Growth and Mortality of the Queen Conch, *Strombus gigas*, in Florida

A Progress Report

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ABSTRACT

The von Bertalanffy growth curve parameters K and L_∞ and the total mortality coefficient Z were calculated for three nearshore and three offshore aggregations of *Strombus gigas* in the Florida Keys. Several models were used. Estimated values of L_∞ varied from 11.9 cm at Coffins Patch to 32.2 cm at Tingler's Island. The growth constant, K, ranged from 0.20 at Coffins Patch to 2.63 at Walker's Island. The mortality coefficient, Z, varied from 0.606 to 2.49. The Wetherall method incorporated into the ELEFAN 2B computer program was inappropriate for use with this species.

METHODS

Growth parameters and mortality rates are integral components of fisheries stock-assessment models (*e.g.*, Ricker, 1975; Seber, 1982; Gulland, 1983). Tag-recapture methodologies are accurate predictors of these parameters (Fabens, 1965; Ssentongo and Larkin, 1973; Ricker, 1975; Seber, 1982). Length-frequency data are also used to determine these parameters (Rosenberg and Beddington, 1988). Pauly and David (1981) developed a computer program (ELEFAN) that reduces the subjectivity inherent in length-frequency data analyses. The ELEFAN program has been used in modeling the growth of a variety of invertebrates and vertebrates (Pauly, 1987).

A problem inherent in accurately estimating these parameters for stocks whose growth is described by the von Bertalanffy equation is the determination of an appropriate L_∞ (Pauly, 1984). Ideally, the estimate of L_∞ reflects the asymptotic size of the stock under study. This is not always the case with gastropods in general (Sainsbury, 1980) and with *S. gigas* in particular (Alcolado, 1976; Appeldoorn, 1986).

Study sites were chosen in nearshore and offshore waters based, in part, upon the diversity of habitats and the disparate locations that the sites occupied. Nearshore sites typically had an abundance of macroscopic red algal and octocoral species. *Strombus gigas* was rarely found where *Thalassia testudinum* was present at the nearshore sites. Two offshore aggregations of *S. gigas*

(Molasses Reef and Looe Key) were located on reef flats where the benthos was typically dominated by *T. testudinum* and *Syringodium filiforme* interspersed with numerous sand patches. The third offshore aggregation (Coffins Patch) was located on a sand plain in water approximately 15 m deep.

Tag-recapture sampling was conducted at three nearshore sites (Walker's Island [N = 1378 conchs tagged], Tingler's Island [N = 796], and Big Pine Key [N = 1696]) and 3 offshore aggregations (Molasses Reef [N = 212], Coffins Patch [N = 1011], and Looe Key [N = 274]). The nearshore aggregations of *S. gigas* were sampled once every three months from March 1987 to October 1989. The aggregation at Coffins Patch was sampled monthly from January 1988 to October 1989, whereas the other two offshore aggregations were sampled on an infrequent, haphazard schedule. All conchs at the nearshore sites were double-tagged using one of the following:

- a numbered, stainless-steel clip tag (National Band and Tag, Newport, Kentucky, USA) inserted through a hole drilled through the shell on the lip of the aperture above the most anterior spine, and
- a numbered, plastic tag (Floy Tags, Seattle, Washington, USA) inserted over monel wire wrapped tightly around the shell's spire.

Conchs at offshore sites were tagged using only the second method.

The length of each conch was measured with wooden tree calipers calibrated to 0.1 in. Lengths were converted to the nearest cm for analyses. The Coffins Patch aggregation, because of the smaller size of individuals, was measured to 0.1 mm with dial calipers.

Tag-recapture and length-frequency data were analyzed independently to compare the derived estimates. Growth curves derived from the models were compared to empirical growth observations of individual conch. Length-frequency analyses for the nearshore aggregations were performed using the ELEFAN 1 computer program of Pauly and David (1981). ELEFAN 2B (Brey and Pauly, 1986), based upon the method developed by Wetherall (1986), was used to determine L_∞; the derived L_∞ was then inserted in Fabens' model (Fabens, 1965) to estimate the von Bertalanffy growth parameter, K.

The estimation of L_∞, the asymptotic maximum length of the stock, is critical in determining K, and in several models, the mortality constant, Z. A variety of methods were used to determine L_∞:

- $L_{max\ ever}$, defined as the largest observed individual for the species (*i.e.*, Bermuda, 32.5 cm);
- $L_{0.95}$, defined as the mean of the largest ten adults in the aggregation divided by 0.95 (Pauly, 1984);

- L_{CV}, defined as the mean of the K values derived for each recapture within an aggregation divided by the standard deviation and then determining the best fit iteratively; and
- L_W, determined from the Wetherall (1986) estimates of the ELEFAN 2B program.

In all instances, the parameter T_0 was set to 0.064 yr, the time at metamorphosis. Values of L_∞ ranged from 11.9 cm for the Coffins Patch aggregation analyzed using the L_W method to 32.2 cm at Tingler's Island using the $L_{0.95}$ method. For all aggregations, the $L_{max\ ever}$ of 32.5 cm was also used.

Tag-recapture data were entered into Fabens' model (Fabens, 1965) using the L_∞ derived from all methods. An estimate of K was made with each recapture using only those conchs that were initially tagged as juveniles. Values for K ranged from 0.20 for the Coffins Patch aggregation to 2.63 for the Walker's Island aggregation. Both of these estimates were obtained using the L_∞ derived from the L_W method (Wetherall, 1986). For the Walker's Island (K = 1.02) and Tingler's Island (K = 0.82) aggregations, the K derived using the L_∞ from the L_{cv} method correlated best with the empirical growth data. Time to maturation for these aggregations predicted by both the model and empirical growth data was approximately two years. These are the highest values for K reported for *S. gigas* from the Caribbean; however, this is not entirely surprising given the abundance of readily available food at these sites. For the Big Pine Key (K = 0.72), Molasses Reef (K = 0.79), and Looe Key aggregations (K = 0.57), the K derived using the L_∞ from the $L_{0.95}$ method correlated best with empirical observations. Time to maturation predicted using this model for these aggregations was three years. The Coffins Patch aggregation could not be analyzed using the $L_{0.95}$ method because all individuals were juveniles and, therefore, L_∞ could not be determined. The Wetherall method (Wetherall, 1986) was unsuitable at all sites because the curves produced from the derived parameters were inconsistent with individual growth data.

Tag-recapture estimates of the total mortality coefficient, Z, were obtained using two models: the Ssentongo-Larkin (1973) model and the Jolly-Seber model (Seber, 1982). Ssentongo and Larkin (1973) used tag-recapture data and parameters derived from Fabens' analyses (Fabens, 1965) in accordance with the previously described methods. This model was used on all aggregations. The Jolly-Seber model provides temporal estimates of Z for open populations using tagging data independent of growth parameters. It allows for immigration and emigration by treating them as births and mortality, respectively. Only the nearshore aggregations were analyzed using the Jolly-Seber model because of the limited number of tag returns elsewhere.

RESULTS AND DISCUSSION

Values of Z ranged from 0.408 for the Tingler's Island aggregation using L_∞ derived from $L_{max\ ever}$ to 2.49 for the Walker's Island aggregation using L_W. The Jolly-Seber model yielded values for Z ranging from 0.510 at Tingler's Island to 0.700 at Walker's Island. The L_∞ derived from $L_{max\ ever}$ inserted into the Ssentongo-Larkin model produced results most similar to the results obtained from Jolly-Seber analyses. Values of Z for the offshore aggregations derived using the $L_{max\ ever}$ method ranged from 0.673 at Molasses Reef to 0.981 at Coffins Patch. The apparent validity of the results using $L_{max\ ever}$ may be fortuitous; 32.5 cm may best fit the growth curve because of the determinate growth of *S. gigas*. Once again, the Wetherall plot within ELEFAN 2B produced results inconsistent with the other methods.

Our results suggest that the selection of an appropriate mathematical model is extremely important in producing values that most reflect the stock under study. Additionally, our data and that of Alcolado (1976) suggest that spatially isolated aggregations within the same stock can exhibit heterogeneity in growth. Because most yield models require input of growth and mortality data (*e.g.*, Ricker, 1975), careful selection of these criteria is essential.

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