Growth of Queen Conch, *Strombus gigas*, In Xel-ha, Quintana Roo, Mexico

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ABSTRACT

Queen conch grow in shell length only until the onset of sexual maturity. Adults do not grow in shell length but in shell-lip thickness. Growth of juvenile and adult queen conchs was studied in a population off Xel-ha, Quintana Roo, Mexico over a nine month mark-recapture study. Data consisted of length and lip thickness increment information from recaptured individuals.

Growth was modelled using the von Bertalanffy growth function. The parameters k (growth coefficient) and L_∞ (asymptotic length) were estimated by two methods: 1) Gulland and Holt Plot, and 2) Fabens' least squares method. The third parameter, t0 cannot be estimated without specific size at age information. A total of 1,443 growth increments in length and 720 in lip thickness from 470 individuals were recorded and used for growth parameter estimation. Resulting parameter estimates with Fabens' method were comparable to literature values for other locations. Estimates for adult growth were high with both methods compared to other studies. The separation into two different life-history stages for this species was clear.

KEY WORDS: Queen conch, *Strombus gigas*, growth, Mexico

INTRODUCTION

The queen conch, *Strombus gigas*, is an economically important fishery resource in the Caribbean region. This has led to an expansion of conch fisheries, which has resulted in heavy stock exploitation throughout its distributional range. In Mexico, the most important stocks occur along the coasts of the state of Quintana Roo, where intense fishing activity, added to inappropriate regulations and ineffective enforcement have caused a significant decline in the conch populations. Rational management decisions need to be based on a solid understanding of the biology and demography of the populations under exploitation.

Individual growth is an essential component of the population dynamics of a species that undergoes fishing: stock biomass production, the age of first reproduction, the age of recruitment into the fishery, and the time it would take an overexploited stock to recuperate, are all highly dependent on the growth rate of the species.

The peculiar growth pattern that characterizes the species has been the subject of several studies (Randall, 1964; Berg, 1976; Alcolado, 1976; Iversen *et al.*, 1987; Weil and Laughlin, 1984; Appeldoorn, 1985, 1987, 1988, 1990, 1992, etc.). Conch grow in shell length only until the onset of sexual maturity, when the flared lip develops. Adult growth occurs as a progressive thickenning of the shell-lip (Appeldoorn, 1988). Previous studies have shown a high variability in growth among locations, and parameters from one population should not be extrapolated to other places. The purposes of this study are to contribute to the knowledge of such variability by taking into account the discontinuous individual growth pattern and to expand the available information on the queen conch populations that dwell the Mexican coasts.

METHODS

The study area, Xel-ha, is located in southeast Mexico, 110 km south of Cancun in the state of Quintana Roo. A small population of queen conch was found distributed between two main bodies of water: an inlet and a small semi-enclosed lagoon (200 m long and 50 m wide), formed by a branch of the inlet (Figure 1). The inlet area has a variable depth ranging between 2 and 4 m and consists of a sandy plain with occasional sea-grass patches and rocks covered with algae. The depth in the lagoon ranges between 2 and 5 m and the substrate is composed of fine sand and rocks covered with algae. The lagoon is practically isolated from the inlet, which prevents the exit of conch and the entrance of large predators. This, added to the ban of tourists and fishermen from the area, made it possible to conduct a tag-recapture study with a very high rate of recovery.

Sampling was conducted monthly from November 1990 to July 1991, resulting in eight sampling periods spanning nine months. A mark-recapture method was used for data collection. The area was surveyed by scuba divers and all data were collected in situ. Attempts were made to cover the largest possible area by using specific search patterns in both sampling sites. All queen conchs were tagged when initially encountered by tying a numbered steel plate to the shell spire with a nylon string. Upon each encounter, numbers were recorded and individuals measured for siphonal length and shell lip-thickness. Length was measured to the nearest 1 mm from the tip of the spire to the end of the siphonal canal using a plastic ruler attached to a specifically designed plexiglass measuring board. Shell thickness measurements were taken at the central part of the lip, using calipers, and to the nearest 0.05 mm. In addition, qualitative observations were recorded regarding the degree of development of the flared lip of each tagged and measured individual. These were used along with the shell dimensions as external indicators of sexual maturity to classify the conchs into juveniles, transitional individuals, and adults.

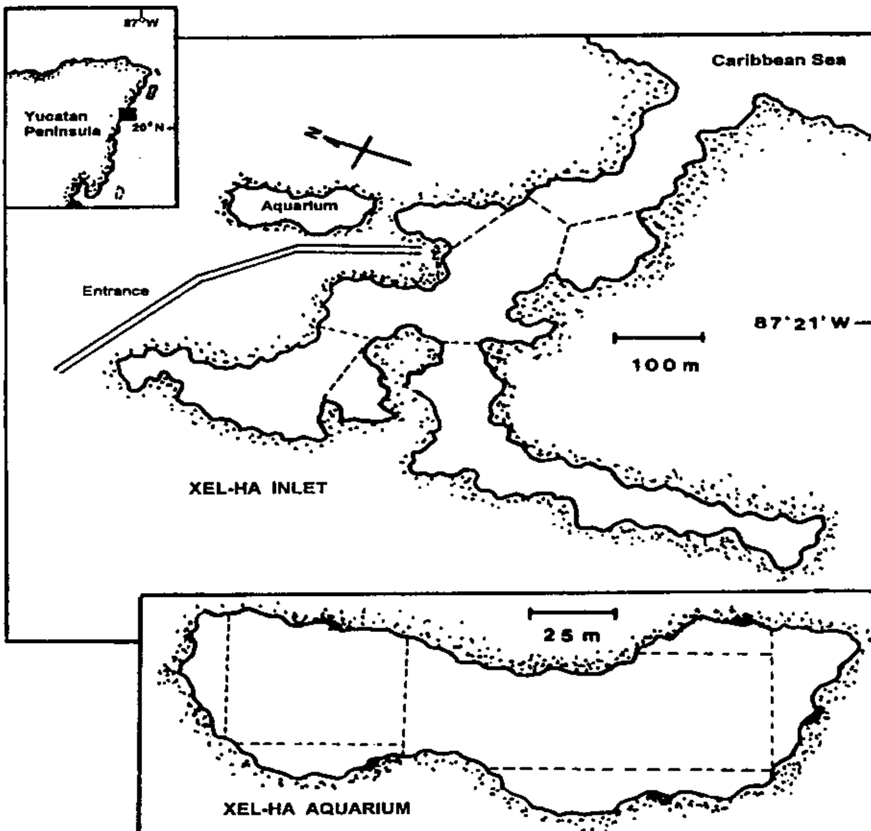

Figure 1. Study site - Xel-ha inlet and aquarium.

The primary data used in this study consisted of growth increment information from recaptured individuals for each sampling period, and of qualitative inferences about the maturity group to which they belonged. This allowed the assessment of growth in length for juvenile conchs and of growth in shell lip-thickness for the adult population. Multiple recaptures of the same individual were treated in the analysis as if they were independent observations.

The von Bertalanffy growth function (1938) was used to model growth in juveniles and adults separately, using length-increment data and lip-thickness increment data respectively,

$$l_t = L_\infty(1 - e^{-k(t-t_o)}) \qquad (1)$$

where lt is the length/lip thickness (mm) at time t (years), (mm) is the maximum length/lip thickness toward which growth tends, k is the instantaneous growth coefficient, and t0 is the hypothetical age at which length/lip thickness equals zero. This parameter is important for estimating size at age, but cannot be calculated from size-increment data alone. It was assumed to be zero for both, juveniles and adults.

The growth parameters and k were estimated using two distinct approaches: (1) Gulland and Holt's (1959) graphical procedure and, (2) Fabens (1965) mark-recapture analysis. Both methods are applicable to growth-increment data obtained at equal or unequal time intervals. A plot of growth increments on average sizes (length or lip thickness) follows a linear trend and is represented by the equation

$$\frac{\Delta L_t}{\Delta t} = kL_\infty - k\,\overline{l_t} \qquad (2)$$

where Δl_t is the growth increment over the time interval between observations ($\Delta_t = d$) in days, k = - slope of the line, $\overline{l_t} = \frac{l_t + l_{(t+a)}}{2}$, and = $L_\infty = \frac{Intercept}{-Slope} = \frac{kL_\infty}{k}$. Estimation of model parameters was made by linear regression of Equation 2 using JMP (SAS Institute, 1995). Occasionally this method yields unreasonable estimates of model parameters, particularly when average size values are few or when the range of sizes is too small (Pauly, 1982). This was the case for adult conch lip-increment data, so a Forced Gulland and

Holt method (Pauly, 1992) was used to estimate k:

$$k = \frac{\overline{y}}{(L_\infty - \overline{x})} \qquad (3)$$

where $\overline{y}$ is the mean of all $\frac{\Delta L_t}{\Delta t}$, $\overline{x}$ is the mean of all $\overline{l_t}$, and L_∞ is a predetermined value for the asymptotic lip-thickness. A bibliographic value of 54.9 mm (Appeldoorn, 1988) was assumed for $L_{(\infty)}$.

The form of the von Bertalanffy growth model appropriate for fitting tag-recapture data is, as described by Fabens (1965),

$$i = (L_\infty - l_1)(1 - e^{-kd}) \qquad (4)$$

where i is the size increment, l1 is the size at release, and d is the time between measurements (days). Parameter estimation was made by nonlinear least-squares regression of Equation 4 using JMP.

RESULTS

A total number of 470 individuals were tagged in Xel-há. Figure 2 depicts the relationship between shell length and lip-thickness of 1265 pairs of data from the tagged conch and their multiple recaptures. The growth pattern is clearly divided into two stages: juveniles grow in length while maintaining a relatively constant lip thickness (ranging around 4mm), cease their growth rather abruptly (at lengths between 200 and 250 mm), and then grow by thickenning the shell.
A total of 1443 observations of growth increment in length and 720 of lip thickness from the 470 tagged individuals were recorded and used for growth parameter estimation. From these, 747 increments in length were recorded for juveniles and 387 for transitional individuals (juveniles 2), accounting for a total of 1,134 length increments for the juvenile population. However, increments in length were recorded for some adults as well, and they were incorporated in the analysis for comparative purposes. The increments in shell lip-thickness were used to assess growth in adults.

Linear regression and resulting parameter estimates for juveniles using Gulland and Holt's method are given in Tables 1 and 2, respectively, and plotted in Figure 3. Resulting estimates with Fabens' method are provided in Table 3, which also includes standard errors of the estimates. Adult growth parameters estimated with both methods are given in Table 4, and Gulland and Holt's plot is provided in Figure 4.

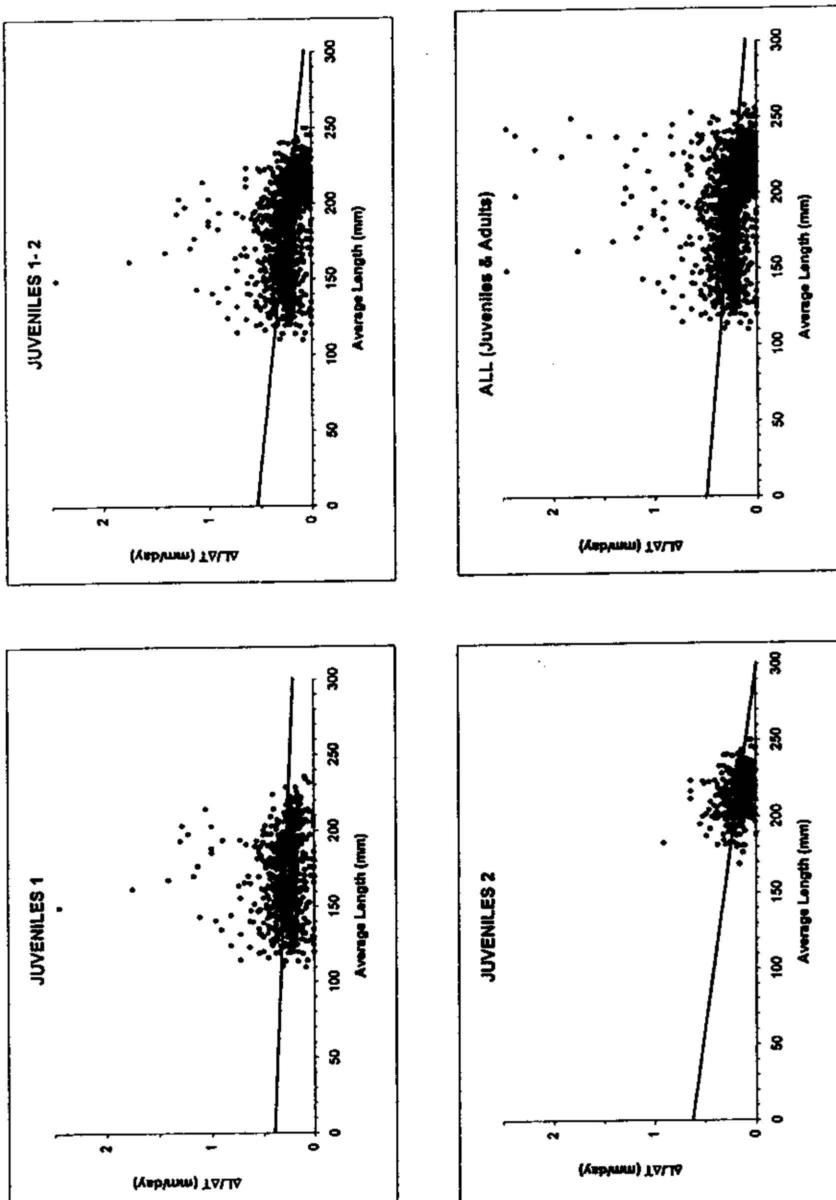

Figure 2. Alometric relationship between shell lip-thickness and shell length. All tagged individuals and recaptures are plotted.

Table 1. Linear regression estimates for growth in length using Gulland and Holt's method. Lengths are in centimeters, K was calculated using time in days.

Juveniles 1 Regression Output:		**Juveniles 1 and 2 Regression Output:**	
Constant	0.039744	Constant	0.05422
Std Err of Y Est	0.019538	Std Err of Y Est	0.01759
R Squared	0.008298	R Squared	0.07559
No. of Observations	747	No. of Observations	1134
Degrees of Freedom	745	Degrees of Freedom	1132
X Coefficient(s)	-0.00064	X Coefficient(s)	-0.0016
Std Err of Coef.	0.000258	Std Err of Coef.	0.00016
K=	0.000643	K=	0.0015864
L_{oo}=	61.79679	L_{oo}=	34.174343
JUV2- Transitional Juveniles Regression Output:		**ALL-(Juveniles1,2, Adults) Regression Output:**	
Constant	0.062492	Constant	0.049584
Std Err of Y Est	0.012001	Std Err of Y Est	0.024035
R Squared	0.060188	R Squared	0.032433
No. of Observations	387	No. of Observations	1443
Degrees of Freedom	385	Degrees of Freedom	1441
X Coefficient(s)	-0.00211	X Coefficient(s)	-0.00132
Std Err of Coef.	0.000426	Std Err of Coef.	0.000189
K=	0.002114	K=	0.0013159
L_{oo}=	29.5643	L_{oo}=	37.6798825

Table 2. Parameter estimates for growth in length using Gulland and Holt's method.Asymptotic lengths are in millimeters.

	Juveniles 1	**Juveniles 2**	**Juveniles 1 & 2**	**All** (Juv1,2 and Adults)
L_∞	617.97	295.64	**341.74**	376.79
k(day)	6.43E-03	2.114E-03	**1.586E-03**	1.316E-03
k (year)	0.23	0.77	**0.58**	0.48

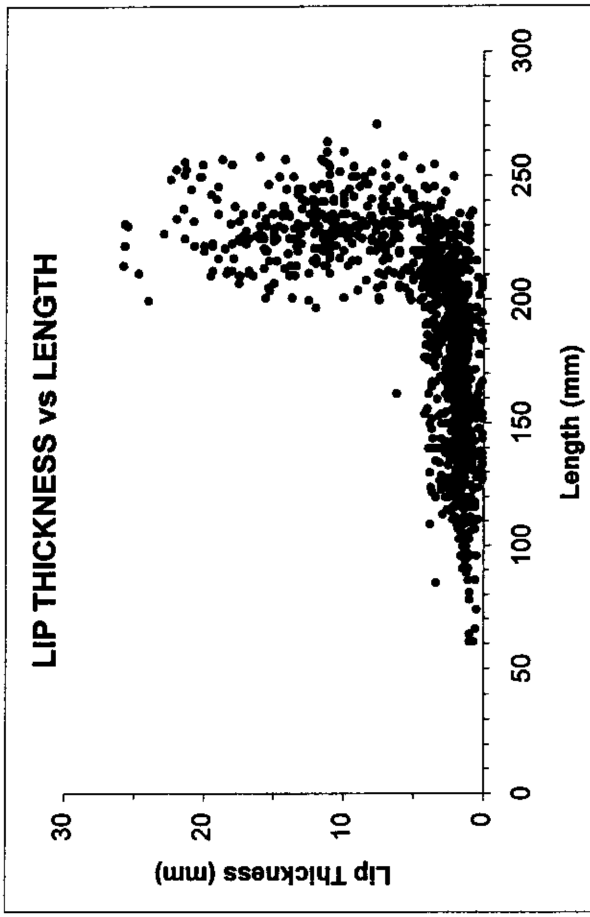

Figure 3. Gulland and Holt's plots for growth in length.

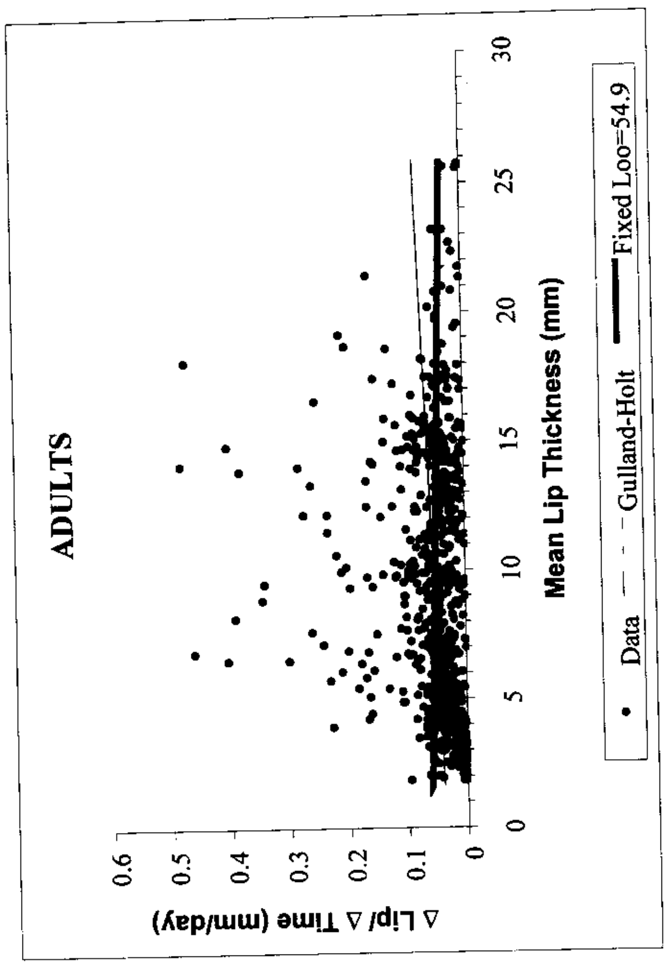

Figure 4. Gulland and Holt's plot for adult growth (lip-thickness).

Table 3. Parameter estimates for growth in length using Fabens' method. Lengths are in millimeters. Values in parentheses are standard errors.

	Juveniles 1	Juveniles 2	Juveniles 1 & 2	All (Juv1,2, and Adults)
L_∞	329.99	249.69 (2.86)	278.16 (3.78)	263.87 (2.47)
k(day)	1.58E-03 (1.37E-04)	4.11E-03 (3.3E-04)	2.34E-03 (9.82E-05)	2.73E-03 (9.46E-05)
k (year)	0.58 (0.05)	1.5 (0.12)	0.86 (0.036)	0.99 (0.035)

Table 4. Parameter estimates for adult growth (lip thickness) using the methods of Fabens and Gulland and Holt. Asymptotic lip-thickness is in millimeters. Values in parentheses are standard errors.

	Gulland-holt	Gulland-Holt Forced Method	Fabens
L_∞	-22.404	54.9 (Appeldoorn, 1988)	93.73 (49.08)
k(day)	-1.64E-03	1.12E-03	3.84E-04 (2.2E-04)
k (year)	-0.599	0.41	0.14 (0.08)

DISCUSSION

Both methods used to estimate the parameters for growth in length allowed to conduct separate analyses for each group of individuals (juveniles, transitional juveniles, all juveniles, and including adults). This was done for comparative purposes however, the parameters for the pooled juvenile group should represent juvenile growth for the Xel-ha population. The growth coefficient parameter (k) for the transitonal or large juveniles appeared to be the highest from the comparison among groups, while the asymptotic length was the lowest. This could mean either that older juveniles grow faster than the younger ones, or that, in fact, these large juveniles constitute a separate group of fast-growers. This has been reported for other areas (Berg, 1976; Alcolado, 1976; Appeldoorn, 1990) and has been interpreted as a sign that populations of large individuals near maturation are large because they grow faster, and not because they grow for a longer period of time. Additionally, fishermen in the area (pers. comm.) claim that there are two clear morphos: "small" conchs and "haysoles", or large conchs. Therefore, some small and large individuals near maturation may belong to the same age group.

With Gulland and Holt's method the estimates for growth in length in the group that includes adults fall within the ranges reported in the literature (see Appeldoorn 1990, Table1). Nevertheless, length increments in adults can most certainly be attributed to sampling errors and should not be incorporated in the analyses. The analysis of the pooled juvenile group indicates a high growth rate and asymptotic length, which are only comparable to those reported by Alcolado (1976) for some populations in Cuba, and by Berg (1976) for St. John, USVI.

All asymptotic length estimates using Fabens' method are comparable to literature values for other locations. However, growth rates are too high. This may be a consequence of using only positive growth increments in the analysis, which is an important assumption of the method. Therefore, parameter estimates with both methods are relatively high compared to other locations. This could be attributed to high and constant temperatures throughout the year, which is known to speed up the feeding and metabolic rates of these organisms and is translated into high growth rates (Alcolado, 1976). It is important to note that seasonality in growth was not accounted for in this study, since it is known from other sources (Alcolado, 1976; Weil and Laughlin 1984) that seasonal variation in juvenile growth is not large.

Gulland and Holt's graphical procedure did not yield reasonable estimates of adult (lip-thickness) growth parameters due possibly to insufficient data or a small range of lip sizes. On the other hand, estimates obtained with Fabens' method are within the ranges of reported values. Clearly, these methods work with juveniles but lip-thickness must be assessed with caution and over longer periods of time. Additionally, it must be considered that Gulland and Holt's is a graphical procedure, so the statistical significance attained through analytical methods such as Fabens' is higher.

This study contributes to the knowledge of the growth pattern of the populations of *Strombus gigas* in Quintana Roo and Mexico, and should be valuable for future stock assessments and for the development of fisheries management strategies.

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