A Method for the Analysis of Pond Growth Experiments

DANIEL PAULY and KEVIN D. HOPKINS
ICLARM

Pond growth experiments play an essential role in aquaculture research in assessing the growth potential of the various species and strains in all those experiments needed to transform aquaculture from the art it is now into the *science* it should become.

A major problem with pond growth experiments is the extreme difficulty of effectively controlling not only the "control" variables (e.g., food supply to the fish in integrated pig-fish culture experiments) but also extraneous variables (e.g., climatic factors) capable of affecting the results. Because they are rather costly in time and resources, pond growth experiments are often not replicated sufficiently, leading to results of dubious validity.

Usually, growth experiments are run for a set period, at the end of which the total yields are compared with that of a control to infer the effect of the treatments. Such treatments include:

- different stocking rates
- different stocking sizes
- different feeds
- different strains of a given species

In polyculture systems, different treatments include:

- different species ratios (at stocking time)
- different predator species for a given prey species

while in integrated systems (e.g., pig-fish), there are:

- different sizes (or numbers) of pigs, and
- different forms of transfer of pig wastes to the ponds

Additionally, nature itself and the vagaries of life may provide such "treatments" as:

- floods that wash the fish out of a few ponds
- ponds with different bottom type and productivity
- pumps that break down with all fish dying one month before harvesting
- all fish stolen, one week before harvesting

Since they can't deal with all these problems at the same time, aquaculturists have tended to concentrate on one or two of the variables believed likely to affect yields.

Such experiments need a lot of ponds. For example, a set of four treatments (+ control) with five replicates requires 25 ponds. Indeed, experimental designs based on the analysis of final yields—the black-box approach, see Fig. 1—are essentially wasteful of time and other resources because they make no use of the information that can be extracted from the *growth*

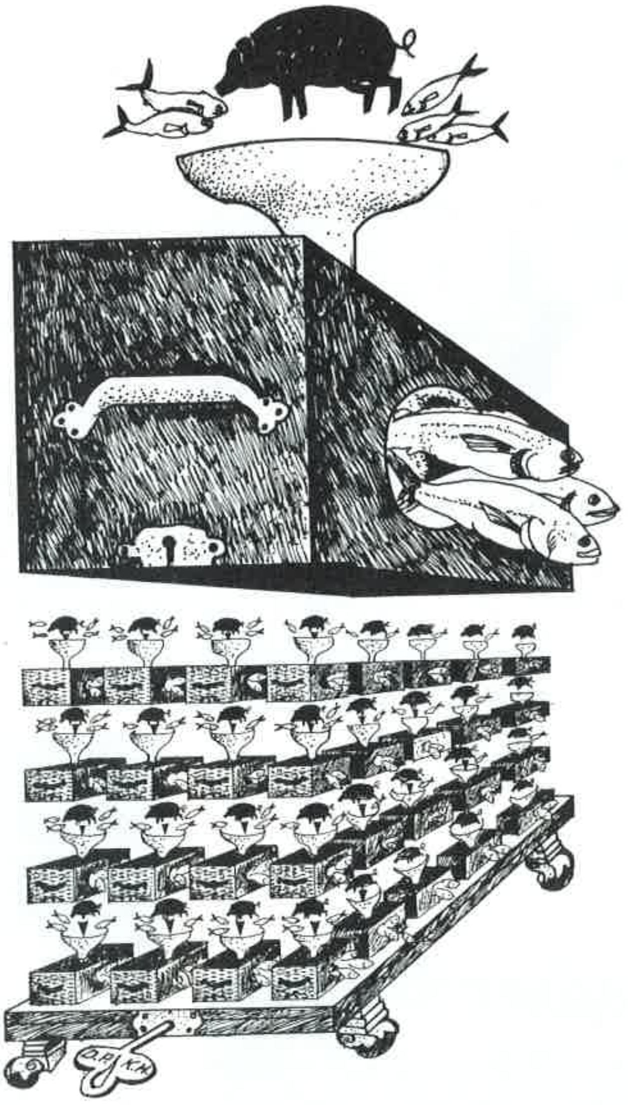

Fig. 1. The traditional method to analyze a pond growth experiment is based on a big *black box,* with a set of inputs, and one output (final yield); our method opens the box and uses the large number of *black boxes* (and their inputs and output) that can be obtained by breaking up the overall growth of the stocked fish into a number of growth increments.

process which leads to the final yields.

The final yield of a growth experiment can be conceived as the sum of a number of *growth increments* (Fig. 2), as could be assessed by weighing fish in a given pond at regular intervals. Moreover, the final yield is the sum of growth increments of individual fish, each of which can also be conceived to have grown incremently, as also shown in Fig. 2. These two features of the yield of an aquaculture experiment have led us to propose a new method of conducting and analyzing pond growth experiments.

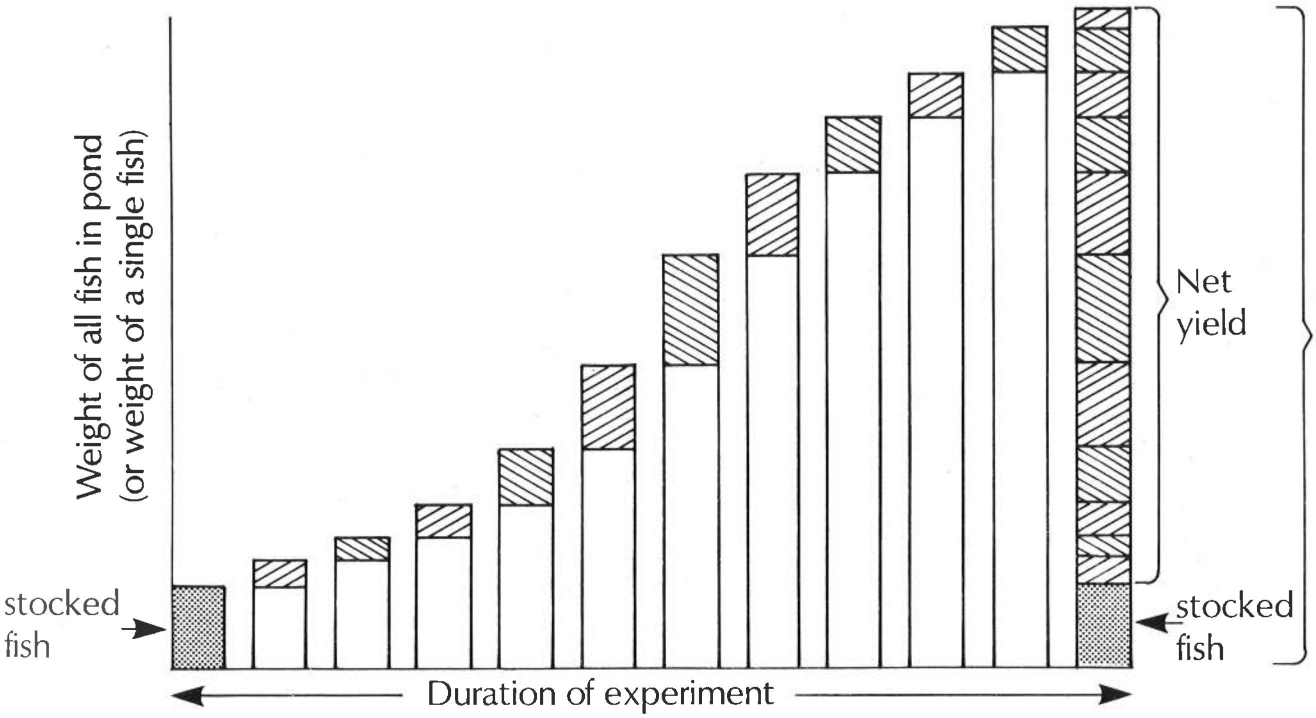

Fig. 2. The final yield of a growth experiment can be viewed as the sum of a number of growth increments, either of a single fish or the whole population of the pond.

The Method

All that is required is to measure the fish in the pond(s) preferably (but not necessarily) on a regular basis. Sometime between fish measurements, measure the values of those variables you think are likely to affect fish growth. Use dummy variables for items that cannot be quantified (e.g., 0 for ponds in site A, 1 for ponds in site B).

Next, calculate the mean growth increments of the fish per day ($\Delta L_i/\Delta t_i$) for each time interval and tabulate these against the mean length ($\bar{L}_i$) and the values of the corresponding variables. Use all tabulated values to estimate the parameters of a multiple regression as shown in box, p. 12. The number of variables which can be included in the analysis is limited in principle only by the available number of $\Delta L_i/\Delta t_i$ and $\bar{L}_i$ values: the more frequently the fish in the experiment have been measured, the more data sets will be available for the multiple regression. In practice, the number of variables will be limited to those that can be monitored concurrently with the growth of the fish.

An Example

From 1978 to 1981, pond growth experiments were conducted in a cooperative project on animal-fish culture between Central Luzon State University and ICLARM. The project experiments involved fish grown with pigs or chickens, the fish consisting of various combinations and stocking rates of tilapia *(Oreochromis niloticus)*, carps *(Cyprinus carpio)* and a predator *(Channa striata)*. Different numbers of pigs and chickens were also used, and, as the animals grew during the course of the various experiments, their inputs (fecal matter and urine) differed within and between the various growth experiments. Moreover, as is always the case with outdoor experiments, climatic factors (such as rain, wind, light, affecting temperature and oxygen) changed within and between experiments, not to mention those factors (e.g., floods) which caused experiments to be interrupted prematurely (for a detailed narrative, see "The ICLARM-CLSU Integrated Animal-Fish Farming Project: Final Report" by K.D. Hopkins and E.M. Cruz. 1982. ICLARM Technical Reports 5.)

Altogether, 117 experiments were completed. A very large number of variables were, in the course of the experiments, hypothesized to affect yields. No conventional experimental design existed with which, using the yield values available, one could have tested the effect of such a large number of variables.

Throughout the experiments, however, samples of fish had been seined and measured at biweekly (generally) intervals, from which mean values of $\Delta L_i/\Delta t_i$ and L_i could be obtained; these measurements also provided a framework for the computation and tabulation of mean values of the variables pertaining to each of the separate intervals Δt. In this fashion, 713 data sets were obtained.

Four of the hypothesized variables turned out to have a significant impact on the growth increments, as shown in the Table. Of these, mean length contributed most of the explained variance (31%) while pig manure, tilapia biomass and tilapia recruitment contributed to a lesser extent (9.4%, 6.0% and 2.4%, respectively).

Advantages and Potential

The advantages of the method proposed here are, we believe, five-fold:

- it uses more of the data generated during growth experiments;
- it replaces the rather inflexible analysis of variance generally used for pond growth experiments by a much more versatile and powerful method. Multiple regression allows (i) analysis of residuals to test for departures from linearity of the equation (4); (ii) use of dummy variables for non-quantifiable effects; and (iii) use of *beta* coefficients to compare the effects on growth of variables expressed in different units (see Table);
- it allows for a linkup of the results obtained in growth experiments with growth models used in the general field of fishery biology and population modelling;
- it can be used for any fish production experiments in which there are many variables which influence the results: not just integrated farming/pond experiments;
- it permits a new approach to designing experimental aquaculture facilities, since it offers an alternative to replication of treatments.

Equation (1) is a differential form of the von Bertalanffy growth equation, while equation (3) is also a method for estimating the parameters K and L_∞ of that equation.

The method proposed might thus help, in addition to facilitating analysis of aquaculture data, to bridge the gap separating fishery biologists working with wild populations and aquaculturists working with confined populations.

A longer paper, covering in detail the various aspects of the new methods will be submitted for publication in a scientific journal in due course. ●

Variables significantly affecting growth rate of tilapias in pig-fish growth experiments, 1978 to 1981.

Variable	Slope	Standardized or *beta* slope[a]	Variance explained (%)
Length of tilapias	–0.0111	–0.3753	30.52
$\log_e$ pig manure input	+0.0223	+0.2930	9.36
$\log_e$ total weight of tilapias	–0.0550	–0.2940	6.02
$\log_e$ tilapia recruits	–0.0118	–0.3052	2.35

[a] *Beta* coefficients are standardized slopes which allow comparison of variables expressed in different units. Thus, in the present case, it can be assessed that tilapia recruitment and tilapia biomass have as much *negative* effects on tilapia growth as manure input has a positive effect.

Derivation

The new method makes the assumptions (1) that mortality of fish stocked is nil or negligible, such that the final yield is (at least approximately) equal to the number of fish stocked times the mean weight of fish at harvesting; and (2) that the growth rate of fish (in length) decreases linearly as the fish get larger, expressed by

$$dl/dt = a + bL \qquad (1)$$

where a and b are empirically determined constants.

The validity of the first assumption is easily assessed in a given set of experiments and requires no further comment. The second is known to apply to most fish past their fingerling stage. The relationship between length (L) and weight (W) of fish is generally proportional to length raised to a power of between 2.5 and 3.5, generally close to 3; weight growth data can always be rendered approximately proportional to length-growth data by taking the cubic root of weight ($\sqrt[3]{W}$).

These concepts imply that the final yield of a growth experiment can be viewed as a function (f) of the length-growth increments of the fish in the pond, i.e.,

$$Y = f\,[dl/dt] \qquad (2)$$

The *differential* equation (1) can however, for short time increments, be replaced by the *difference* equation

$$\frac{\Delta L_i}{\Delta t_i} \approx a + b\bar{L}_i \qquad (3)$$

where ΔL is a length increment, i.e., the difference between the length at the beginning (L_1) and end (L_2) of a given time period Δt_i, while $\bar{L}_i$ is the mean of the L_1 and L_2 values.

From equation (2), any factor increasing the $\Delta L_i/\Delta t_i$ values of a given growth experiment will increase the yield at harvesting. Equation (3) suggests that it is only length itself which affects the $\Delta L_i/\Delta t_i$ values; however nothing prevents us from expanding the regression equation (3) into a multiple regression of the form

$$\Delta L_i/\Delta t_i = a + b\,\bar{L} + b_1 X_1 + b_2 X_2 \ldots b_n X_n \qquad (4)$$

where a number of variables ($X_1, X_2 \ldots X_n$) are conceived as affecting growth rates and hence yield at harvesting. Therefore, given measurements of the variables $X_1, X_2 \ldots X_n$ likely to affect growth rates and pertaining to the time periods for which the $\Delta L_i/\Delta t_i$ and $\bar{L}_i$ values apply, those variables affecting growth (and hence yields) can be identified as those that have slopes ($b_1, b_2 \ldots b_n$) significantly different from zero, while the values of the slope quantify the effects. (The parameters of equation (4) may be estimated using any standard program for multiple regression.)