ESTIMATION OF GROWTH PARAMETERS

The study of growth means basically the determination of the body size as a function of age. Therefore all stock assessment methods work essentially with age composition data. In temperate waters such data can usually be obtained through the counting of year rings on hard parts such as scales and otoliths. These rings are formed due to strong fluctuations in environmental conditions from summer to winter and vice versa. In tropical areas such drastic changes do not occur and it is therefore very difficult, if not impossible to use this kind of seasonal rings for age determination.

Only recently methods have been developed to use much finer structures, so-called daily rings, to count the age of the fish in number of days. These methods, however, require special expensive equipment and a lot of manpower, and it is therefore not likely that they will be applied on a routine basis in many places.

Fortunately several numerical methods have been developed which allow the conversion of length-frequency data into age composition. Although these methods do not require the reading of rings on hard parts, the final interpretation of the results becomes much more reliable if at least some direct age readings are available. The best compromise for stock assessment of tropical species is therefore an analysis of a large number of length-frequency data combined with a small number of age readings on the basis of daily rings.

Mathematically von Bertalanffy equation expresses the length, L, as a function of the age of the fish, t:

$$L(t) = L_{\infty} *[1 - \exp(-K*(t-t_0))]$$

The parameters can to some extent be interpreted biologically. L_∞ is interpreted as "*the mean length of very old (strictly: infinitely old) fish*", it is also called the "*asymptotic length*". K is a "*curvature parameter*" (Figure 1) which determines how fast the fish approaches its L_∞ . Some species, most of them short-lived, almost reach their L_∞ in a year or two and have a high value of K. Other species have a flat growth curve with a low K-value and need many years to reach anything like their L_∞ . The third parameter, t_0, sometimes called "*the initial condition parameter*", determines the point in time when the fish has zero length. Biologically, this has no meaning, because the growth begins at hatching when the larva already has a certain length, which may be called L(0) when we put t = 0 at the day of birth.

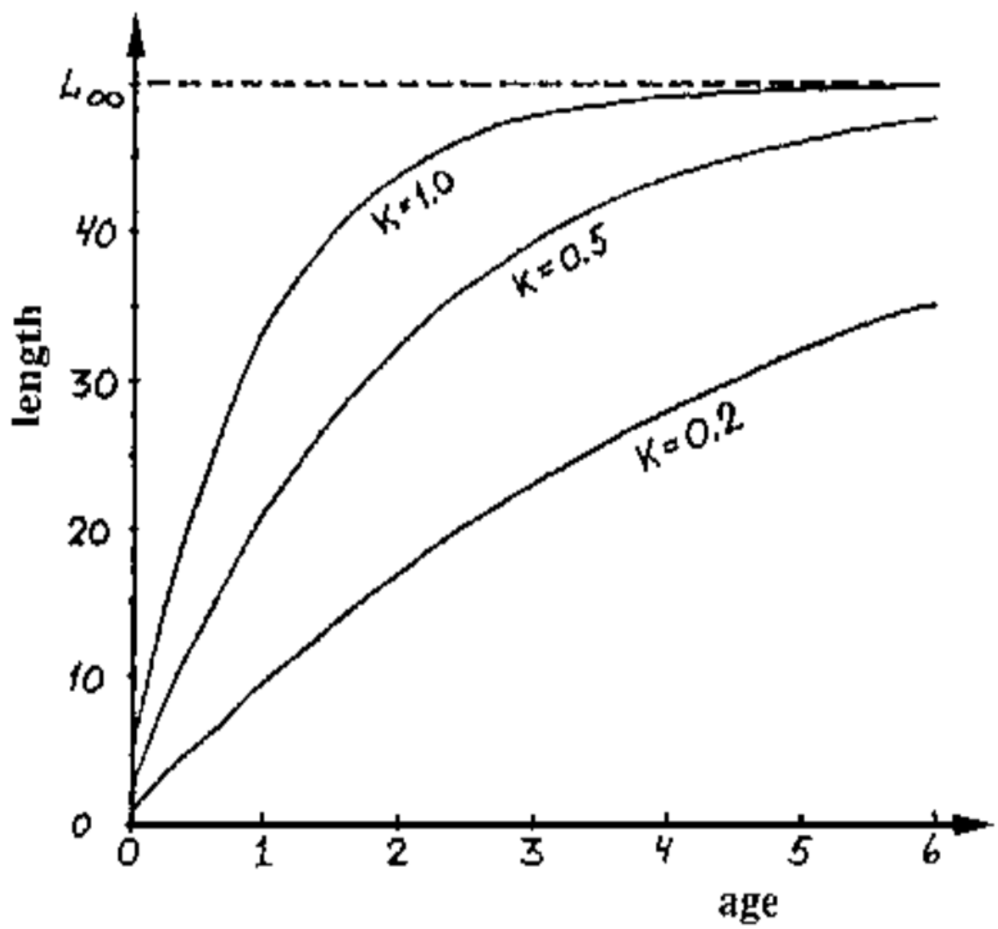

Figure 1: Growth curves with different curvature parameters, different K values

Variability and applicability of growth paran

Growth parameters, of course, differ from species to species, but they may also var stock to stock within the same species, i.e. growth parameters of a particular species m different values in different parts of its range. Also successive cohorts may grow diff depending on environmental conditions. Further growth parameters often take di values for the two sexes. If there are pronounced differences between the sexes i growth parameters, the input data should be separated by sex and values of K, L_∞ should be estimated for each sex separately.

The weight-based von Bertalanffy growth equation

Combining the von Bertalanffy growth equation

$L(t) = L_\infty * [1 - \exp(-K*(t-t_0))]$

with the length/weight relationship

$W(t) = q*L^3(t)$

One can deduce the weight of a fish as a function of age as:

$$W(t) = q * L_\infty^3 * [1 - \exp(-K * (t - t_0))]^3$$

$$\mathbf{W(t) = W_\infty * [1 - \exp(-K*(t-t_0))]^3.}$$

ESTIMATING THE GROWTH PARAMETERS

The Gulland and Holt plot

$\Delta L/\Delta t = a + b* \bar{L}(t)$

The growth parameters K and L_∞ are obtained from:

$K = -b$ and $L_\infty = -a/b$

The Ford-Walford plot and Chapman's method

$L(t+\Delta t) = a + b*L(t)$

where

$a = L_\infty*(1-b)$ and $b = \exp(-K*\Delta t)$

Since K and L_∞ are constants, a and also b become constants **if Δ t is a constant**. The growth parameters K and L_∞ are derived from:

$$K = -\frac{1}{\Delta t} * \ln b \text{ and } L_\infty = \frac{a}{1-b}$$

For Chapman

$L(t+\Delta t) - L(t) = c*L_\infty - c*L(t)$.

where

$c = 1 - \exp(-K*\Delta t)$

Thus, since K and L_∞ are constants, and if Δ t remains constant, c will remain constant and consequently the equation becomes a linear regression

$y = a + bx$

where

$y = L(t+\Delta t)-L(t)$, $a = c*L_\infty$, $b = -c$ and $x = L(t)$

Note that the slope is negative and also that on the abscissa (x-axis) the smaller of the two lengths is used, instead of the mean value.

The growth parameters are derived from

$K = -(1/\Delta t)*\ln(1+b)$ and $L_\infty = -a/b$ or a/c

Inverse equation of VBGF for estimating t_o

$t(L) = t_o -1/K* \ln(1 – L/L_\infty)$

MORTALITY RATES

Mortality is caused by either fishing or through natural phenomena such as old age, disease and predation.The key parameters used when describing death are called mortality rate.

Natural mortality rate, M: This can be estimated using Pauly's empirical model or equation:

$\ln M = -0.0152 - 0.279 * \ln L\infty + 0.6543 * \ln K + 0.463 * \ln T$

Where T = mean annual water temperature

Total mortality rate, Z: can be estimated in various ways among which is the linearised length-converted catch curve

$$\ln \; C[L1, L2]/\Delta t[L1, L2] = C - Z * t[L1 + L2]/2$$

From here, fishing mortality,F, can be estimated as

$$F = Z - M$$

And exploitation rate, E, as

$$E = F/Z$$

E ranges from 0 to 1. It is optimum at 0.5, under-exploitation when it is less than 0.5, and over-exploitation when the estimate is above 0.5.

YIELD PER RECRUIT MODEL

This model is used to assess the effect of mesh size regulations. Beverton and Holt developed a relative yield per recruit model which can provide the kind of information needed for management.

This is defined as:

$(Y/R)^1 = E * U^{M/K} * [1- 3U/1+m + 3U^2/1+2m - U^3/1+3m]$

Where $m = \frac{1 - E}{M/K} = K/Z$

$U = 1 - Lc/L\infty$ the fraction of growth to be completed after entry into the exploitation phase.

$E = F/Z$ fraction of death caused by fishing

Lc = the length of the smallest fish in the sample

$(Y/R)^1$ can be calculated for a given input values of M/K, $L\infty$ and Lc for values of E ranging from 0 to 1, corresponding to F values ranging from 0 to ∞.

The plot of $(Y/R)^1$ against E gives a curve with a maximum value, E_{MSY}, for a given value of Lc. Thus, when Lc, F and Z are known for a certain fishery, the actual exploitation can be compared with the E_{MSY} level and management measures be proposed as required.