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APPENDIX F

EXAMINATION OF LENGTH FREQUENCY DISTRIBUTIONS TO EVALUATE OVERFISHING

By
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I originally intended to adapt the single gear approach of BEVERTON and HOLT (1957) to the multiple gear fishery of Lake Victoria. This approach has the limitation of being highly demanding of information, in that it requires growth and natural mortality parameters for each kind of fish. The method of SSENTONGO and LARKIN (1973) for estimating the ratio of the total mortality coefficient (Z) to the van Bertelanffy growth coefficient (K) using length frequency data has been a major step toward using this approach where data are at a minimum, but it is still necessary to get additional information to estimate the absolute levels of the growth coefficient (K) and the natural mortality coefficient (M).

Although the EAFFRO fish tagging programme may eventually provide estimates of K suitable for the Beverton-Holt method, such estimates cannot be expected immediately. I was therefore motivated to find an approach that does not require explicit information on growth or natural mortality. The approach I selected requires only information on average lengths.

It will be assumed that length growth is linear to the maximum length ($L\infty$), reached at an age (t) of unity and that the length-weight relationship is cubic.

$$\begin{aligned} L(t) &= L\infty t \quad \text{when } 0 \le t \le 1 \\ L(t) &= L\infty \quad \text{when } t > 1 \\ W(t) &= W\infty t^3 \quad \text{when } 0 \le t \le 1 \\ W(t) &= W\infty \quad \text{when } t > 1 \end{aligned} \qquad (1)$$

This assumption has the advantage of leading to a simple solution, and growth studies by RINNE (1975) have indicated it to hold approximately for Lake Victoria fish. However, the simple growth function is not a necessary feature of my approach, which could be applied to other growth functions, such as the van Bertelanffy equation, requiring however numerical evaluation of the integrals presented below.

If there is a constant mortality rate (Z), which is the sum of fishing mortality (F) and natural mortality (M), the probability density function of age is

$$p(t) = Z_e^{-Zt} \qquad (2)$$

The weight yield is that fraction of recruitment (R) which dies due to fishing multiplied by the average weight ($\overline{W}$).

$$Y = \frac{F}{Z} R\overline{W} \qquad (3)$$

The average or expected value of weight is

$$\overline{W} = \int_0^\infty W(t)\, p\,(t)\, dt \qquad (4)$$

Substituting (1) and (2) in (4),

$$\overline{W} = \int_0^1 W\infty t^3 Z_e^{-Zt}\, dt + \int_1^\infty W\infty Z_e^{-Zt}\, dt \qquad (5)$$

The first term applies to fish which are growing and the second term to fish which are full grown.
Integrating (5),

$$\overline{W} = W\infty \left[\frac{6}{Z^3} - \left(\frac{3}{Z} + \frac{6}{Z^2} + \frac{6}{Z^3} \right) e^{-Z} \right] \qquad (6)$$

Substituting (6) in (4)

$$Y = FRW\infty \left[\frac{6}{(M+F)^4} - \left(\frac{3}{(M+F)^2} + \frac{6}{(M+F)^3} + \frac{6}{(M+F)^4} \right) e^{-(M+F)} \right] \qquad (7)$$

Note that although $W\infty$ and R must be known to calculate yield they need not be known to identify the fishing intensity at which yield is greatest.

Fig. 1 shows how yield depends upon fishing intensity in equation (7) when natural mortality is unity. The maximum possible yield, which is 12% of the yield which would be possible if all fish could grow to full size with no mortality before cropping, occurs at a fishing intensity of 0.83. The yield is severely reduced once fishing intensity is more than three times the optimum.

In order to use equation (7) in practice, it is necessary to estimate M and to translate fishing intensity from practical terms (such as number of boats in the fishery) into F. This can be done from data on average lengths.

The average or expected value of length is

$$\bar{L} = \int_o^\infty L(t)\, p(t)\, dt \qquad (8)$$

Substituting (1) and (2) in (8),

$$\bar{L} = \int_o^1 L\infty + |Z_e^{-Zt}\, dt + \int_1^\infty L\infty Z_e^{-Zt}\, dt \qquad (9)$$

Again, the first term applies to growing fish and the second term to fish already grown.

Integrating (9) and solving for Z,

$$\hat{Z} = \frac{L\infty}{\bar{L}}(1-e^{-\hat{Z}}) \qquad (10)$$

Although equation (10) does not have an explicit solution it can be solved easily by interation, using $L\infty/\bar{L}$ as an initial guess for Z.

Because fish of very small sizes may not be properly represented in real samples, it will often be desireable to use fish above only a certain length (L_o) to calculte L_o. In that case

$$\hat{Z}^1 = \frac{L\infty - L_o(1-e^{-\hat{Z}^1})}{\bar{L} - L_o} \qquad (11)$$

and $\hat{Z} = \dfrac{L\infty \hat{Z}^1}{L\infty - L_o}$

Note that $\hat{Z}$ is not an estimate of mortality per a unit of time such as a year. The time unit is the age at which maximum size is reached, which may not and need not be known.

It is necessary to sample two or more populations experiencing different fishing intensities in order to estimate M. A regression line is fitted with $\hat{Z}_i$ as the dependent variable and f_i, the known fishing intensity in terms of boats or fishing gear, as the independent variable.

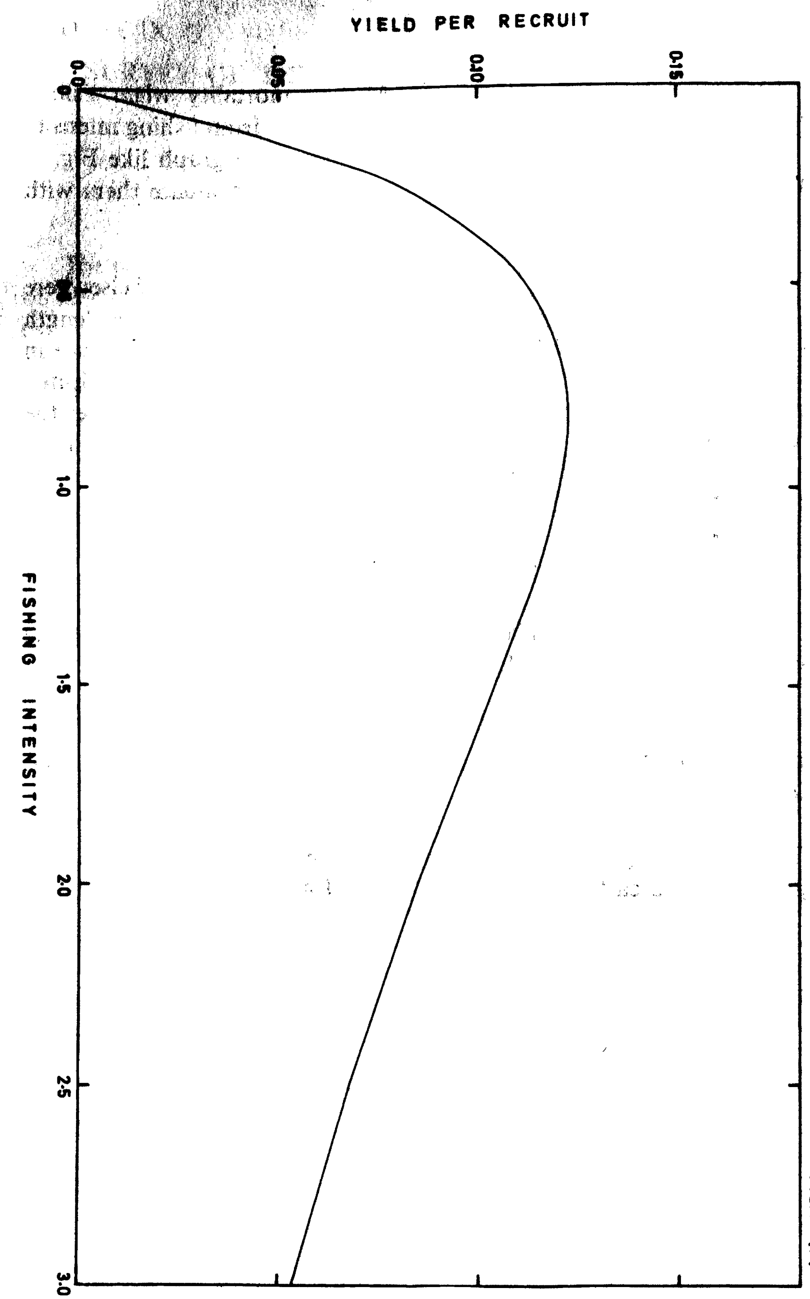

FIG.1 (F)

$$\hat{Z}_i = M + bf_i \tag{12}$$

The Z-intercept gives an estimate of M (i.e. mortality when fishing intensity is zero) and the slope gives a conversion factor from fishing intensity (f) to F. It is then possible, with M known, to prepare a graph like Fig. 1, position the existing levels of fishing on the graph, and evaluate them with respect to the optimum.

Fish samples taken in Kenya by Wanjala and Marten (presented elsewhere in this report) have demonstrated a striking difference in average length inside and outside of Nyanza Gulf, corresponding to a known difference in fishing densities. During 1975, length frequency information will be collected on all species of fish occuring in bottom trawls. Samples will extend over the entire year to average over seasonal variations in length frequency distributions, and the data on average lengths will be used to calculate Z using equation (11), M using equation (12), and Y using equation (7).

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APPENDIX G

SURVEY OF THE LAKE VICTORIA FISHERY IN KENYA

BENNY WANJALA
AND
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The purpose of the survey, begun in 1973, has been to assess the condition of breeding stocks in the heavily fished Kenya waters of Lake Victoria and evaluate existing fisheries regulations. Although tabulation of data from the survey is not yet complete, some initial results are available for presentation. A detailed geographic breakdown of the composition of fish population and commercial catches will be given at a later date.

The procedure in the survey was to visit a different region each month, such that each major fish landing was sampled three to four times a year. At the same time that length-frequency distributions of the commercial catch were being sampled at a particular landing, we fished nearby with a 450 meter beach seine and a fleet of gillnets ranging in size from $1\frac{1}{2}$ to 7 inches at $\frac{1}{2}$ inch intervals. Fish we caught ourselves were measured as to length, weight, sex and gonad maturity state. This allowed us to compare the commercial catch with fish available in adjacent waters and provided information for estimating length at maturity. We were then able to judge on the basis of length how many immature fish were appearing in the commercial catch.

(1) *Composition of fish effort:*

There are approximately 2000 fishing boats inside Winam (formerly Kavirondo) Gulf and 2000 boats outside the Gulf. The fishing inside the Gulf is more intense because the area inside the Gulf is less than half the area accessible to fishing canoes outside the Gulf. There is also a greater emphasis on seines inside the Gulf and large mesh gillnets outside the Gulf (Table 1). The percentage

shown in Table I for $2\frac{1}{2}$ gillnets may be underestimated because nets in this size range are illegal and therefore difficult to record.

The quantity of fishing gear per boat is similar inside and outside the Gulf (Table 1), except there are some areas inside the Gulf where the number of $1\frac{1}{2}$-$1\frac{7}{8}$" gillnets per boat exceeds one hundred and the number of hooks is low.