A Method for the Estimation of the von Bertalanffy Growth Rate Parameter by Direct Examination of Otolith Microstructure

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ABSTRACT

A method is introduced which uses otolith growth rate to provide a direct estimate of K, the von Bertalanffy growth rate parameter. We obtained estimates of K of 1.078 $\pm$ 0.687 y^{-1} and 0.621 $\pm$ 0.076 y^{-1} for the queen snapper, *Etelis oculatus*, by two variations of the method. There is no significant difference between the two estimates of K, or with an earlier value estimated with the use of ELEFAN 1. We suggest that this method may be used where otolith microstructure analysis does not allow for ageing the fish either by conventional counting of rings or even by analysing the width of growth increments. We acknowledge that from a statistical perspective, with one of the variations we may have violated the assumption regarding the independence of the observations used in the linear regression. Notwithstanding this, we propose that estimates of K by this general method can, at least, be a starting point or seed value for the use in other length-based methods.

KEY WORDS: *Etelis oculatus*, Growth rate parameter, otolith analysis

INTRODUCTION

Changes in otolith size, with few exceptions, are thought to closely reflect the somatic growth rate of fish, an observation which is of critical importance for studies of fish age and growth at the annual and daily levels of precision (Campana and Neilson 1985). Recently, workers have attempted to use the property of isometric growth with respect to somatic growth to develop approaches for investigations of age and growth which do not rely on conventional techniques for otolith microstructure examination. The latter techniques often involve complete enumeration of all increments along a standard axis of the otolith, a task which has proven difficult in older fish and in otoliths which have complex growth patterns.

Ralston and Miyamoto (1983) and Ralston (1984) have suggested that one can estimate the average width of daily increments at various points in the otolith, and an estimate of this rate and total length of the otolith would allow one to estimate the age of the specimen by dividing the otolith length by its rate of growth. It is suggested (Ralston 1984) that this procedure works well if one takes into account otolith and fish size. Ralston and Miyamoto (1983), while admitting that some of the precision theoretically possible with daily increments is sacrificed in using this method, have suggested that it provides a reasonably reliable estimate of age.

This essay suggests a method for directly calculating von Bertalanffy growth rate parameter, K, based on a study of otolith growth rate for *Etelis oculatus* Val. landed at Vieux Fort in the south of St. Lucia during 1987. Consistent with the Ralston and Miyamoto (1983) method, we wished to develop an approach which did not entail complete enumeration of growth increments along a given radius of an otolith. Our suggested technique differs from that of Ralston and Miyamoto in that a direct estimate of K is derived rather than an estimate of age. In the latter case, further computations would be required to arrive at an estimate of K. The occasional inability to detect all growth increments using a light microscope (Morales-Nin 1988) means that otolith microstructure may not always give results that can be used directly for obtaining age-at-length. Thus, if the researcher is only able to easily access light microscopy, as may often be the case in developing countries, a reasonable estimate of the growth rate parameter can nonetheless be obtained.

METHODS

The Gulland and Holt plot (Gulland and Holt 1959) is a length-based method of von Bertalanffy growth parameter estimation which provides estimates of L_∞ and K through the feature that the difference between successive lengths of a fish, when divided by the difference in the corresponding ages can be plotted as a straight line against the mean of the successive lengths, with the modulus of he slope of the line being equal to K, L_∞ being the ratio between the y-intercept and the modulus of the slope. The method finds use when continuous growth lines cannot be traced, or when only unequal time intervals (for example, those that may be obtained from tagging and recapture data) are available (Pauly 1983).

Measurements taken for the Ralston and Miyamoto method on otolith thin sections (Figure 1) are used in a "quasi-Gulland and Holt" plot (after Murray 1989) wherein the regression of the otolith growth rate, assuming increments to be daily, for a given segment of the otolith against the distance of the mid-point of that segment to the focus of the otolith is calculated. This is done for all otoliths where at least two segments had been measured and where it could be seen that the otolith growth rate decreased with increasing distance from the nucleus. The absolute value of the slope of this curve is considered to be equal to K for that fish *(ibid.)*. Initially, the estimates of K were averaged over all the individual otolith determinations. For comparison, the regression was also done with the segments from all the otoliths (in other words, all nine fish) pooled into one regression. The two estimates of K thus obtained were in days $^{-1}$, and converted to years $^{-1}$ by multiplying by 365.25.

RESULTS

Table 1 is a summary of the otolith growth rate analysis for *Etelis oculatus* (after Murray, 1989). When data from the otolith thin sections of *E. oculatus* were used individually and the mean value of K, at the 95% confidence level calculated, the value obtained was 1.078 ± 0.687/year. The value obtained when the segments from all the otoliths were pooled (Figure 2) was 0.621 ± 0.076/year (dL/dt = 5.738 - 0.0017 L; n = 34; K = 0.0017 x 365.25). There is no significant difference (t_{calc} = 1.627; $t_{0.05(2),6}$ = 2.447) between the two estimates of K. The mean value of K estimated from the individual regressions is also not significantly different (t_{calc} = 1.310; $t_{0.05,(2),6}$ = 2.447) from the average of 0.71/year obtained (Murray, 1989) with the use of ELEFAN I (Gayanilo et al. 1988).

DISCUSSION

The "quasi-Gulland and Holt" plot may be a way of estimating K where otolith microstructure analysis does not allow for either conventional counting of rings or when the growth marks are not seen clearly enough for use of the Ralston and Miyatmoto method (1983). Such a circumstance may arise where, having attempted one of the "usual" methods it is found there is, for example, unevenness in the incremental plane such that increments cannot be observed clearly all along the otolith radius being used. This method can also be used where the data available for input into one of the length-based methods such as the ELEFAN I, Shepherd (1987), Ebert (1987), or Damm (1987) methods are such that there would be difficulty deciding among (say) multiple maxima, or was otherwise not of a quality that would allow them to be used without some type of "seed" value with which to start. If a few otoliths are available, our suggested method could then provide an estimate of K to serve as such a starting point or seed value.

Like other techniques of otolith microstructure study, our method may be considered to be limited by the assumption as to the periodicity of increment deposition. Additionally, if growth fluctuates on a seasonal basis, results may be biased if increments were selected from one part of the seasonal cycle only. It would seem likely that the period of faster growth, and hence more noticeable increments, could be chosen, thus leading to an overestimation of the growth rate parameter. To avoid this, it would be advisable to choose the segments at random.

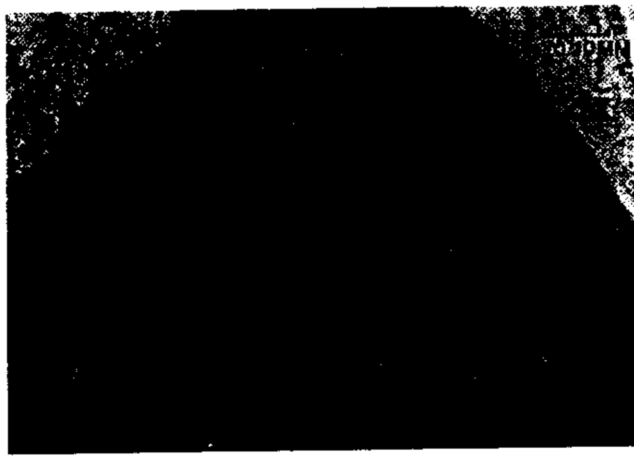

Figure 1. Photomicrograph of sagitta of *Etelis oculatus*.

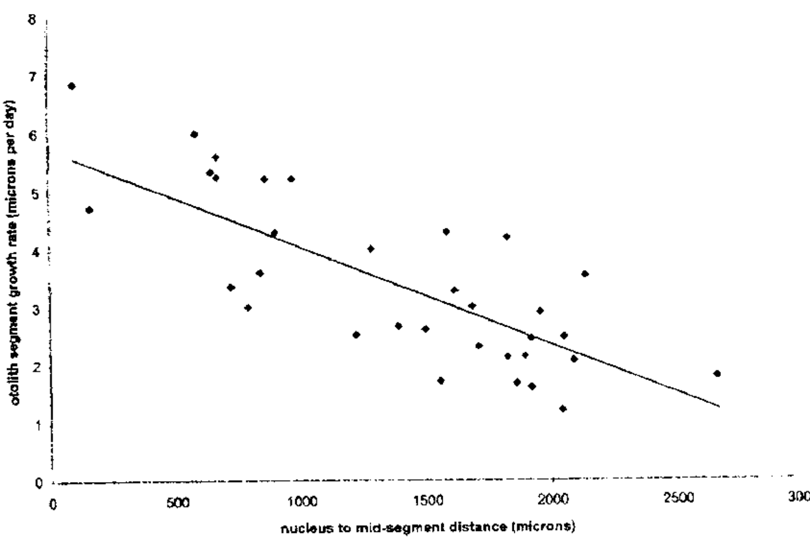

Figure 2. Graph showing otoliths segment growth rate versus nucleus to mid segment distance.

Table 1. Summary of growth rate analysis for *E. oculatus*. Individual estimates of growth rate parameter are shown

Length		# of Rings dt	Width of Segment dL (µm)	Otolith Growth Rate dl/dt (rings/day)	ln dL/dt	Nucleus to Mid-segment Distance l (µm)	K (per year)
Total Length of fish (mm TL)	Otolith length L (µm)						
570	2033	28	192	6.857	1.89	96	---
763	3216	17	432	25.412	3.235	286	(--)
		14	108	7.714	2.043	913	
577	2390	28	48	1.714	0.539	1558	1.549
		9	48	5.333	1.674	648	
		23	120	5.217	1.652	864	
452	3554	16	84	5.250	1.658	672	0.745
		30	120	4.000	1.386	1284	
542	1854	30	168	5.600	1.723	672	
		10	60	6.000	1.792	588	

Table 1 continued:

674	1944	42	180	4.286	1.455	1584	2.593
		43	180	4.186	1.432	1824	
		45	96	2.133	0.758	1896	
		30	48	1.600	0.470	1920	
635	1475	20	72	3.600	1.281	840	0.537
		14	60	4.285	1.455	900	
		23	120	5.217	1.652	972	
		19	48	2.526	0.927	1224	
		9	24	2.666	0.981	1392	
		54	132	2.444	0.894	1920	
		20	24	1.200	0.182	2040	
		17	60	3.529	1.261	2136	
632	2145	33	156	4.727	1.552	156	0.489
		25	84	3.360	1.212	720	
		20	60	3.000	1.099	792	

Table 1 continued:

		20	60	3.000	1.099		1686	
		36	60	1.667	0.511		1860	
763	2090	14	60	2.609	1.455		1500	0.555
		17	36	2.118	0.750		1824	
763	2755	11	36	3.272	1.186		1615	0.416
		52	120	2.308	0.836	1710		
		58	168	2.897	1.604	1957		
		17	42	2.471	0.905	2052		
		35	72	2.057	0.721	2090		
		130	231	1.777	0.575	2660		

Key: – used in pooled version of plot, but not for calculation of individual K values
(–) not used in calculations of mean K value from individual calculations, neither used to calculate "pooled"
K value: obvious outlier

It should be noted that Ralston and Miyamoto (1983) attempt to derive an absolute -- the age of the individual fish. In such circumstances, precise and accurate knowledge of increment deposition rates are more crucial than for the estimation of a population parameter that is itself a mean value having a finite variability. Further, in this method the value used to estimate K is a slope and hence it is only if the time represented by one increment varies within any given otolith, that one would expect significant changes in the value. Our method has analogies to length-based approaches; in fact, the very name "quasi-Gulland and Holt plot" is suggestive of that fact. This implies that the theory derived for length-based methods could apply to this method. Thus, we note Isaac's (1990) suggestion that at least three length-based methods give accurate estimates of K when individual variability of this growth parameter is small (< 20%). Applying her observation to this method, the smaller variability, and therefore greater precision, of the growth rate parameter estimate derived by our pooled-segment determination makes it the preferable form of the method. We suggest that in this form, the method also provides a population estimate for K.

Given the possibility of underestimating the periodicity of increment deposition, a corresponding overestimate of K would not be surprising. The estimate of K obtained with our proposed pooled segment approach technique are comparable with Murray's (1989), but are among the highest recorded by Manooch (1987) in his comprehensive review of age and growth studies of tropical snappers and groupers. Manooch's (*ibid.*) review included values of K for snappers (but not including any estimate for *Etelis* sp.) ranging from 0.090 - 0.370/year. A more recent determination of K = 0.40/year for queen snapper has been made by Murray and Moore (1992).

The large, though not statistically significant, difference between our two estimates is noteworthy. This may in part be related to the high variance associated with the estimate obtained when using the mean of K values calculated from the nine otoliths. We acknowledge that from a statistical perspective we violate an assumption of linear regression with the approach using all individual segments, since they are not truly independent observations. The approach of using one datum from each fish may be better in this regard.

Consideration of the strengths and weaknesses of the two variations on the "quasi-Gulland and Holt" approach also begs the question of whether, to obtain an estimate of K that is representative over the life of the fish, the data collection should be length-stratified in some manner, or whether length segments should be collected at consistent points along the standard radius.

There is also now a need to confirm our estimates of K for queen snapper and to test the pooled segment form of our proposed approach with a species where K is well known from other approaches.

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