ANALOG COMPUTER TECHNIQUES FOR AGE-GROWTH STUDIES OF FISHES[1]

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ABSTRACT

Analog computation and simulation involves the use of an electronic computer in which scaled voltages represent physical variables. This computer solves differential equations to simulate time related systems. Simulation of Von Bertalanffy's equation representing growth in length or weight is a simple procedure. Change of constant values enables a rapid adaptation and fit to a given set of growth data. A check on age analysis by using length-weight plots may be possible with this computer. An example of its use in analysis of striped bass growth is given.

INTRODUCTION

The analog computer is an electronic machine that solves differential equations by manipulation of voltages which represent variables and constants in an equation and can be added, subtracted, multiplied, divided, or integrated as the equation may require. The computer used in this study is an EAI Pace TR-10 coupled with a Dumont type 304-AR oscilloscope and a model 1110 EAI x-y Variplotter. The working voltage limit of this set is plus or minus 10 volts. In simulation of any equation or system, maximum expected values are used to scale voltages to within working voltage limits. In the program for Von Bertalanffy's equations, scaled output voltages representing length, weight, and time are observed on the oscilloscope or plotted automatically on graph paper by an x-y plotter. Accuracy of the analog computer is limited to three significant digits. Essentially, a three dimensional, nearly simultaneous study of growth is allowed. Length, weight, and time relationships may be observed in any of the three possible combinations.

Smith and Wood (1959) and Strong and Hannauer (1962) give detailed information on components and use of analog computers. The circuits shown below occur in Doi (1962), who used an analog computer for study of predator-prey relationships of marine fishes off Japan.

METHODS

The program for weight is identical to the one for length if W is reduced from a power of 1 to 1/n power. The relation between W and L may not be cubic therefore "n" is substituted for 3. The value of "n" may be obtained from calculated length-weight formulae.

Minimum necessary bits of data for simulation of fish growth are: estimate of maximum length and weight attained, length-weight data or a formula expressing their relationship, and an estimate of size at any point or preferably points of time. The last may be known length at year one or size at t equal to zero. Age-length determinations from scales may be used as a check if available. Scale factors were kept at 1, 1/10, or 1/100 to facilitate computations and lessen chance for error. Steps used in simulation of striped bass growth are outlined below.

1. Scale equations to 1/10 L and let "n" equal 3 for W scaled at 1/1. Set time scale at 0.05, 10 volts = 20 years.
2. Set potentiometers nos. 3 & 24 for scaled values of maximum weight and length.
3. Plot length versus the cube root of weights, on the oscilloscope grid and on the XY plotter.
4. Set computer for repetitive operation and adjust slope potentiometers 22 and 23 until machine output of L and W matches data plots on the oscilloscope grid.

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The equations of Von Bertalanffy are well known:

$$L_t = L_\infty(1 - e^{-k(t - t_0)}) \qquad (1)$$

$$W_t = W_\infty(1 - e^{-k(t - t_0)})^n \qquad (2)$$

As differential equations these may be written:

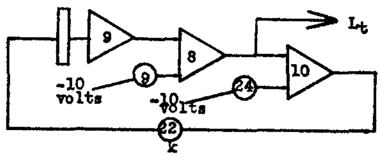
$$dL_t = k\ L\ e^{-k(t - t_0)} \qquad (3)$$

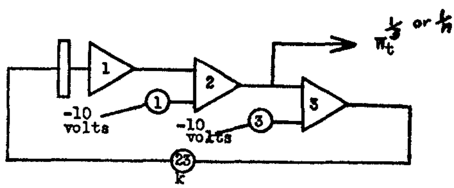
or $$dL_t = -\ k\ (L_t - L_\infty) \qquad (4)$$

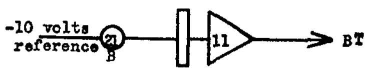
and $$dW_t^{1/n} = -\ k\ W_\infty^{1/n} e^{-k(t - t_0)} \qquad (5)$$

or $$dW_t^{1/n} = -\ k\ (W_t^{1/n} - W_\infty) \qquad (6)$$

Analog circuits or programs representing the above equations are:







5. Switch to the Variplotter and make further adjustments of slope pots and initial conditions pots 1 & 9 to match data plots. Some shifting between oscilloscope and XY plotter operation will be necessary to achieve a best visual fit.

6. Plot out length or weight against time to check on the output at known points. Reset slope pots and initial condition pots (size at t equal zero) to achieve agreement. If settings are changed then a shift back to L-W observation for adjustment may be in order.

7. When length versus weight and length versus time machine plots best match length-weight data and known age-length of age-weight data the process is completed. Read out the settings for k, length at t equal zero, and those for weight.

8. Substitute these values into the equation and calculate by the formula, length or weight for age at a few points to get a final check that the equations obtained are not in error.

RESULTS

In the case of striped bass *(Roccus saxatilis)* maximum sizes were, initially, set at 125 lbs. and 55 inches fork length for females and later adjusted. Initial condition weight was set at zero and length at 1 inch. Length-weight data were taken from Mansueti (1961) and a cubic relation between length and weight was assumed. The formulae obtained for growth of female striped bass were:

$$L_t = 60.2\ (1-e^{-0.096(t-0.07)})$$

$$W_t^{1/3} = 4.94\ (1-e^{-0.095(t-0.02)})$$

[redacted]

Graphically, these curves for L_t and $W_t^{1/3}$ are shown in figure 1.

The values for t were obtained by solving of the equation at $t = 0$, $L_{t=0}=0.4$, and $W_{t=0}^{1/3} = 0.01$.

Information bits for simulation of male striped bass growth are not as well known. Estimates of maximum size are not clear; thus, more adjustment of these values was necessary than with female striped bass growth estimates. Final values were 3.6 lbs for the cube root of maximum weight, and 44.5 in. for maximum fork length. The plots of the growth curves for males are shown in figure 1. Their equations are:

$$L_t = 44.5\ (1-e^{-0.141(t-0.06)})$$

$$W_t^{1/3} = 3.6\ (1-e^{-0.144(t)})$$

LITERATURE CITED

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Figure 1. Age-growth analog computer plots for male and female striped bass.