# A NEW METHOD FOR ESTIMATING GROWTH AND MORTALITY PARAMETERS FROM LENGTH-FREQUENCY DATA

by

Jerry A. Wetherall
Southwest Fisheries Center Honolulu Laboratory
National Marine Fisheries Service, NOAA
2570 Dole Street, Honolulu, Hawaii, U.S.A. 96822-2396

A new, simple method has been found to estimate the asymptotic length ($L_\infty$) and the ratio of the coefficients of mortality and growth (Z/K) using only length-frequency data from a fish catch. Theoretical details of the method are given in a paper by J.A. Wetherall, J.J. Polovina, and S. Ralston, to appear in the forthcoming ICLARM proceedings of the 1985 Sicily conference on length-based stock assessment (See Fishbyte 3(1), March 1985). A practical user's guide to the new procedure, with computational algorithms and Turbo Pascal code, will be available soon from the author. In this report only a brief description of the method is given. (see also Pauly, this issue).

The sampled fish population is assumed to be stable, with constant annual recruitment, von Bertalanffy growth, and continuous mortality occurring at a uniform, instantaneous rate. A random sample of n fish are measured, m of these longer than a particular knife-edge selection length. The measurements are retained for analysis, and data on fish shorter than the selection length are neglected. In practice the assumptions on recruitment, growth, mortality and size selection are rarely satisfied. But if they are roughly true, or if corrective steps are taken during analysis, the method provides estimates that are useful for many tropical fishery management decisions and which are superior to estimates produced by other simple procedures.

With the above assumptions, it is shown in the Sicily paper that the mean length of the m selected fish ($\bar{L}$) is a linear function of the knife-edge selection length ($L_c$):

$$L = L_\infty \left(\frac{1}{1+\theta}\right) + L_c\left(\frac{1}{1+\theta}\right) \tag{1}$$

where $\theta = Z/K$, Z is the instantaneous mortality rate, and K and $L_\infty$ are the growth coefficient and asymptotic length of the von Bertalanffy model.

Equation (1) is the basis of Beverton and Holt's well-known method of estimating $\theta$ given $L_\infty$, $L_c$ and $\bar{L}$. Rearrangement of (1) results in their classic formula

$$\theta = \frac{L_\infty - \bar{L}}{\bar{L} - L_c} \tag{2}$$

The new approach improves on the Beverton-Holt method, allowing the estimation of $L_\infty$ in addition to $\theta$. It does this by making fuller use of information in the sample besides the overall mean length. Specifically, it takes advantage of the linear relationship between sample mean length and the selection length.

For a series of p arbitrary cutoff lengths within the size range of the m selected fish, we construct a corresponding series of partially overlapping subsamples. The i-th subsample consists of those $m_i$ fish whose lengths exceed $L_{ci}$ ($i = 1, \ldots, p$). If the mean lengths for the subsamples are plotted against the cutoff lengths, a positive linear relationship results, as predicted by formula (1). For clarity, we label the intercept and slope of the straight line with conventional symbols:

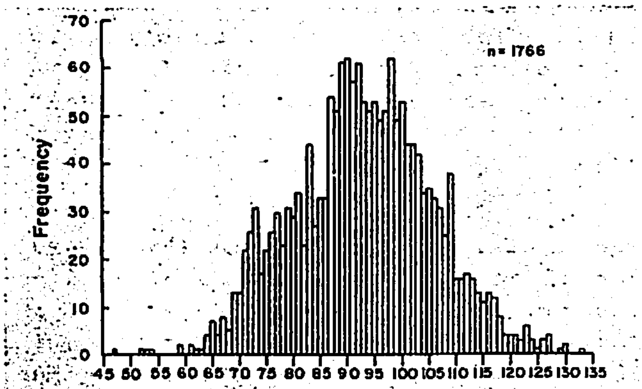

Fig. 1. Length-frequency distribution for male *Panulirus marginatus* on Maro Reef, Northwestern Hawaiian Islands.

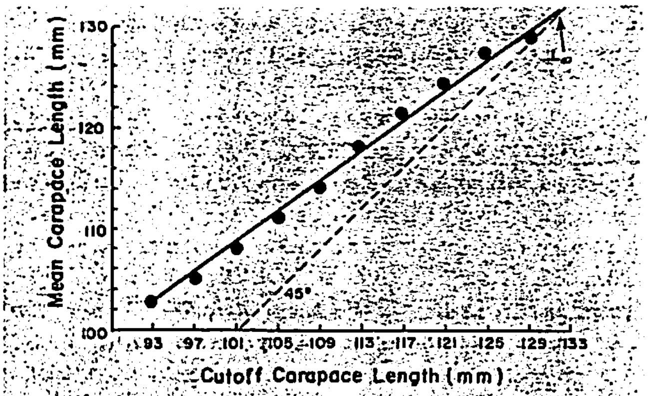

Fig. 2. Regression of mean carapace length on cutoff carapace length for 10 lobster subsamples.

$$\alpha = \left(\frac{L_\infty}{1+\theta}\right) \tag{3}$$

and

$$\beta = \left(\frac{\theta}{1+\theta}\right) \tag{4}$$

The parameters of interest, $L_\infty$ and $\theta$, can be estimated in two simple steps:

Step 1. Compute $\alpha$ and $\beta$ from a linear regression of $\bar{L}_i$ on $L_{ci}$. Statistical weights should be used. It will usually suffice to weight each subsample mean length by the reciprocal of its variance, or even by the corresponding subsample size.

Step 2. Given the estimates of $\alpha$ and $\beta$, compute $L_\infty$ and $\theta$ as the solution of Equations (3) and (4):

$$L_{oo} = \left(\frac{\alpha}{1 - \beta}\right) \tag{5}$$

and

$$\theta = \left(\frac{\beta}{1 - \beta}\right) \tag{6}$$

The standard errors of the estimates of $L_\infty$ and $\theta$ can be calculated using methods discussed in the Sicily conference paper.

Figures 1 and 2 show an example, based on male spiny lobsters, *Panulirus marginatus*, taken in 1977 on Maro Reef in the Northwestern Hawaiian Islands (data compliments of J.J. Polovina, Honolulu Laboratory). Out of the entire sample of 1,766 lobsters, 904 lobsters had a carapace longer than the assumed knife-edge selection length of 93 mm. Measurements from these lobsters were partitioned into 10 overlapping subsamples, based on arbitrary cutoff lengths of 93 mm, 97 mm, 101 mm, 105, ..., 129 mm. The linear regression was run using reciprocals of the variances of subsample means as statistical weights. Estimates of the intercept and slope were $\alpha = 0.251$ mm and $\beta = 0.743$ mm$^{-1}$. Step 2 yielded the final results, $L_\infty = 131.1$ mm and $\theta = 2.89$.

## USE OF ELEFAN PROGRAMS FOR EMIGRATING SPECIES

by
L. Pinto
Department of Zoology
Open University of Sri Lanka
Colombo 10, Sri Lanka

Mangroves and seagrass beds are the nursery grounds of many juvenile marine fishes in the tropics. If one undertakes an ecological study in such an environment with population dynamics as an aspect, one is faced with a number of problems when using the ELEFAN programs. In using the programs, at one stage approximate $L_\infty$ and K are needed to begin the analysis of length-frequency data gathered from the field. Since, only juveniles are found in these habitats, $L_\infty$ cannot readily be estimated from the samples collected and estimates have to be obtained from published data. If the approximate K for the same species is not available, the parameter $\phi'$ for the species or genus might be obtained from the relationship of Pauly and Munro (1984), where

$$\phi' = \log_{10} K + 2 \log_{10} L_\infty$$

Substituting $L_\infty$ for the stock and $\phi'$ for the species or genus, an approximate K can be found for the stock. Using this approximate K and $L_\infty$ thus obtained, ELEFAN I program can be run to extract the best K value from the length-frequency data for juvenile fishes.

Another problem is encountered when using the ELEFAN II program to estimate mortality rates of those fish species which emigrate from their nursery grounds. The apparent Z derived from the catch curve is likely to be an over-estimate, which includes both mortality and emigration. That is,

$$Z' = Z + I \quad \text{or} \quad Z = Z' - I$$

where, Z' is the apparent total mortality coefficient obtained from ELEFAN II, Z is the true mortality coefficient and I is the instantaneous rate of emigration out of the mangroves.

For a fish community in which the different species are of approximately the same size, occupy the same microhabitat and have similar behavior, individuals ought to have the same chance of being caught by a particular fishing gear. In such a community, the older individuals of large species may emigrate out of it while the other species may remain in the same environment throughout their lives. Emigrating species can be identified if the $L_{max}$ in nearby fishing grounds is very much greater than the $L_{max}$ in the samples from the mangroves. Thus the average fishing mortality for resident species should approximate the fishing mortality for emigrating species. The average fishing mortality (F') is the fishing mortality for the community which can be substituted in the equation

$$Z = M + \bar{F}$$

where, M is an estimate of the natural mortality of the species, obtained from the empirical equation developed by Pauly (1982) which is incorporated into ELEFAN-II. The $\bar{F}$ obtained for the resident species in the community in Table 1 is 0.91 which is also the fishing mortality coefficient for the