Growth of Juvenile Queen Conch, Strombus Gigas L., Off La Parguera, Puerto Rico

Richard S. Appeldoorn
Department of Marine Sciences
University of Puerto Rico
Mayaguez, Puerto Rico 00709

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Short Title: "Growth of juvenile queen conch"

Key Words: queen conch, Strombus gigas, growth, Puerto Rico

ABSTRACT

Queen conch grow in shell length until the onset of sexual maturation. Growth in shell length of juvenile queen conch was studied over a two-year period in a population at 17 m depth off southwest Puerto Rico. Parameters of the von Bertalanffy growth model were determined using two types of data: length-at-age obtained from from length-frequency analysis, and growth increments. Resulting parameters were, respectively, $\underline{L}_8$= 340 mm, K = 0.437, $\underline{t}_o$ = 0.462 and $\underline{L}_8$= 460 mm, $\underline{k}$ = 0.250, $\underline{t}_o$ = 0.244. Model parameters from the two types of data are significantly different and are felt to reflect differences in the nature of the respective data. Both models give good fit to the age-length data and can be used for predictive purposes. Predicted ages for the onset of sexual maturation (length = 240 mm) are 3.19 yr and 3.28 yr for the growth-increment and age-length models, respectively. The high values of L. relative to mean adult length are reflective of the fact that growth at maturation does not stop, but only changes in form, with subsequent shell growth resulting in a thickening if the adult's flared shell lip.

INTRODUCTION

The queen conch is one of the most prized fishery resources in the Caribbean. As a consequence, much attention has been given to its biology, ecology and fisheries potential. Growth has been the subject of various studies. Conch grow in shell length only until maturation. At this time the flared shell-lip, characteristic of the species, is formed. Subsequent shell growth occurs as a progressive thickening of the shell-lip (Appeldoorn 1988). Because of this change in mode of shell growth, most studies have concentrated on growth of juveniles. Randall (1964) presented data on juvenile growth in shell length from tagging studies in St. Johns, U.S. Virgin Islands. Berg (1976) used this and other data to develop von Bertalanffy growth models of juvenile shell growth. Hesse (1976) developed a growth trajectory for conch at Turks and Caicos. Alcolado (1976) used length-frequency analysis and tagging studies to model shell growth in a number of populations from Cuba. Strasdine (1988) reported similar work in Belize. Iversen et al. (1987) calculated von Bertalanffy parameters for conch in the Bahamas. Weil and Laughlin (1984) gave growth trajectories of marked individuals from Los Roques, Venezuela, but did not determine model parameters.

Comparison between areas has shown growth to be markedly variable, both in rate of growth and in time to, and size at, maturation (Tables 1 and 2). Such variability is due, in large part, to local environmental factors (Alcolado 1976).

Growth and population dynamics were studied in a Strombus gigas population off southwest Puerto Rico over a 2-year period (Appeldoorn.J 987a, 1988). This paper reports on juvenile growth for this population.

METHODS

The study site was located 7 km south of La Parguera, P.R. and consisted of a broad, patchy sand and macroalgal plain with occasional patch reefs. Depth was approximately 17 m, and temperature ranged from 25.5 °C to 29.5 °C. Sampling ran from August 1983 to August 1985 and was conducted quarterly, generally in the latter half of August, November, February, and May, resulting in a total of nine samples. Attempts were made to locate a minimum of 200 individuals (juveniles and adults) for each quarterly sample. Further details on sampling are given in Appeldoorn (1987a).

All individuals, when initially encountered, were tagged using 4.5-cm strips of numbered Dymo label tarpe tied to the shell spire with nylon line. Upon each encounter, numbers were recorded and individuals measured for shell length (tip of the spire to end of the siphonal canal) to the nearest 1 mm, in situ, using calipers.

Data thus consisted of growth increment information from recaptured individuals and of length-frequency distributions for each sampling period. Only data from juveniles are considered here.

Growth was modelled using the von Bertalanffy growth function,

$$l_t = \underline{L}_{\infty}(1 - e^{-\underline{k}(t-\underline{t}_o)}) \quad (1)$$

where l_t is length (mm) at time t (years), $\underline{L}_{\infty}$ is asymptotic length (mm), and $\underline{k}$ is the growth coefficient. The parameter $\underline{t}_0$ is a location parameter and is defined as the hypothetical age at which length equals zero assuming that extrapolated early growth follows the von Bertalanffy model. This parameter does not convey information on growth rate, but is essential for estimating size at age.

For growth increment data, the von Bertalanffy equation is recast in the following form (Fabens 1965):

$$i = (L_{\infty} - l_1)\,(1 - e^{-kd}) \qquad (2)$$

where i is the growth increment, l_1 is the length at release, and d is the time between length measurements. Estimation of model parameters was made by nonlinear least-squares regression of Equation 2 using SYSTAT (Wilkinson 1987), which also gives standard errors of the estimates. This method cannot estimate t_o without specific size-at-age information (see Results). The analysis treated multiple recapture measurements made on individuals as if they were independent. In these cases, the increment used for each recapture was over the time period from initial capture, as opposed to most recent previous recapture. Multiple recaptures made up 10 % of the data.

To compensate for small sample sizes, length-frequency data were pooled by season, resulting in four samples. However, only samples from August, November and February were used. Data from May were felt to be unsatisfactory because significant partial recruitment and partial maturation within year classes affected the frequency distribution (Appeldoorn 1987b). Underlying distributions were determined using Akamine's (1985) method, a nonlinear, maximum-likelihood technique. In total, 1124 measurements were included in the analysis. This yielded a total of 8 estimates of mean length at time. Coupled with resulting standard deviations and number of individuals per year class, these were used to generate 1124 observations of length at time. Corresponding ages were calculated assuming a birth date of July 1, the approximate midpoint of the spawning season. Resulting length-at-age data were used to calculate von Bertalanffy parameters by nonlinear regression of Equation 1 using SYSTAT. This procedure allowed all the variability contained in the data to be incorporated into parameter estimation.

RESULTS

A total of 187 growth increments from 168 individuals were recorded and used for growth parameter estimation. A total of 1416 measures of shell length of juveniles were taken. Length-frequency distributions from all nine samples are given in Figure 1. Resulting estimates of length-at-age are given in Table 3 and plotted in Figure 2. Also plotted are the resulting von Bertalanffy curves for the two methods. Parameter values for the models are given in Table 4. The estimate of t_o for tagging data was approximated by substituting the growth-increment derived model parameters (L_8, k) into Equation 1 and fitting the model to the length-at-age data obtained from length-frequency analysis. The nonlinear regression was solved for t_0 using SYSTAT.

DISCUSSION

No attempt was made to account for seasonality in growth. It is known from other studies (Alcolado 1976, Well and Laughlin 1984) that juveniles do show seasonal growth, but that seasonal variation in growth is not large. As such, it was felt the use of more complicated models was unwarranted. Nevertheless, a seasonal pattern in growth is indicated in the age-length data. Data points from February (minimum water temperature) are low, while points from August and November (maximum water temperature) are high, relative to the predicted growth curve.

Both models predict an $\underline{L}_8$, substantially higher that the mean or largest adult sizes observed from the La Parguera population, 240 mm and 283 mm, respectively. A general rule of thumb is that $\underline{L}_8$ should be roughly 95% of the maximum observed size (Beverton 1954, in Sundberg 1984, Pauly 1980). The discrepancy, here, lies in the fact that conch continue to grow after maturation, but not in shell length (Appeldoorn 1988). Thus, the extrapolation of the curves toward $\underline{L}_8$ represents potential growth in length had shell growth continued in the same manner and had energy not been utilized for reproduction.

Using the calculated confidence limits, it is evident that the differences in parameters between the growth-increment and age-length models are statistically different. This is felt to be due to differences in the nature of the data used for the two models, particularly at lengths near maturation. Being at one extreme of the data, these points exert greater influence during regression than points within the midrange of data. An effort was made to eliminate data from the length-frequency analysis obviously subject to partial year-class maturation (Appeldoorn 1987b), and the largest year-class mode used in the analysis was at 230 mm, 10 mm below mean adult length. However, all data for tagged juveniles were used; growth-increment data included juvenile growth up to 254 mm. Furthermore, Alcolado (1976) presented data indicating that populations of large individuals at maturation are large because they grow faster, and not because they grow for a longer period of time. Thus, on the one hand, growth-increment data tend to show continued growth near maturation, resulting in a higher $\underline{L}_8$ and lower $\underline{k}$, while on the other hand age-length data did not show this, and, in addition, they, man have been affected in an opposite manner by the fact that the last (largest length) data point came from February, and its mean length may be suppressed due to low winter growth. This would tend to lower $\underline{L}_8$ and increase $\underline{k}$.

In the most practical sense, both models give a good fit to the known age-at-length data. Thus, they can be used equally well for predictive purposes, either for growth rate or length-at-age, within the range of data. Predicted ages at the mean adult size of 240 mm were similar, at 3.19 yr and 3.28 yr for the growth-increment and age-length models, respectively. Note should be taken of the magnitude of $\underline{t}_o$. This parameter is necessary if the growth-increment model is to be used to predict length-at-age. Some previous studies have not been able to incorporate t_0 into their predictions (e.g. Berg 1979, Wood and Olsen 1983). The fact that $\underline{t}_o$ here is positive indicates the presence of an early inflection point in growth.

Relationships useful for converting length to shell weight, wet tissue weight, and wet meat weight (after removal of the visceral mass) for juveniles in the La Parguera population were given by Appeldoorn (1988). Using these, the von Bertalanffy models can be further used to investigate potential fisheries yield. However, it is clear that extrapolated $\underline{L}_8$, values should not be used, via conversion equations, to generate values of asymptotic weight, $\underline{W}_8$, for yield-per-recruit calculations as has been done in the past (Wood and Olsen 1983, Berg and Olsen, in press). At a minimum, such an extrapolation would not account for the lost proportion of energy channeled to reproduction. It is also possible that decreases in adult shell-volume (Randall, 1964) could adversely affect adult tissue growth. A more appropriate approach would be to model adult growth directly (Appeldoorn 1988).

ACKNOWLEDGEMENTS

I wish to thank all those who aided in data collection, particularly D.L. Ballantine, A.T. Bardales, J.Colley, G. Gonzalez, I.M. Sanders, and Z.A. Torres. Bonnie Bower-Dennis drew the figure. This work was supported by the U.S. National Marine Fisheries Service (NA81-GA-C-00015).

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TABLE 1. Reported estimates of von Bertalanffy parameters for growth in shell length of juvenile *Strombus gigas* from the literature. Lengths are in millimeters, time is in years.

LOCATION	L_∞	k	t_0	SOURCE
Boca Chica, Belize	268.	0.223	-0.05	Strasdine 1988
Tres Cocos, Belize	332.	0.207	-0.33	"
Water Caye, Belize	269.	0.290	-	"
St. John, U.S.V.I.	260.4	0.516	-	Berg 1976
St. Croix, U.S.V.I.	241.7	0.420	-	"
Cabo Cruz, Zone A, Cuba	383.4	0.330	-0.05	Alcolado 1976
Cabo Cruz, Zone B, Cuba	380.6	0.287	-0.12	"
Diego Perez, Zone A, Cuba	232.7	0.429	-0.09	"
Diego Perez, Zone B, Cuba	207.6	0.442	-0.09	"
Cayo Anclitas, Cuba	259.8	0.571	0.09	"
Rada Inst. Oceanol., Cuba	334.0	0.360	0.13	"
Six Hill Cay, Turks & Caicos	256.0	0.563	-0.16	Appeldoorn et al. 1987*
Berry Islands, Bahamas	300.	0.200	-0.65	Iversen et al. 1987

*From Hesse (1976).

TABLE 2. For *Strombus gigas*, reported age (years) and mean shell length (mm) at the onset of maturation, defined as when growth in length ceases and the flared-lip begins to form.

LOCATION	AGE	LENGTH	SOURCE
Bermuda	4	-	Wefer & Killingley 1980
Bahamas	4+	193	Iversen et al. 1987
Turks & Caicos Islands	2.8	212	Hesse 1976
Cuba	3-4	173-234	Alcolado 1976
Belize	3	204	Strasdine
Puerto Rico	3.2	240	Appeldoorn 1988
St. John, U.S.V.I.	3	204	Berg 1976, Randall 1964
St. Kitts/Nevis	2.3-2.8	-	Wilkins et al. 1987

TABLE 3. Results of length-frequency analysis for juvenile Strombus gigas. Mean lengths and standard deviations are in millimeters, ages are in years, N is the number of individuals, and Date is the midpoint of each sampling period.

DATE	AGE	MEAN LENGTH	STANDARD DEVIATION	N
XI-21	1.40	117.9	12.36	47
II-21	1.65	133.5	13.08	108
VIII-21	1.90	163.7	16.34	231
XI-21	2.15	168.2	20.51	131
II-21	2.40	191.2	21.73	134
VIII-21	2.65	212.2	15.64	301
XI-21	2.90	223.4	16.29	112
II-21	3.15	230.7	10.89	60

TABLE 4. Estimates of von Bertalanffy parameters for growth in shell length of juvenile *Strombus gigas* from La Parguera, Puerto Rico. Lengths are in millimeters, time is in years. Values in parentheses are standard deviations. Value of t_o for the growth-increment model was estimated by fitting the model to age-length data (see text).

SOURCE	L_∞	k	t_o
Growth-Increment Data	460 (67.2)	0.250 (0.061)	[0.244 (0.025)]
Age-Length Data	340 (22.9)	0.437 (0.062)	0.462 (0.068)

FIGURE 1. Length at age and von Bertalanffy growth curves for juvenile Strombus gigas from Puerto Rico. A: growth curve derived from growth-increment data, B: growth curve derived from age-length data.

(Shell Length)