



# PD/A CRSP NINETEENTH ANNUAL TECHNICAL REPORT

## DECISION SUPPORT SYSTEMS FOR FISH POPULATION MANAGEMENT AND SCHEDULING IN COMMERCIAL POND AQUACULTURE OPERATIONS

*Ninth Work Plan, Decision Support Systems Research 2 (9DSSR2)  
Progress Report*

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### ABSTRACT

We report on the development of a new software tool for the analysis of fish population size distributions, focusing initially commercial catfish operations in the southeastern United States, but generalizable to other types of operations and locations. Progress has been made in two primary areas: 1) continued development of models of size distributions and their dynamics through time related to biological and management factors, and 2) software development for the decision tool deliverable from this study. Software development has focused on developing entity descriptions and resulting implementations for describing populations and population dynamics in the model. Further, interoperability with datasets used by other catfish production software, (Fish98) was developed. The resulting Catfish Inventory Management (CIM) software allows users to represent populations of catfish in any number of ponds, and simulate the population dynamics and associated variability in response to differential growth rates and harvest practices of these ponds.

### INTRODUCTION

A study was initiated to develop decision support software to assist commercial aquaculture producers in managing fish population dynamics and variability in stock size and weight resulting from biological and management factors. The objectives of this study are 1) to modify previously developed fish growth models so as to enable simulation of population growth of multiple fish lots in pond environments, 2) to develop methods for estimating fish biomass in ponds that are stocked and harvested at various time intervals in continuous production systems, 3) to implement software support for inventory management of fish stocks in operational farms, and 4) to provide training to farmers on the use of decision support software for routine pond management. We give a description of the model below and report on its basic structure and functioning. Presentation of the growth models has been described previously (Nath, 1996)

### APPROACH AND RESULTS

#### Models for Size Distribution Analysis

Explicitly describing the distribution of fish sizes within a pond population is one of the required features for the population management model. Few models exist which offer a mathematical description of size classes within a population. None were found that describe differential growth with respect to fish size within a fish population. Since no acceptable models were found a new model of population size distribution has been developed.

The model is based on the concept of mass balances. Let  $P(w)$  describe the fraction of the population that has mass  $w$ . Then

$$\frac{\partial}{\partial t} P(w) = \text{input} - \text{output}$$

where *input* is the fraction of the population that grows to size  $w$  and *output* is the fraction of the population that grows out of size  $w$ . We can define *input* and *output* by first defining a function  $d(w_1, w_2)$  that describes the fraction of fish at mass  $w_1$  that grows to mass  $w_2$ . Now *input* and *output* can be described as:

$$\text{input}_{w_0} = \int_0^{\infty} P(w) \delta(w, w_0) dw, \text{ and}$$

$$\text{output}_{w_0} = \int_0^{\infty} P(w_0) \delta(w, w_0) dw,$$

where  $w_0$  is a constant. Furthermore,

$$\text{output}_{w_0} = P(w_0)$$

because  $P(w_0)$  is constant with respect to the variable of integration and the integral is equal to 1. So we have:

$$\frac{\partial}{\partial t} P(w) = \int_0^{\infty} P(w) \delta(w, w_0) dw - P(w_0).$$

This system can easily be discretized by first defining  $n$  weight intervals,  $w_i, i=0..n$  and letting  $P_{i,k}$  be the fraction of the population at weight  $w_i$  at time interval  $k$ . Then:

$$P_{i,k} = \left( \sum_{j=0}^n P_{j,k} \delta(w_j, w_i) \right) - P_{i,k}.$$

It is shown via the fundamental theorem of calculus that

$$\lim_{n \rightarrow \infty} \sum_{j=0}^n P_{j,k} \delta(w_j, w_i) = \int_0^{\infty} P(w) \delta(w, w_0) dw.$$

Let  $P^k$  denote the columns of  $P_{i,k}$  so that  $P^k$  is a vector of fractions for each size class at time interval  $k$ . If we define a matrix,  $\Delta$ , such that:

$$\Delta_{j,i} = \delta(w_j, w_i),$$

then

$$P^{(k+1)} = \Delta P^k.$$

This allows computation of  $P^k$  for all desired  $k$  assuming that  $\Delta$  does not change significantly with time. What still remains, however, is a definition for  $\delta$ .

$\delta$  represents the amount of growth of a fish at a certain weight. The bioenergetics model (BE) provides this information; however, we cannot use it directly. The BE model (as it is used in POND) can be represented in a simplified form as:

$$\frac{\partial}{\partial t} W(t) = H(t)w^n - k(t)w^m.$$

The first term represents anabolism and the second catabolism. This equation represents the growth of a fish at a certain weight, based on anabolic and catabolic balances. To use the bioenergetics model as  $d$  we must first make an assumption about the distribution of growth within the population. If we assume that growth for a given size class is normally distrib-

uted with variance  $s$  and mean given by:

$$\mu = w_1 + g(w),$$

where  $g(w)$  is the growth predicted by the BE model, then we can define  $d$  by using the probability density function for the normal distribution;

$$\delta(w_1, w_2) = \left[ \frac{1}{\sigma} \frac{\sqrt{2}}{\sqrt{\pi}} \right] e^{\left( \frac{-1}{2} \frac{(w_2 - \mu)^2}{\sigma^2} \right)}.$$

### Database Development

The existing POND software uses proprietary database code. Relationships between entities in the database are "hard coded" into the software and cannot be changed without recompiling the software. While this implementation produces fast and efficient database functionality, the implementation also slows the development process when changes to database structure are required. Also, the POND database uses specially formatted text files to store database contents. This also hinders interoperability between other database software.

One of the design goals for the Catfish Inventory Management (CIM) software was to provide compatibility with Fish98 database files and provide mechanisms for interoperability with other Windows Software. To achieve this goal it was decided that the CIM tool should use the Microsoft DAO database technology. Choosing DAO simultaneously provides interoperability with existing Microsoft tools like Excel and Access and compatibility with Fishy98 files (Dbase 2 format).

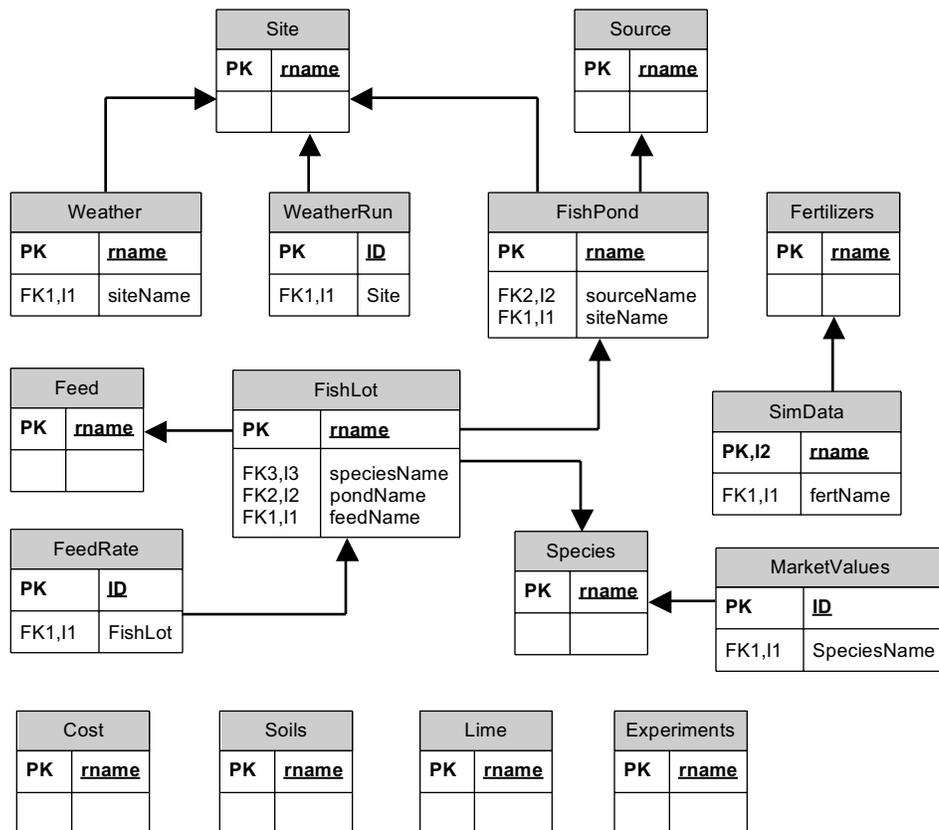


Figure 1: New POND Database schema

Three significant drawbacks were associated with choosing DAO. First the POND software had to be restructured to use DAO instead of the existing database code. Second, the POND database structure had to be implemented in an external database accessible via DAO. Finally the POND database had to be modified to address the different model structure used by the CIM software.

Development of the CIM database proceeded in three phases. First, the POND database was re-implemented in Microsoft Access. The DB structure of the new POND DB is shown in figure 1 (in abbreviated form; table names, relations, and keys only). While the DB structure is not extraordinarily complex, implementation required a considerable amount of time. The new POND DB contains over 300 fields in 16 tables. Table 1 shows what metadata information was included in the database. Much of this information had to be extracted directly from the POND source code.

Table 1: Pond Database Metadata

TableName	Textual name of the data table
VariableName	Name of variable used in source code
DisplayTitle	Name used when displaying variable with interface or user manual
Units	Physical units of the variable (if applicable)
Type	Data type of the variable
Min	Minimum value of the variable (if applicable)
Max	Maximum value of the variable (if applicable)
Default	Default value of the variable (if applicable)
Description	Textual description of the variable's purpose or meaning

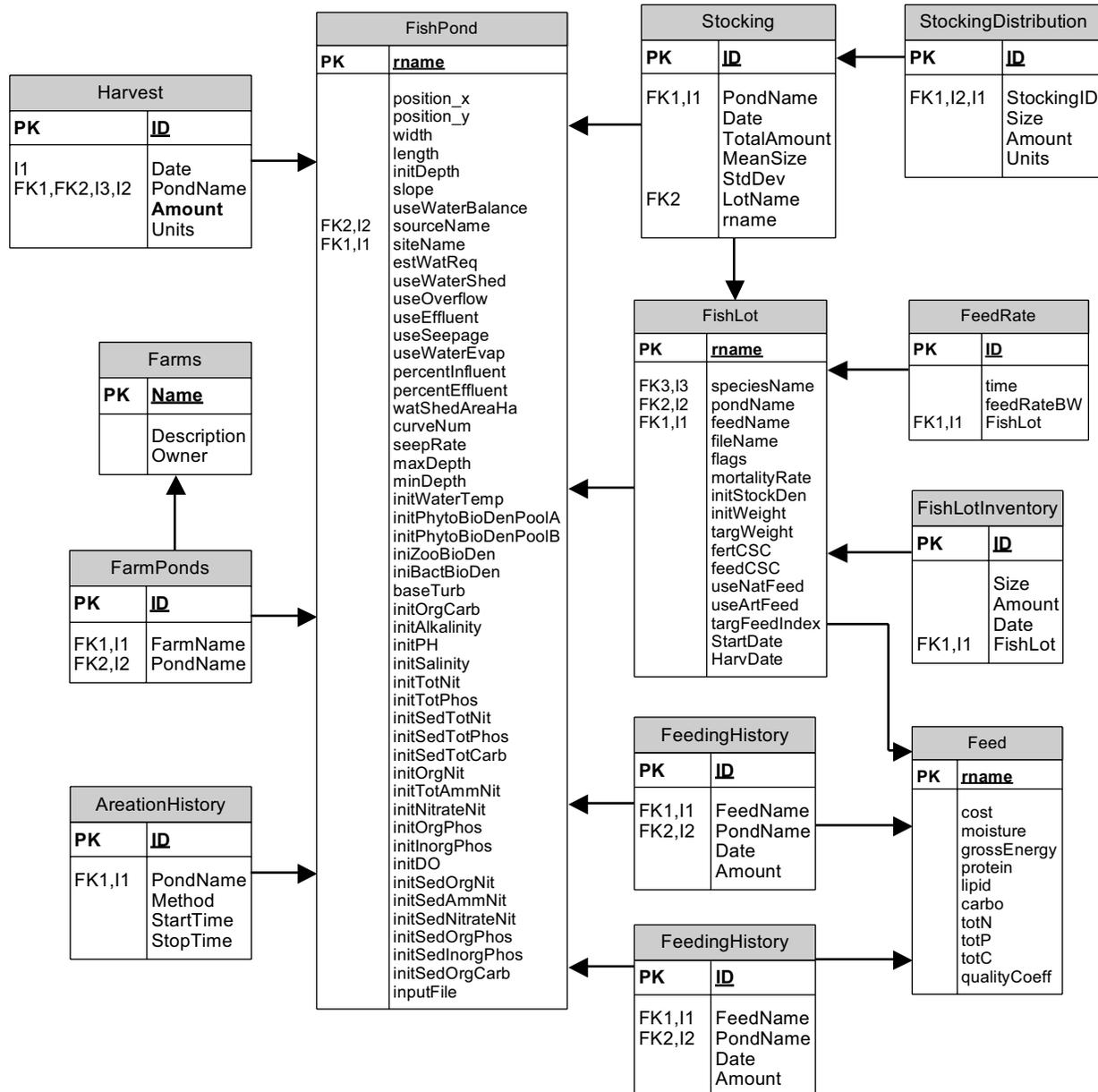


Figure 2 : Revised POND database schema

The second phase of CIM database development involved adding additional tables account for the different model structure used by CIM. POIND makes the assumption that all the fish within a single FishLot are approximately the same and can be modeled as a single entity. The CIM tool does not make this assumption. Instead, the entire distribution is modeled in a piecewise fashion. Figure 2 shows the DB structure with the new tables highlighted (note: some tables shown in fig. 1 are omitted for brevity).

The third phase of database development involved integration of the revised POND database structure into the existing POND software. Figure 3 is a Booch class diagram depicting the POND DB classes before and after modification. The modifications where chosen to minimize the impact on existing POND database structure.

### CONCLUSIONS

The CIM tool allows users to effective model dynamic changes in size class distributions in fish ponds by modeling the changes in these distributions in response to fish growth and management. By using basic growth models and databases in common with the POND software tool, it can be readily adapted to new species and situations. We will be making CIM available on the web as it becomes ready for release at <http://biosys.bre.orst.edu>.

### LITERATURE CITED

Nath, S.S., 1996. Development of a decision support system for pond aquaculture. Ph.D dissertation, Oregon State University. Corvallis, Oregon.

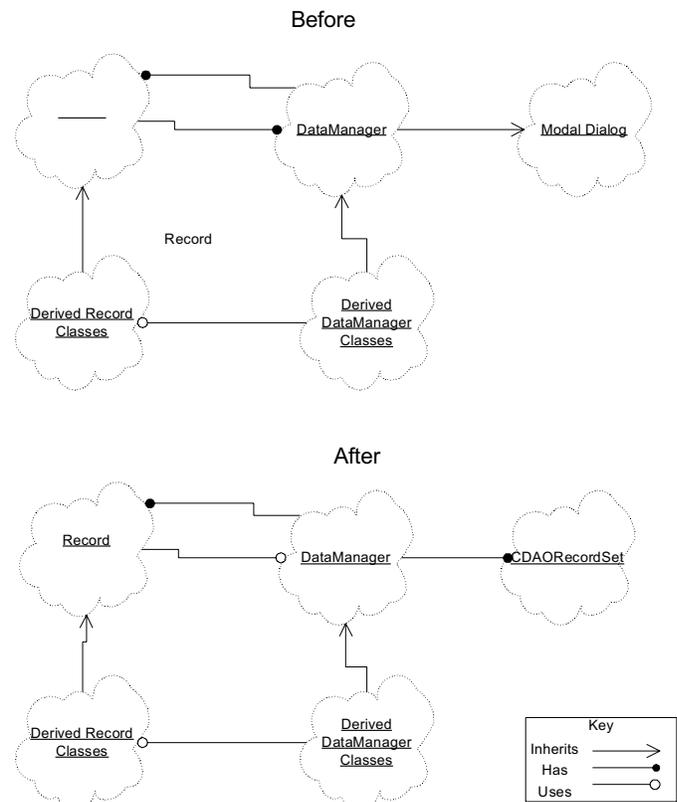


Figure 3. Booch Diagram of key objects in CIM