ENHANCING THE POND© DECISION SUPPORT SYSTEM FOR ECONOMICS, EDUCATION, AND EXTENSION

Ninth Work Plan, Decision Support Systems Research 3 (9DSSR3)
Progress Report

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ABSTRACT

Decision support systems (DSSs) are potentially valuable tools for assessing the economic and ecological impacts of alternative decisions on aquaculture production. This report discusses the latest design, functional modules, and application areas of POND©, a decision tool that has been developed to allow analysis of pond aquaculture facilities by the use of a combination of simulation models and enterprise budgeting. The software makes use of a simulation framework to provide much of the generic simulation, data handling, time flow synchronization, and communication features necessary for complex model-based DSSs. POND© contains representations for manipulating pond aquaculture and utilizes a series of mini-databases, a number of knowledge-based components ("experts"), models of the pond ecosystem, and various decision support features (e.g., assembling alternate management scenarios, economic analysis, and data visualization). A typical POND© simulation consists of assembling a number of appropriate objects or entities (e.g., multiple ponds and fish lots) and their management settings together with appropriate experts (e.g., an aquaculture engineer, an aquatic biologist, and an economist), and projecting changes in the facility over time. Most recent efforts have focused on improving the economic analysis capabilities of POND© and improving the usefulness of the software for addressing specific needs of the education and extension community.

INTRODUCTION

Ponds used for aquacultural production are typically complex systems which can be driven by a wide range of inputs and interactions. This complexity can make designing and managing these systems challenging; successful fulfillment of these tasks can often be assisted by the application of tools which capture important system drivers and their interactions. These drivers can be both ecological and economic in nature. Within the realm of pond aquaculture planning and management, decisions must be made regarding site locations, target fish species, and appropriate practices such as fish feeding, pond fertilization and liming, stocking densities, aeration, and water exchange (Boyd, 1979; Colt, 1986; Hepher, 1988). These decisions typically have considerable effects on resource use efficiency and therefore the economics of an aquaculture facility. The decisionmaking process typically requires some expertise on the part of the planner, manager, or extension agent. Such expertise includes an understanding of the principles of pond aquaculture and the implications of various decisions on facility-level economics (Shang, 1981). In certain situations, it may also be necessary to address socioeconomic issues such as receptivity of farmers to new technology and alternative uses of available resources (Molnar et al., 1996). Decisionmakers usually acquire the required knowledge via a combination of formal education and experience.

Often, the immediate need for pond aquaculture technology may cause decisionmakers to apply or recommend management practices developed and tested at one location to a new site, without first assessing the appropriateness of the technology. A technology found to be suitable for one location may very well be inadequate when applied elsewhere (Colt, 1986). This may be due to differences in fish production potential caused by the variability in climate, water, and soil characteristics among sites and differences in the availability and cost of resources used in pond production (Shang, 1981). For example, a decision as specific as the calculation of feed requirements for a pond requires consideration of fish biomass, natural food availability, and water temperature, which vary both with time and among different locations (Hepher, 1988). Similarly, calculation of fertilizer application rates requires a basic understanding of soil and water chemistry, both of which also vary among different sites. In both cases, availability and cost of appropriate inputs should be factored into the decisionmaking process (Shang, 1981).

The complexity of decisionmaking for an aquaculture facility resulted in the development of POND©, a software decision support tool for analyzing and projecting important cultural and economic aspects of warmwater aquaculture production systems. POND© has been through several iterations of development, with effort during the first year of the Ninth Work Plan focused on completing POND© Version 4.0. Previous iterations of POND© have been documented in PD/A CRSP Annual Technical Reports. Here, we provide a current overview of POND© and discuss the changes in design incorporated into Version 4.

The POND© Architecture

In developing POND©, we utilized an existing simulation framework (Bolte et al., 1993), which provides a wide range of simulation services for managing collections of interacting simulation objects. These services include:

a) Basic time-flow synchronization of system components;
b) Data storage, collection, display, and output;
c) Linear programming tools for optimization; and
d) Parameter estimation methods (for determining best-fit model parameters).

The framework also provides a generic simulation object class, which was subclassed into specific simulation components relevant to pond modeling and decision support. The framework also relieves the developer of much of the management of simulation details and instead allows focus on the specific components of the (physical) system to be modeled. This approach has proven to be an effective and powerful approach for model and/or DSS development and has provided the ability to effectively share simulation objects between applications. Because the underlying framework takes care of simulation details, the primary task in developing POND© was to specify important factors controlling the dynamics and decisionmaking processes of an aquaculture facility and to define a corresponding set of simulation objects. It was important that these components allow simulation of pond dynamics at both the individual pond level, as well as at the facility level. Addressing this need involved providing capabilities for simulating processes within a pond as well as allowing the definition of multiple ponds and multiple fish lots (i.e., a population of fish stocked in a pond), each with their own characteristic data. Simulation of dynamic pond process requires expertise from a number of domain areas, include aquatic biology, aquatic chemistry, fish biology, fish culture, aquacultural engineering, and economics. In an aquaculture facility, each of these domain areas is typically represented by well-defined entities; a facility is a collection of these entities, operating under a particular management context to allocate resources and produce fish.

POND© contains a series of mini-databases, which are accessible to the various objects in the software. For instance, databases are maintained for each lot and pond in a facility as well as for simulation settings, economic information, soil types, fertilizers, feeds, liming materials, site information, and weather characteristics. The software also has an experimental database that allows users to specify the combination of the above databases to be used in a model experiment. This feature has proven useful for quickly assembling and executing relatively complex scenarios of alternate pond management practices.

Additional objects representing "experts" managing the facility were defined. These experts include 1) an aquatic chemist, with the ability to perform a wide range of water chemistry calculations, 2) an aquatic biologist, with the ability to perform functions related to fish growth and algal dynamics, 3) a weather manager, with the ability to estimate weather conditions for specific sites, 4) an aquacultural engineer, with the ability to perform heat and water balance calculations, among others, and 5) an economist, capable of performing enterprise budget analyses and managing costs of various facility operations.

The various experts in POND© have capabilities for simulating different aspects of production. These areas include fish performance, water temperature, water quality dynamics, and primary and secondary productivity. Models in POND© are organized hierarchically into two levels, allowing users to perform different kinds of analyses based on data availability and output resolution requirements. Level 1 models are fairly simple, require minimal data inputs, and are intended for applied management and rapid analysis of pond facilities. At this level, the variables simulated are fish growth (based on a bioenergetics model) and water temperature. Consumption of natural food by fish is assumed to be a function of fish biomass and appetite. Fertilizer application rates are typically user-specified, but the model optionally generates supplementary feeding schedules.

Level 2 models provide a substantially more sophisticated view of pond dynamics, allowing prediction of phytoplankton, zooplankton, and nutrient dynamics (carbon, nitrogen, and phosphorus) in addition to fish growth and water temperature. This modeling level is intended for detailed pond analysis, management optimization, and numerical experimentation. Fish can feed from natural and/or artificial food pools. Consumption of natural food (phytoplankton and zooplankton pools) by fish is predicted on the basis of a resource competition model and also depends on fish appetite. At this level, a constant, user-specified concentration of pond nitrogen, phosphorus, and carbon is assumed. Mass balance accounting for each of these variables is maintained, allowing estimation of fertilizer requirements necessary to maintain steady state levels. Level 2 models generate both fertilization and feeding schedules. Further details regarding the models in POND© and their verification can be found elsewhere (e.g., Nath, 1996).

Economics

POND© allows the incorporation of economic analyses of facilities in the form of enterprise budgets. Enterprise budgets allow for the accumulation of various types of cost and income streams, summarized and coupled with interest and depreciation expressions, to assess the overall economic viability of a particular production enterprise. POND© supports three cost categories: 1) fixed, 2) depreciable, and 3) variable costs. Fixed costs are those costs that do not change over the course of facility operation (e.g., construction cost for a pond, a one-time cost that does not vary over time). Related to fixed costs are depreciable costs, which typically are used for items that require up-front expenditures, but which may have some back-end redeemable value after some period of time. POND© incorporates depreciation schedules describing the loss of value of the depreciable asset over time. An example of a depreciable cost is a tractor, which has an initial cost as well as a resale value after some period in use at the facility. Variable costs are those costs that are not fixed or depreciable and typically vary according to the scale of production (e.g., labor costs, fertilizer and feed costs, and fuel and electricity costs).

To generate an enterprise budget, income sources are also required. POND© allows the specification of any number of income sources, based on either a per unit area, per unit of production, or per facility basis. The facility simulator provides income sources relating to fish production. Additionally, interest rates used for calculating fixed and variable investment costs are required. After specifying each cost by an amount—a cost type (fixed, depreciable, or variable), basis (per unit area, per unit of production, or per facility), and other related information—the economics module in POND©

summarizes costs on an areal, per unit of production or per facility basis, balances those costs against income, and reports the results in a tabular form. By including and/or excluding particular costs/incomes, or adjusting cost/income details, one can quickly "experiment" to determine alternative possibilities for the economic viability of various facility and management configurations. Version 4 expands on previous enterprise budget capabilities in several important areas. The first of these is an ability to specify market prices for different sizes of a particular target species, thus determining a) at what point in the culture period returns from harvest begin to exceed fixed and variable costs (where the facility becomes profitable) and b) where the optimal harvest time occurs, based on maximizing marginal returns relative to marginal costs. A second enhancement is the ability to schedule periodic costs, allowing more accurate representation of annual cycles of production and providing the ability to conduct long-term facility analyses.

EXPERIENCE GAINED

The design, development, and implementation of the POND© software has provided useful lessons in several areas. As the user base for POND© has grown, we have had the opportunity to solicit feedback on how well POND© is addressing user needs. The first lesson is that a diverse group of users has used POND© to address a diverse set of needs. Although we originally anticipated a research-focused audience, our largest group of users has in fact been commercial aquaculture facility managers. The primary focus of this group has been on economic analyses, with the utility of the biological models contained within POND© of secondary importance. An additional audience has been educators using POND© in the classroom as a tool for examining pond dynamics, where the biological models play a more important role. Each of these groups has a different set of interests and a different user interface requirement, and the "one size fits all" approach that we initially used has not been optimal in addressing their respective needs.

Feedback from POND© users primarily pertained to the ease of use of the software. Although we have spent considerable effort in developing a modern user interface for POND©, because of the underlying complexity of the models POND© employs and our desire to fully expose these models, the user interface proved to be burdensome for many users. Exposure of the underlying models is helpful to those focused on understanding the detailed biological dynamics of these systems, but it is less helpful or irrelevant to those focused primarily on economic analyses of facility operations.

We have started to address this issue in the latest release of POND© in two ways. First, the focus of POND© Version 4, from a user interface perspective, is more on decision support and less on models of the underlying biophysical system. The underlying models continue to be an essential tool for supporting decisionmaking but are less apparent to the user. In other words, they operate in the background but play a secondary role to higher-level decision-making processes. Second, we have introduced a series of "wizards" into POND©. These wizards are software tools that "walk" the user through specific and frequently used tasks (e.g., estimating feed, fertilizer, and water requirements and associated economic implications). The wizards hide much of the complexity of these tasks and provide immediate help to users in accomplishing their goals. We anticipate continued development of these wizards to address specific needs of different user groups and to improve ease of use of the program.

The development of specific wizards was driven by 1) identifying frequently used application areas within POND© and 2) identifying areas which were sufficiently complex to warrant additional user support. This resulted in the development of the following wizards, which have been incorporated into Version 4:

- A *pond setup* wizard to enable users to define new ponds at their facility;
- A *lot setup* wizard to enable users to define new lots that are associated with specific ponds;
- A *fertilizer* wizard to generate routine pond fertilization recommendations;
- A *liming* wizard to estimate lime requirements for ponds associated with specific soil types;
- A *feed optimizer* wizard to generate feed schedules that minimize the amount of feed needed to reach a specified fish target weight;
- A *water balance* wizard to conduct water balance calculations and estimate water requirements;
- An *economics* wizard to assist in calculating enterprise budgets and optimize economic performance; and
- A *simulation* wizard to conduct facility-level simulations at a given site and view simulation results in graphical and tabular formats.

The target audience for POND© continues to evolve. The bulk of our requests come from commercial producers looking for tools to improve their ability to design and manage their facilities. We are examining the possibility of developing an additional product specifically oriented towards routine management of aquaculture ponds. It is expected that some of the components developed and tested in POND© will be reused for this product. Another audience from whom we have had numerous requests is small commercial entrepreneurs, often new to aquaculture, who are looking for tools to help them explore the financial feasibility of launching an aquaculture venture. Both of the above groups tend to focus primarily on economic analyses but require some basic understanding and consideration of the biophysical processes underlying facility operation. Aquaculture educators represent a final audience for POND©. Their requirement is for readily accessible tools that students can use in class to enhance their understanding of the biophysical processes controlling aquaculture ponds, as well as to complete specific design tasks related to facility management.

ANTICIPATED BENEFITS

The work accomplished in this study will provide improved analytical tools for managing warmwater aquaculture facilities and increase understanding of the economic implications of various facility configurations and management options. Additionally, it will provide tools for educators to integrate the biological and economic aspects of pond dynamics in a readily accessible format appropriate for students to explore important issues of pond production.

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