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The von Bertalanffy Growth Curve: When a Good Fit is not Good Enough

P.C. Craig

Abstract

The von Bertalanffy growth function (VBGF) is used for length based analyses of growth and mortality patterns for management of fisheries. However, certain fish have growth patterns that the VBGF may not be able to describe adequately, e.g., the *Acanthurus lineatus* in Samoa. In such cases a two-phase VBGF may be a useful approach.

Management of small tropical fisheries can be challenging when the fish are difficult to age and advanced fisheries models have limited application (Longhurst and Pauly 1987). Basic growth and mortality parameters must often be pieced together by indirect techniques, such as length-based analyses and empirical relationships among large groups of species. Such analyses are typically dependent on estimates of the growth parameters derived from the von Bertalanffy growth function (VBGF):

$$L_t = L_\infty\left[1 - e^{-K(t-t_0)}\right]$$

where L_∞ is the asymptotic length, that is, the mean length the fish of a given stock would reach if they were to grow indefinitely; K is the rate (of dimension time^{-1}) at which L_∞ is approached; and t_0 is the "age of the fish at zero length" if they had always grown in the manner described by the equation (note that t_0 is generally negative). This paper examines an old problem lurking within VBGF that may seriously bias growth and mortality analyses for some tropical fishes.

The concern is that VBGF can be affected by differing age ranges of the fish being analyzed (Hirschhorn 1974, cited in Ferreira and Russ 1994). Although the effect is often inconsequential, it is exacerbated by a growth pattern that is common among tropical fishes, whereby the fish are long-lived (up to 20-40 years) but attain most of their adult size very early in life (Williams et al. 1995; Choat and Axe 1996; Hart and Russ 1996; Newman et al. 1996; Craig et al. 1997). As much as 70-80% of the growth may occur during the first year. This, coupled with a long lifespan, creates a growth curve that looks almost right-angled.

Growth of the surgeonfish *Acanthurus lineatus* in Samoa illustrates VBGF's performance with this growth pattern (Craig et al. 1997). At first glance, there is no problem at all - VBGF convincingly captures the age-length relationship (Fig. 1A). However, there is an equally good but very different fit to the same data when the youngest fish are excluded (Fig. 1B). This occurs because K and L_∞ are strongly age-dependent. Deletion of the youngest fish from the sample produces systematic changes in K and L_∞ (Fig. 2A). Ferreira and Russ

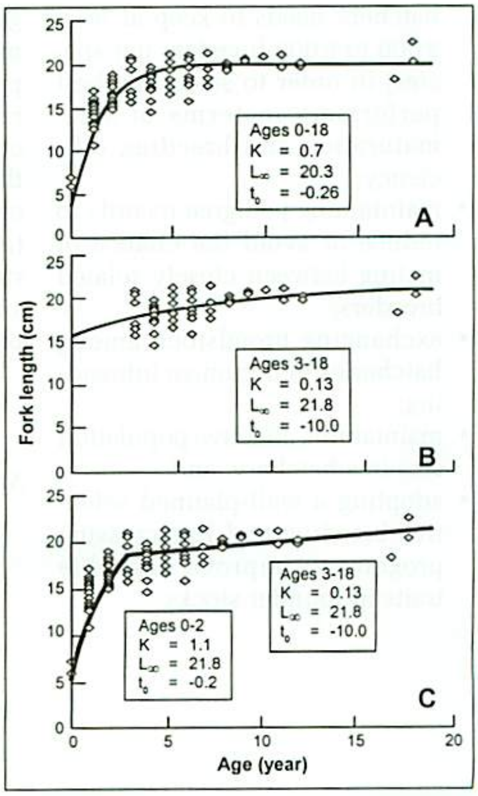

Fig. 1. Age-length relationships for A. lineatus*: (A) a single VBGF, (B) a single VBGF without ages 0-2 and (C) a two-phase VBGF, separated at age 3 when fish become fully recruited to the fishery. Estimates of K and L_∞ were derived from a Ford-Walford regression of the age-length relationship. Estimates of t_0 (time when length would theoretically be zero) were made by Pauly's (1979) methods, where $\log(-t_0) = 0.392 - 0.275 \log(L_\infty) - 1.038 \log(K)$, or by best fit by eye. Fig. 1C differs slightly from results presented by Craig et al. (1997) who separated the growth phases based on the age at which 50% of the population was mature, and calculated K = 0.12 and L_∞ = 22.1 cm for the larger fish.*

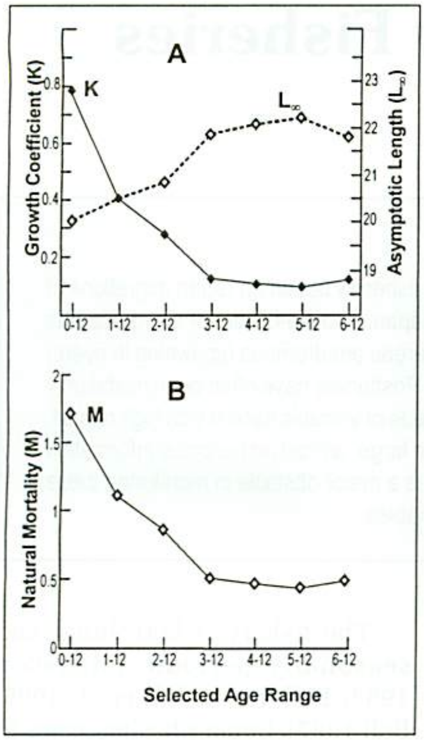

Fig. 2. Changes in K and L_∞ based on iterative Ford-Walford regressions that progressively excluded age classes of younger fish. Age-length data used in this calculation were derived from a smoothed plot of mean size at age. Changes in M (natural mortality) were estimated using Pauly's (1980) method, where $\log(M) = 0.007 - 0.279 \log(L_\infty) + 0.654 \log(K) + 0.463 \log(\text{temperature})$.

(1994) reported similar results for the coral trout *Plectropomus leopardus* on the Great Barrier Reef.

This sliding scale of K and L_∞ values introduces considerable subjectivity into the analyses - what values are "correct" and why? The uncertainty is amplified when the values selected are used to estimate natural mortality (Fig. 2B) or total mortality from length-converted catch curves (Pauly 1983). A stock might erroneously be managed as a fast-growing, short-lived species.

One approach to describing this growth pattern is to recognize two separate growth phases in the growth curve (Soriano et al. 1992; Ross et al. 1995; Craig et al. 1997). For *A. lineatus*, there is rapid initial growth followed by many years with little or no growth. Craig et al. (1997) separated the two segments of this species at the age when 50% of the population was mature. The resultant two-phase curve was similar in appearance to that obtained by the single VBGF, but K and L_∞ differed greatly (Fig. 1C). The single VBGF yielded values of K and L_∞ that did not adequately describe the complete growth pattern. The double VBGF produced "adult" values of K and L_∞ that were consistent with other analyses (Craig et al. 1997) and literature values.

For comparability among studies that encounter age-dependent growth parameters, consistent criteria are needed when deleting the youngest fish or separating apparent growth phases. While further scrutiny is warranted, a functional guideline for sampling is to use only those ages or sizes of fish that are fully recruited to the fisheries (Ferreira and Russ 1994). For research samples that include very young fish, a two-phase VBGF may be a useful approach.

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P.C. CRAIG *is a Fish Biologist. Box 532, Klamath, California 95548 USA.*