Chapter 7. Fertile Areas for Practical Fertilization Research

Aquaculture is a relatively new scientific discipline. There are an infinite number of uncharted directions on which researchers can focus their attention and energies. Although I have attempted to answer some ecological questions regarding the fertilization of earthen ponds, this book best serves as a platform for further scientific exploration. Discussed below are some possible research directions and ideas categorized under the familiar headings of pond ecology, fertilizers, and methods for determining pond fertilization requirements, and a final section on experimental design.

Pond Ecology

Perhaps the strongest research need for aquaculturists with respect to pond ecology is to develop a better understanding of primary and secondary productivity from a limnological perspective, i.e., through ecological relationships. This can be best accomplished by conducting library, not laboratory, research. There exists a tremendous wealth of knowledge in the limnological and oceanographic literature with direct relevance to understanding the dynamics of pond aquaculture—literature which has been largely ignored in pond aqua culture research. Ecological studies on nutrient cycling, algal productivity relationships, nutrient limitation, sediment/water interactions, predator/prey relationships, and the ecological importance of thermal stratification are among the many areas of published research which can benefit aquaculture scientists.

The easiest way to begin is to review general limnology texts, e.g., Wetzel (1983) and Goldman and Horne (1983), for a synthesis of the topic and to find citations of relevant research. A more comprehensive, and likely more interesting, way is to go to a university or institutional library and scan article titles of the more recently published research in journals such as: *Limnology and Oceanography*, *Canadian Journal of Fisheries and Aquatic Sciences*, *Oikos*, *Ecology*, *Aquatic Botany*, *Hydrobiologia*, etc. Searching on-line through the Internet may even be simpler and more efficient. Those aquaculture scientists who have not looked much beyond the aquaculture literature would be surprised at the great number of relevant and interesting articles related to their research interests, and research funds are too scarce to be "reinventing wheels."

An important area of field research is the effect of pond depth on nutrient recycling (i.e., internal fertilization) and algal productivity. The regeneration of algal nutrients from algal and detrital decomposition reduces the need for external fertilization, thereby increasing fertilization efficiencies. Understanding how pond depth and pond mixing characteristics affect internal fertilization processes may provide an additional pond management strategy for farmers.

Fertilizers

Fertilizer research should focus on improving the knowledge and potential application of organic fertilizers. Although inorganic fertilizers have a number of advantages over using organic inputs to stimulate algal productivity (discussed in Chapter 4), the potential use of organic by-products produced locally or on-farm should be explored more fully. In particular, nitrogen-fixing legumes have a real potential for providing a relatively economical source of algal nutrients. Criteria for evaluation should include actual costs (including labor) of production and application; nutrient release characteristics; and ecological impacts on oxygen demand, turbidity, and discoloration of pond water. Included in this line of research is an examination of how different types of storage and composting techniques affect nutrient release characteristics of the manure or leaf biomass.

Methods for Determining Pond Fertilization Requirements

A prime area of research would be to fine-tune fixed-rate recipes. As previously discussed, current use of fixed-rate recipes is seriously flawed because generally the only determinative criterion is the country the pond happens to be located in or where the fertilization research took place. Since the relationship between country and ecological parameters which actually determine the efficacy of a particular fertilization strategy is tenuous at best, these recipes may have little relation to ecological reality. However, by relating recipes to actual pond conditions (e.g., pond depth, mixing characteristics, culture fish behavior related to pond-water mixing, prevalence of inorganic turbidity, source water chemistry), sources of variation can be reduced and more predictive recipes can be established. This would be a very good use of computer modeling together with global experimentation (i.e., identical experiments conducted in a variety of environmental conditions).

A second area of research would be to examine further the relationship between areal and volumetric loading rates on predicting algal productivity, and therefore NFY. In Chapter 5, I made clear my reasons why I believe areal rates are more useful to the farmers for whom fertilization rates are intended. Nevertheless, these ecological relationships have not been well examined for pond culture, and further research may produce valuable insights and understanding regarding nutrient dynamics of fertilized ponds. The roles and relationships of internal fertilization, pond morphometry, and pond mixing characteristics should be included in any such research.

A third area of research would be to look at the role of calcium additions, through liming and/or fertilization, on pond productivity. The precipitation of calcium carbonate may become more important as calcium concentrations increase over years of pond culture. This relationship between calcium inputs and pond productivity merits further study.

Experimental Design

My final word on research directions concerns experimental designs. Scientific research is simply a systematic way to understand the universe in which we live. Research designs to provide answers can be loosely divided into two approaches based on two general hypotheses. The first can be described as the "Is this *significantly different* from that?" hypothesis. Different treatments are selected, and responses are evaluated by comparing the results of one treatment with another. Depending on how treatments were selected and replicated, significant differences between response variables may or may not be revealed. This emphasis on treatment comparisons, and limiting data analyses to these comparisons, characterizes most fertilization research. Unfortunately, such comparisons generally provide little insight into the ecological relationships which actually govern algal productivity, and therefore NFY.

The second approach can be described as the "What is the *relationship* between this and that?" hypothesis. The emphasis here is not on significant differences, but on significant relationships. Rather than comparing treatment means, statistical analyses focus on regression and correlation analyses. Relationships may be the stated objective of fertilization research, but research designs are most frequently of the significant-difference variety. For example, the typical design for examining the relationship between chicken manure input and fish yield (or oxygen depletion) would have four treatment levels of manure input with three replicates per treatment. Trying to describe a relationship (e.g., linear, quadratic, exponential, nonexistent) with just four manure levels is difficult at best, and subject to the limited range of manure inputs selected. If the goal is to examine the relationship, then there should be twelve different levels of manure, equally spaced, ranging from zero to obviously excessive. Statistically, this can be viewed as one treatment (i.e., manure input) with twelve replicates (with experimental error determined from variability about modeled relationships), and is clearly more likely to reveal the presence and nature of an existing ecological relationship.

If scientific research is thought of as a body, then statistics is the skeleton which gives the body structure and support. A more grounded understanding of experimental designs and corresponding analyses can only improve the quality of research. Hard work and mountains of data can not overcome analytical deficiencies in poorly designed or unfocused research. The entire conceptual approach to aquaculture research from hypothesis formulation, to selecting response variables, to optimizing experimental units (e.g., ponds), to minimizing experimental error through appropriate experimental designs, to data analysis, and finally to publication of results is systematically presented in Knud-Hansen (1997). Interested readers should find this relatively short (50 pages) presentation a good place to begin formulating research ideas, or strengthen existing research capabilities. Lastly, it is important to keep in mind the rural farmers in the developing tropics, who are the ultimate beneficiaries of quality fertilization research.