the period March to August, 1989. Only adult conch were collected by free diving and all data was recorded *in situ*.

Treatment of Samples

The lip-thickness for each conch was measured and the data recorded. Significant changes in lip-thickness were observed only in the months of March, June and August. So to graph the changes over time March was used as the first month to maximize the growth changes from March until August. Using March, June and August (with maximum growth rate changes) in ELEFAN version 1.1 (Gayanilo *et al.*, 1989), the growth parameters were obtained using (ELEFAN 0 and 1). Mortality, exploitation rates, and recruitment patterns were obtained using (ELEFAN II).

Growth Parameters

ELEFAN 0. This routine uses two subroutines. The first (Data entry and Edition) was used for the frequency data input at intervals of 1 mm. The second routine (Class Interval Adjust) regrouped the data for the intervals of 2, 3, 4, and 5 mm to adjust the class intervals, using the option of length frequency data.

ELEFAN I. The five intervals mentioned above were then used in ELEFAN I to obtain the optimum growth parameters of L and K and from these selected the optimal interval, based on the most closely graphed points passing through the distribution modes of the lip-thickness frequencies for each month. ELEFAN I is based on the identification of possible age groups in each sample. Following time growth intervals, one can obtain growth curves characteristic of von Bertalanffy (1938). This routine utilized a numerical procedure for the identification of possible age groups and secondly used an iterative procedure to maximize a function (ESP/ASP) that resulted in the best possible combination of the parameters K and L .

The routine also estimates the parameters C and WP, characterizing the seasonal growth oscillations. C represents the magnitude of oscillation and WP the period of the year when growth is at a minimum. This system assumes that individual growth of a species is adequately represented by von Bertalanffy's growth curve and implies a seasonal oscillation in the growth rate. This aspect offers better estimates than procedures developed by Cassie (1954), Tanaka (1956) and Bhathacharya (1967).

The ELEFAN I requirements are the following: the samples must represent the structure of the population, the growth must follow von Bertalanffy's seasonal growth curve, and the recruitment must occur in seasonal pulses.

Table 1. Optimal parameters resulting from the combination of L and K for each interval class selected, based on lip-thickness frequency data of an adult population of milk conch *Strombus costatus*.

Interval (mm)	L	K	Starting Length	Sample	Rn
1	44.99	0.621	3	1	0.170
2	42.97	0.286	15	3	0.139
3	47.20	0.556	3	2	0.155
4	52.00	0.909	6	2	0.306
5	48.74	1.351	0	2	0.669

Mortality Parameters

After obtaining parameters L and K from the optimum interval, ELEFAN II was then used to obtain the catch curve, using Wetherall's method and recruitment patterns.

Catch Curve

This method uses age structure data (in terms of absolute age), or frequency distributions (in terms of relative age) of a sample. The catch curve is a graphic representation of the natural log of the survival number (ln N_t/N_0) or of the natural log of the number of individuals in a sample (ln N). The graph of ln N as a function of the relative age indicates that the left-hand portion of the curve (ascending) originates from the decreasing efficiency of the catch curve. ELEFAN II utilizes this portion of the curve to estimate the probabilities of the catch per animal length and the seasonal recruitment patterns. The right portion (descending curve) estimates Z beginning with the first point to the right of the maximum point of the ascending curve on the left (Pauly, 1983 and1984).

Requirements

The estimation of the instantaneous mortality rate (Z) requires estimates of the growth parameters and assumes the following: Z is a constant over all of the size classes included in the calculation, that there is little variation in recruitment and that recruitment is random, and the sample used must represent the mean structure of the population in the period of time observed.

Steps of the Analysis

The estimation of Z from the catch curve using length data involves the following steps: sum of individual length frequency samples to one sample only (normally for one year), using a set of growth parameters for its construction (L and K), and estimating Z from the right-hand side of the catch curve.

Wetherall's Method

Wetherall (1986) and Wetherall *et al.* (1987), based on Powell (1979), developed a technique using the principle that the form of a size distribution representative of a population is determined by the asymptotic length (L) and the ratio between the mortality rate and the growth constant (Z/K). These parameters are estimates from simple regression. This method is based on estimation of Beverton and Holt (1956).

This method was slightly modified by Pauly (1986) and included as a subroutine in ELEFAN II, as an option to obtain a preliminary estimate of L . This modification permits the graphic representation of L as a point intercepting the x axis.

Requirements

The requirements for application of this method are as follows: the sample must represent a stable population (with constant recruitment and mortality), continual recruitment, the growth curve following the von Bertalanffy function (without seasonal oscillations) and deterministic growth (with no individual growth variability). It is considered that it is impossible to find natural stable populations. The samples taken from the population (with discontinuous recruitment) were summed to an annual sample. The assumption was that this is a reasonable approximation of a stable state.

Advantages

This method has the advantage that it is rigorous, but simple and permits the calculation L of the variance of L and Z/K. The disadvantage is that the parameter K cannot be estimated. Only the ratio of Z/K is calculated.

Natural Mortality (M)

For most of the fisheries models, the rate of natural mortality is assumed to be a constant over the exploitation phase because the mortality data for one specific age are not available. Frequently, an approximate estimation of M is obtained using empirical relationships between biological parameters of various populations without exploitation.

Hoenig (1983) constructed the following empirical equation using the mean of the maximum age of various species of molluscs to predict the total mortality:

$$\ln (Z) = a + b \ln (t_{max}),$$

where Z = M in populations not exploited and t_{max} for mean longevity.

The constants a and b were estimated to be 1.23 and -0.832 , respectively, for 28 populations of thirteen species of mollusks with a maximum age between 2.5 and 25 years.

For natural mortality estimates, the following is assumed: using growth parameters data, maximum longitude [L_{max} = L (0.95)] was calculated first; secondly the maximum age was estimated, assuming that the lip thickness follows the von Bertalanffy growth model and giving t_0 the value of 0 (t_{max} = ln L_{max}/K); then with this maximum age, the natural mortality is calculated with Hoenig (1983) equation.

Fishing Mortality

This was estimated by subtracting the instantaneous mortality rate from the natural mortality (F = Z - M).

Rate of Exploitation

This was estimated by the division of the mortality values from fishing (E = F/Z).

Recruitment Patterns

The recruitment in a natural population generally does not represent (even in the tropics) a continuous introduction of juveniles into the exploited population. Rather recruitment usually represents a seasonal pattern with one or two pulses (usually two) during the yearly cycle (Longhurst and Pauly, 1987). This method is responsible for the peaks representing modes (cohorts) in the length frequency distributions.

Pauly (1987) mentioned that the pattern of recruitment results have the following characteristics: the absolute position of the recruitment frequency over the time axis is unknown, because the true value of t_0 is unknown; for procedural reasons, the procedure is standardized to give a zero value to the recruitment in the first month. Given a set of growth parameters and assuming that t_0 = 0, the program estimates the growth pattern over the length data base information and presents them as a percentage of the recruitment as a function of relative time, taking into account that the numbers in the abscisa only corresponds to the successive months and not to the actual months of the year (Issac, 1990).

RESULTS

Growth Parameters

The objective of this experiment was to estimate the growth parameters from one set of data. The sampling frequency data of lip-thickness of 1 mm interval and those readjusted in 2, 3, 4, and 5 mm resulted in total classes of 30, 15, 10, 8, and 6, respectively. The parameters L , K, SL, SS, and RN for each class interval is found in Table 1. As the amplitude in class intervals increases, the value of L is augmented and K is diminished, since L tends to be overestimated and K tends to be underestimated.

Considering the seasonality and starting with C = 0.04 and WP = 0.25 and utilizing the subroutine of optimization, it was found that the optimum interval was where the 2 mm data was readjusted, taking into account that the growth lines pass better through the peaks of the modes (cohorts) in the frequency distribution of the three selected months in comparison with the other intervals (Figure 3).

Using ELEFAN I, the von Bertalanffy results were: L = 43.76 and K = 0.286 with a Rn = 0.144, considering the values of C = 0.6, WP = 0.11, SS = 2, SL = 40. Using Wetherall's method the results were: L = 30.594, Z/K = 1.664 and taking into account the Z value of the catch curve of 0.883, the K value was 0.538 (K = Z/1.664 = 0.833/1.664 = 0.538) (Table 2).

Instantaneous Mortality Rate (Z) Catch Curve

After summing the data frequencies to obtain only one (pooling), not one sample was disregarded to estimate the value of Z, considering N < 5 and L_t < 70% of L, since the value of 70% of L was 31 mm and the sample data were a maximum of 30 mm. The total mortality rate was estimated with a Z value of 0.89 (Figure 4).

The program ELEFAN II was not able to estimate capture probabilities using the subroutine of the catch curve. Taking into account that the left hand part of the catch curve is usually used to construct catch probabilities, but recognizing that a selectivity problem was present, only one sample was used to calculate this portion of the curve. It is impossible to estimate probabilities. As a consequence, recruitment yields were also impossible to calculate since the capture length (L_c) of 50% is needed.

Natural Mortality (M), Fishing Mortality (F), and Exploitation Rate(E)

Two methods were used: Wetherall's Method and ELEFAN I parameters. Using Wetherall's method, L = 30.59 mm was used to estimate the maximum L_{max}. length, = (30.59)(0.95) = 30.06, which was used to estimate the maximum age, t_{max}: = ln L_{max}/K = 6.33 years. Using Hoenig's (1983) equation, M was estimated to be equal to 0.7. As a result, the fishing mortality was F = Z - M = 0.886 - 0.7 = 0.186. With this mortality result, the exploitation rate (E) was estimated as E = F/Z = 0.186 / 0.886 = 0.21 (Table 3). Using this strategy, the exploitation rate indicates that the population is being underexploited. However, one has to be careful when using these results.

Using the ELEFAN I method, L = 43.76 mm was used to estimate the maximum length, L_{max} = (43.76)(0.95) = 41.72 mm. This value was used to estimate the maximum age, t_{max} = ln L_{max}/K = 13.03 years. Hoenig's (1983) equation estimated M = 0.04. As a result, the fishing mortality was F = Z - M = 0.886 - 0.4 = 0.486 (Table 3).

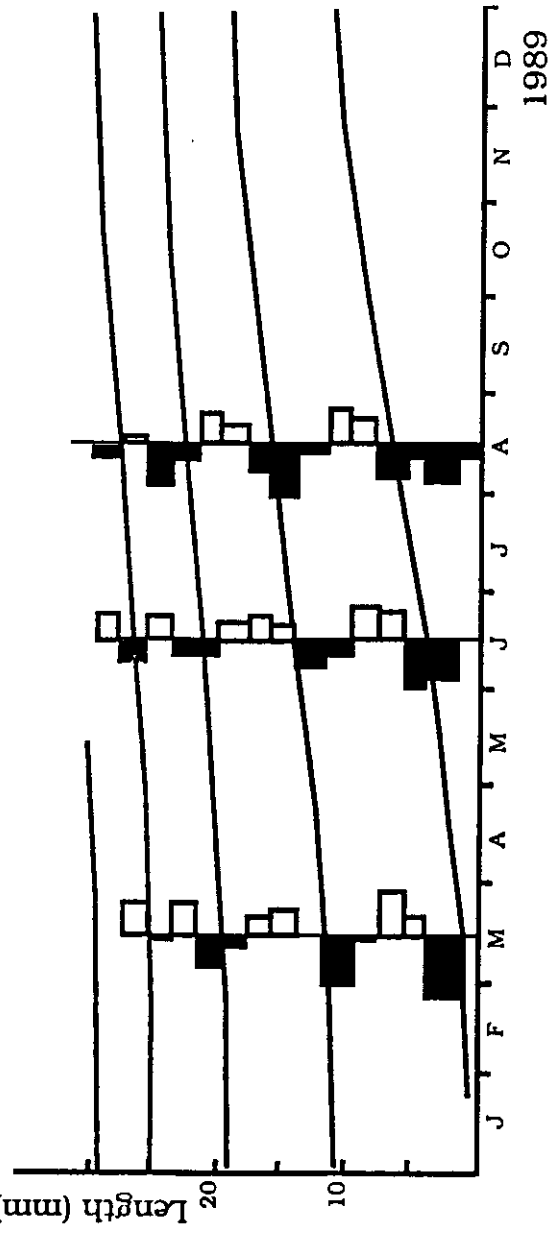

Figure 3. Optimization of combination of parameters L and K, using a class interval of 2 mm, of lip-thickness of milk conch, *Strombus costatus*.

Table 2. Growth parameters obtained using methods from ELEFAN I and Wetherall of an adult population of milk conch (*Strombus costatus*), based on lip-thickness frequency data.

Parameters	ELEFAN I	Wetherall
K	0.086	0.54 *
L	43.76	30.59
C	0.6	-
WP	0.11	-
Rn	0.144	-
Z/K	-	1.66

Note: * Considering the value of Z in the catch curve.

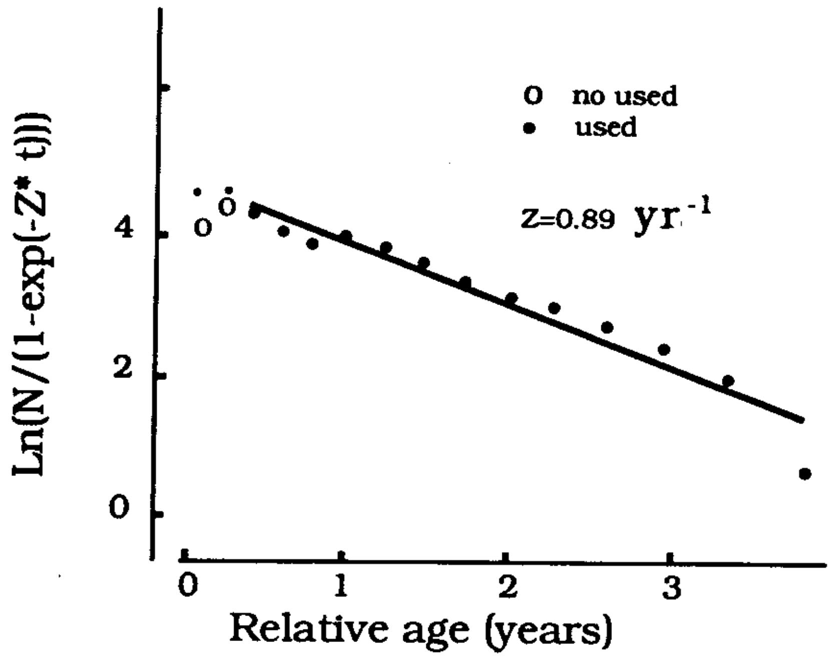

Figure 4. Catch curve, using selected points to estimate the value of Z, for the milk conch, *Strombus costatus*.

With these mortality results, the exploitation rate (E) was estimated as E = F/Z = 0.486/0.886 = 0.549. Using this strategy, the rate of exploitation indicates that the resource is overexploited even after the fishery has been closed for two years. This indicates that the resource has not been able to recuperate due to illegal fishing or from other factors.

Another important aspect to consider is that Gulland (1971) suggests that the level of optimum exploitation (E_{opt}) is reached when F = M at the point of maximum sustainable yield (MSY) and consequently when E = 0.5. This indicates that the population should be maintained at a maximum level of production, when the level of exploitation is under optimum conditions. However, Francis (1974) mentioned that the relationship is not always maintained, so if it is considered that in the tropics the rates of mortality tend to be higher, then the value of M could be overestimated. This would indicate that at values less than E = 0.5, overexploitation would exist.

Recruitment Pattern

Two pulses of recruitment were observed. However, considering its seasonal reproduction which is relatively long, the recruitment pattern was considered unimodal, but skewed to the right, corresponding to the month of May and the other during October (Figure 6).

DISCUSSION

Growth parameters were obtained by selecting the optimum class interval which was 2 mm. This is considered adequate based on the growth lines passing through most of the peaks of the modes. However, the data are considered preliminary and must be compared with other studies using mark and recapture techniques which incorporate the growth increments according to Fabens (1965) and using the growth function of von Bertalanffy.

The parameters C and WP suggest moderate oscillations in growth, which is attributed to the fluctuations in temperature (with ranges of temperatures to 6 °C from personal observations). Longhurst and Pauly (1987) suggested that if intra-annual differences exist in temperatures greater than 10 °C, the expected values of C could be greater than unity. However, in this study it did not occur because the value of C was equal to 0.6.

The growth parameters obtained by ELEFAN I and which were utilized for estimating natural mortality (M) by Hoenig's empirical formula were considered most adequate. Taking into account this natural mortality and the total mortality (Z) estimate of the catch curve, the rate of exploitation established that the resource is overexploited, even after the fishery has been closed for two years. It is suggested that the instantaneous mortality rate parameters obtained by the catch curve and the natural mortality obtained by Hoenig's empirical formula be compared to mark and recapture methods such as the multiple method of

Table 3. Mortality parameters and exploitation rates obtained using ELEFAN II and the empirical formula of Hoenig of an adult population of milk conch (*Strombus costatus*), based on results of ELEFAN I and Wetherall.

Parameters	ELEFAN II	Hoenig
Z	0.89	-
F1	-	0.49*
F2	-	0.19**
M1	-	0.4 *
M2	-	0.7 **
E1	-	0.55*
E2	-	0.21*

Nota: * Based on results of ELEFAN I.
** Based on results of Wetherall.

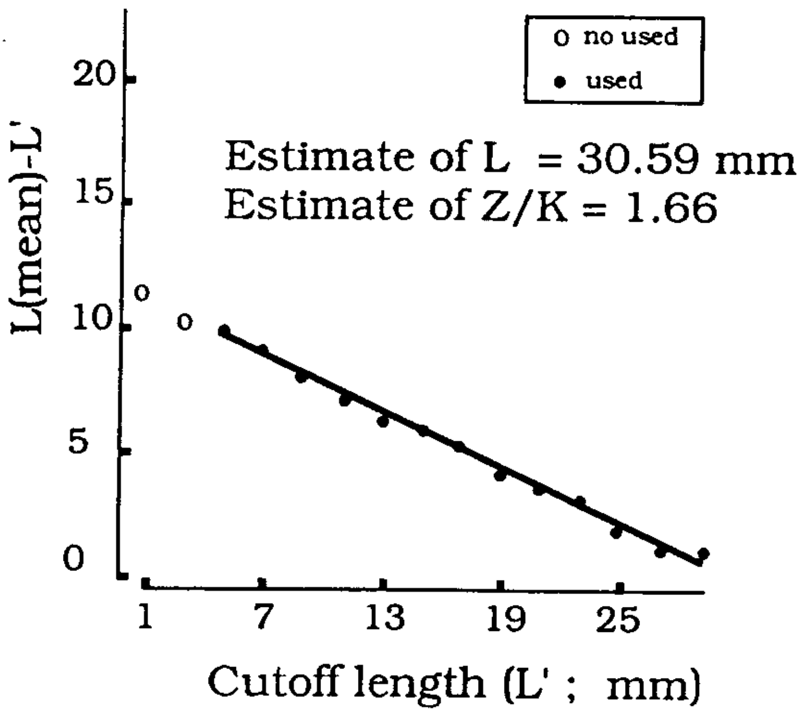

Figure 5. Wetherall's graphic method to estimate L and the value of Z/K, for the milk conch, *Strombus costatus*.

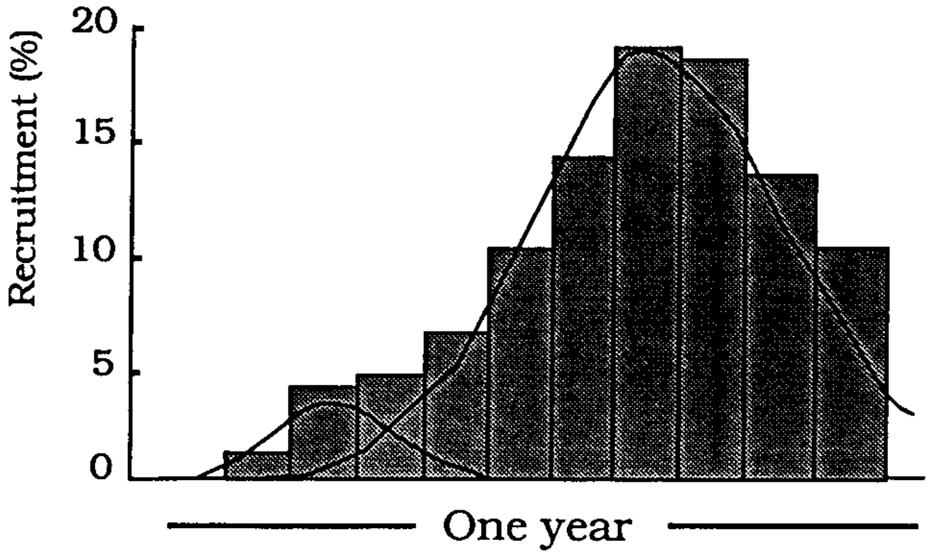

Figure 6. Annual recruitment pattern for milk conch, *Strombus costatus*.

Jolly-Seber used by Appeldoorn (1987 and 1988) with queen conch, *Strombus gigas*.

Considering the situation of the closed fishery and that only the length measurements could be obtained (lip-thickness) by means of experimental fishing to establish the status of the population rather than the yield, effort, etc., then the use of length frequency data, in this case, is a powerful tool to estimate the existing status of this fishery.

The overexploitation indicates that even though the fishery has been closed, the fishermen continue to exploit it. So they run the risk that as price increases, their catch will diminish drastically. In subsistence fisheries and with shortages of variable food sources, the entire species or even groups of species can be eliminated. All this can be accelerated by the adverse effects to the environment.

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