



AES News, Spring 1999, Vol. 2, No. 2

Letter From Your President

Dear AES Members,

I am happy to inform you that by all measures, the latest Aquacultural Engineering Society sponsored conference sessions were a booming success. The venue was Darling Harbor, in Sydney, Australia! If you survive the 14 - 1/2 hours from Las Angeles to Sydney in the air, you were in for a real treat! World Aquaculture '99, the annual conference and tradeshow of the World Aquaculture Society was held in Sydney from April 24 – 30, 1999. With more than 3,100 participants from 84 countries, this was one of the largest WAS meeting ever held outside of the United States.

The AES was well represented. Our sessions covered two full days and included invited speakers only "Presidents Session", a contributed papers session, and two 1/2 day workshops. The Presidents Session featured four speakers, Dr. James Muir from Scotland, Dr. John Patterson from Australia, Dr. Rolando Platon from the Philippines, and Mr. German Marino from Chile. The speakers highlighted aquacultural engineering advancements in Europe, Australia, Southeast Asia and Latin America, respectively.

The workshops focused on water reuse in aquaculture. On the first day, Drs. Dave Brune, Tom Schwedler and John Collier presented in detail the "Partitioned Aquaculture System" (PAS) that has been developed to intensify fish production in ponds while reusing water at Clemson University. On the second day, Dr. James Muir and myself presented technical considerations in recirculating aquaculture tank systems. All of the sessions were presented to "standing-room-only" crowds! For the effort, the Aquacultural Engineering Society signed up a handful of new

members from Australia, and earned over \$5,500 in a participation fee from the conference planners. These fees for our efforts are vital to the upkeep and future of the society (sorry folks, your dues do not pay for much more than the Journal!).

So...where to from here? We hope to see you all in Raleigh in November for our "members only" Issues Forum. If not, please plan to travel to New Orleans in February, 2000 or Nice, France in May of 2000. As usual, the AES will be participating in these conferences by taking the lead in the development of the engineering sessions. If you would like to be involved in the planning for any or all of these sessions, please contact me and I will put you in touch with the session chairman.

I hope you all have a safe and productive summer. As always, let me hear from you if you have any suggestions or comments. My email is: Tlosordo@Unity.ncsu.edu and my phone number is (919) 515 – 7587.

With Best Regards,

Tom

Thomas M. Losordo, President

AES Column in Aquaculture Magazine.

Articles are needed for our column in *Aquaculture Magazine*. They are generally popularized versions of the technical aspects of aquaculture production, about 2000 words long. Longer articles are welcome; they are generally broken into parts for sequential issues.

This column is excellent PR for the AES, but it needs the support of the membership to continue.

To date, they have mostly focused on recirculating systems, but other technical subjects are welcome. Please contact me to discuss proposed articles and to check on what has already been covered.

Dick

Dick Patterson, AES Coordinator with *Aquaculture Magazine*
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Computer Monitoring for System Planning, Design and Management

By Paul H. Piedrahita,^aDoug Ernst,^band Shree Nath^c

INTRODUCTION

The status of practical applications of computer modeling to aquaculture research, teaching, planning, design, and management is highly variable. This is due to many factors such as; limitations in our understanding of processes and systems, differences in user expectations and requirements, and differences in the development effort devoted to the different application targets. For example, whereas there is a great deal of quantitative information available on some processes and systems, we have a more qualitative understanding of others. Similarly, ensuring user friendliness is a primary consideration for models to be used for management and design purposes but other considerations are more important for research models. Lastly, model development is a slow and time consuming (therefore expensive) practice and efforts have focused, with a few notable exceptions, on research models. In this paper we will not attempt to present an exhaustive review of aquaculture system modeling, but to discuss and highlight some practical aspects of modeling. Details of existing modeling applications are available in an upcoming special issue of Aquacultural Engineering and other places (e.g. 1,2,3)

SOME DEFINITIONS

We must start with some definitions to make sure we all know what we are talking about. A *model* is a collection of mathematical equations or rules that describe fundamental relationships between components of a system. Therefore, a model provides a rigorous framework for characterizing important variables, relationships, and processes in a system. In general, *equations* represent relationships that are *quantifiable*, while *rules* represent relationships that are at least

partly *qualitative* in nature. Execution of a model tells us something about the response of the system to a particular set of operating conditions or environmental constraints.

Types of Models

Models consist of qualitative rules and/or quantitative equations. Ideally, the type of model should fit its intended use as well as the information or knowledge constraints. There are many different ways of classifying models, and only a few of those classifications are presented here. For example, models may be *simple*, e.g. a fish feeding rate chart, or *complex*, e.g. a pond ecosystem model. Simpler models are typically used for simulating a single process, whereas the more complex models may consider a large number of processes or system components.

Models may be primarily *empirical* or *mechanistic*, although in practice most models include elements of both types. In empirical models, the system described is treated as a “black box” where outputs are related to inputs by statistically based regression models derived from data. Mechanistic models, on the other hand, seek to explain and predict system behavior based on theories of physical, chemical, and biological processes within the system. In general, empirical models are more commonly used for management purposes since they can be easily customized and updated to a particular application, resulting in more accurate simulations. Mechanistic models are normally preferred for research and design since they are more generally applicable, can make better use of related information in aquaculture science and engineering, and can provide new insights into system behavior. For example, an empirical model intended for managing a recirculation system should be easy to execute and update (possibly automatically

through data acquisitions systems) and it should provide accurate estimates of system condition for the particular system being managed. In contrast, a mechanistic model used for research into the design of recirculation systems and its components, should be a great deal more detailed and general, require more data for execution, and generate an output that is useful in increasing the user’s understanding of how and why a recirculation system operates. The process of developing a mechanistic model forces us to clearly articulate and identify both our knowledge of a system and our *lack of knowledge* about specific aspects of a system. Therefore, models provide an opportunity for *knowledge synthesis*, whereby a body of knowledge can be synthesized into a single entity (a model) useful for exploring relationships. In fact, because of the rigorous nature of model specification, a model is a *testable hypothesis* about a system; we can run a model under a set of known conditions and observations to determine to what extent our knowledge of the system, as embodied in the model, is correct.

Models may be *deterministic* or *stochastic*. Deterministic models predict identical results given the same set of input parameters and variables. Deterministic simulations can be based on worst, best, or mean case scenarios. Stochastic simulations require multiple simulation runs (e.g. 30-100) to generate probability distributions of predicted variables, in which selected input parameters and/or system variables vary stochastically within and between simulations. The additional complexity of accomplishing and interpreting stochastic simulations is considerable, and is generally not attempted unless there are strong reasons for doing it.

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HOW DOES ONE GO ABOUT DEVELOPING A MODEL?

All models represent some degree of abstraction and simplification of the components and processes they describe. For example, a road map is a model of a landscape, and if a map included every attribute of the landscape, then it would have to be as big as the landscape itself and would not provide any useful function. Selection and use of simplifying assumptions is a critical and necessary task of model development. The required resolution (detail and complexity) and scope (breadth of view) of a model depends on its intended use. Therefore, the first step in developing a model is determining its intended use and the reasons for its development. Next comes an information-gathering step and the type of information needed is highly dependent on the type of model being developed. For example, a model to be used for management purposes (an empirical model) will require extensive data from the system to be managed. In contrast, a research model (a mechanistic model) will require extensive review of the scientific and engineering literature to develop an understanding of the relevant processes and variables. The information collected is used in formulating the equations and/or rules for the model. In the case of empirical models, statistical methods are used to analyze data and develop equations. In the case of mechanistic models, equations are developed from an understanding of the system, and are usually based on energy and mass balances. Rules are formulated from the coded knowledge about a system. Equations and rules are placed within a simulation framework that allows specification of model inputs and solution of the model equation(s). The modeling process then proceeds iteratively and the model is executed for known conditions, results are analyzed for conformance with observed data, and model equations or parameters are adjusted (*calibration*) until a sufficient level of agreement between the model and experimental observations is reached. At this point, the model is considered *validated* for the range of observations made, and can be used for predictive purposes.

Depending on whether a model is empirical or mechanistic, the equations and parameters used may be highly specific to the particular system for which the model

was developed, or they may be generic in nature. In the case of a generic, mechanistic model, its application to a specific problem is based on the input variables used, and not on modifications of the structure or equations used in the model. However, mechanistic models often require some level of re-calibration of parameter values if the conditions to which they are applied differ markedly from conditions corresponding to the data used for model testing and validation.

Some Critical Decisions

There are a number of critical decisions a modeler must make, and some of those are presented here. One major area of consideration is selecting the temporal resolution, i.e. diurnal versus daily simulations. The simulation time-step is based on the nature of the aquaculture system and the temporal resolution that is required to capture critical system dynamics. Diurnal simulations using time steps ranging from a fraction of an hour to a few hours are required when the variability of process rates and system variables within a 24-hour period significantly impact system performance and management. Daily simulations using one-day time steps represent a level of simplification in which diurnal variables and processes are expressed and used as daily means. Typically, the use of diurnal simulations significantly increases the complexity of a model and is only undertaken if diurnally varying processes need be accounted for in facility design and management, e.g. intensively managed solar-algae ponds, highly intensive recirculation systems.

A second major area of consideration is the selection of the facility specifications and system variables to be included in a model or set of models. This selection depends on the type of facility (e.g. flow-through, recirculating, and ponds) and user design objectives. For example, it may be adequate to simply consider fish size, feed ration, and water temperature, or it may be necessary to also consider dissolved oxygen, fish metabolites, and facility specifications and processes that impact these variables.

Data Needs

One of the biggest obstacles impeding the more widespread development and use of models in aquaculture is the lack of

adequate data sets for model testing. This is especially true for mechanistic models, and applies to the full range of aquaculture systems, from ponds to intensive recirculation. Data collected from aquaculture systems tend to be limited to a small number of variables measured over relatively short periods of time at relatively low frequency. In addition, whatever data are collected, they are normally not collected with the specific goal of using them in modeling. As a result, data are typically not available in standardized formats that permit effective use by multiple modelers. In our own work in pond and recirculation system modeling, it has been difficult to calibrate and validate models because of the lack of suitable datasets.

However, data sets useful for pond modeling have been created by a group of researchers in the Pond Dynamics/Aquaculture Collaborative Research Support Program (PD/A CRSP), a USAID-funded program that conducts research at various sites overseas. This group has developed a protocol for data collection and a set of associated standardized methods to collect the data. The data are archived in a relational database, which can be activated from the Internet at <http://biosys.bre.orst.edu/crspDB/>. The principles behind the overall PD/A CRSP effort in this direction are applicable to other aquaculture systems as well. Apart from the obvious value of such an approach to the developers and users of models, the aquaculture community at large would benefit as well because a standard approach to field experimentation can be implemented. This would allow performance comparison of aquaculture systems across geographical regions and with different operating conditions, and would provide a resource of 'global' value. In the case of intensive recirculation systems, there is an extensive literature base on a variety of water treatment operations. These publications provide data that can be used of a modeler in the development of a model for a particular water treatment system. However, contrary to the pond situation described above, there are no standardized data sets available for complete recirculation systems.

SOME EXAMPLES

A listing and description of some software for aquaculture siting, planning, design, and management is available on the Internet (4). Much of the software listed falls under the general category of decision support systems, in which quantitative methods and models, rule-based procedures (heuristics), and/or databases are packaged into interactive software applications (e.g. POND and AquaFarm). Decision support systems are used to analyze and predict system performance and assist the user in selecting best or optimal system designs and management practices from alternative scenarios. Provision of graphical interfaces and data management mechanisms for decision support systems is critical to support user project specification, performance review, and problem solving tasks. Examples of decisions to be made are: a) site location; b) fish species; c) system design (configuration and specification of water transport, water treatment, and fish rearing systems); d) facility and fish culture management (control of water treatment, fish grading, sorting, and harvesting); e) and economic feasibility.

System dynamic models are a different category of models. These models are strictly quantitative, in contrast with the decision support systems described above. Examples of these models are available for ponds (5) and recirculation systems (6). In general, these models are designed to serve as research tools, with secondary applications in design and teaching. As such, the emphasis in these models is in the development of accurate numerical representations of processes and variables in aquaculture systems. These models tend to be less comprehensive and less user friendly than decision support systems. They also tend to be more detailed in their analysis of specific relationships and processes related to water quality and fish culture.

A third category of models are enterprise budgets that can be used to quantify net profit or loss over given production periods (7). Enterprise budgets are particularly appropriate for comparing alternative facility designs, in which partial budgets are utilized that focus on cost (e.g. fish feed) and revenue (e.g. produced fish) items influenced by proposed system changes. Enterprise budgets are built by combining simulation-generated and user-

specified cost and revenue items. Simulation generated items are those directly associated with aquaculture production and therefore predictable, e.g. facility units, energy and material consumption, and produced fish and wastes. User specified items include additional cost and revenue items outside the scope of most decision support systems, e.g. supplies, equipment, facility infrastructure, and labor. Additional financial statements (e.g. cash flow and net worth), economic feasibility analyses (e.g. net present value and internal rate of return), and market analyses are required for complete economic analyses (7, 8). Generic business software may be utilized for this purpose. Some reported studies combine facility level modeling with a range of economic analyses and optimization procedures in addition to enterprise budgets (9).

CHALLENGES AND OPPORTUNITIES

Model developers and proponents are faced by a number of challenges. First, there is the need to overcome biases and to correct perceptions among aquaculture personnel, including the modeling community. Many field researchers question the value of models, a situation that is related either to a lack of understanding of the modeling process (and associated data needs and time commitments) or to unrealistic (and unmet) expectations of the power and usefulness of models, particularly in terms of predictive capabilities. After all, such capabilities represent one of the many aspects and potential benefits of a model. One way of creating a more receptive audience for models is by making sure that aquaculture experts in related disciplines and potential users are involved in model development. A related issue is the potential for models to be misused because of lack of attention to model assumptions, use of models for situations for which they have not been tested, or application of models in cases where adequate inputs are not available. Further, modern computer technology makes it very easy to execute models at the push of a button – users often do not realize the importance of correctly assembling a set of data for use in the modeling exercise, and critically evaluate model output. The old computer adage of ‘garbage in – garbage out’ is worth recalling in this context. It is the responsibility of

both developers and users to ensure that models are used with an understanding of what they are intended to address.

A second challenge relates to the development of standards for data collection and archiving. This is a critical challenge not only for modelers but also for the aquaculture community as a whole. Standardization of data collection and database development offers unique opportunities for data analysis and knowledge synthesis.

A third challenge for the modeling community is to reach out to end users. In the past, most of the model development activity has occurred in a purely academic, research setting. The efforts have not always attempted to address the needs of potential users such as aquaculture students, planners and managers from the outset. For example, model use in teaching offers especially exciting opportunities for conveying large amounts of information and allowing students to “experiment” with “virtual systems”, but these models have to be created to meet the educational background and goals of the students. Involving users in model development is a way of ensuring that realistic expectations exist for what a model can and cannot do. An important lesson we have drawn from our work on model development is the realization that we, as aquacultural engineers and not just as modelers, continue to have limited understanding about how different aquaculture systems function. Whereas there is a great deal of information about some processes, we have very limited quantitative understanding about other processes. Our lack of understanding becomes even more noticeable when we attempt to look at complete systems rather than individual components. For instance, there is a great deal of information on oxygenation systems but it is still very difficult to model organic matter and ammonia removal, and it is even more difficult to model water quality in a complex recirculation system.

Perhaps it is time to evaluate whether the tools (e.g., simulation models, decision support systems) we currently use are adequate to meet our combined expectations. It may well be that new modeling paradigms are required to help us better understand, design, and manage complex systems. In any event, models clearly have a critical scientific and engineering role in aquaculture, and there

certainly appear to be enough gaps in our knowledge to keep modelers busy for the foreseeable future!

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planning of sustainable aquaculture. In: J.E. Bardach (Ed.), Sustainable Aquaculture, John Wiley and Sons, New York. pp. 149-175.

SUGGESTED FURTHER READING

- Cuenco, M.L., 1989. Aquaculture Systems Modeling: An Introduction with Emphasis on Warmwater Aquaculture. ICLARM Contribution No. 549. 46 pp.
- James, A. (Ed.), 1984. An Introduction to Water Quality Modelling. Wiley Interscience, New York. 234 pp.
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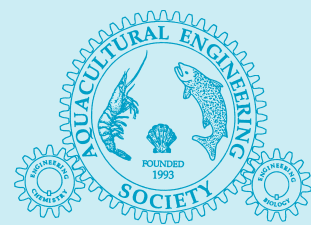
AES Newsletter

The *AES News* is printed quarterly by the Aquacultural Engineering Society. You can receive the *AES News* by joining the Aquacultural Engineering Society. If you would like to discuss the contents of the *News*, or, if you would like to contribute information to the *News*, please contact either of the two Co-Editors:

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The **Aquacultural Engineering Society** was founded in 1993 to provide a forum for addressing engineering problems related to aquaculture. Its membership is open to engineers and non-engineers engaged in the culture, processing, and/or distribution of aquatic organisms or their by-products. The AES serves as an authoritative source of engineering information and support to the aquaculture industry. Working with other aquacultural groups and societies, the AES brings people together to discuss new ideas and technologies of benefit to the aquacultural community as a whole.

AES Members receive a one-year subscription to the journal *Aquacultural Engineering*, updated membership directories, and the *AES News*.

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Where Are We Today?
An Issues Forum for Aquacultural Engineers
November 4-5, 1999 • Raleigh, North Carolina, USA

Prologue

Every once in a while we, the members of the Aquacultural Engineering Society, need to gather together and reflect upon the advances that have been made in the arts and sciences of aquacultural engineering and the important issues facing us. Without a doubt, recirculation, or is it recirculation, has taken much of our time and attention. The advances we have made in recirculating systems, and there are many, not only did not diminish the problem they seemed to have added to its dimension.

At the beginning, we seemed to know what biofilter means. Do we still think so? Bacteria certainly can remove nitrogenous substances from an aquaculture system, but so do algae and vegetables. So here come the Photo-Bioreactor Systems. Are those terms befitting the bioengineering direction many of us are moving toward, or are these terms an indication that we are deserting our farming background?


The marriage of Hydroponics and Aquaculture seems to be made in Heaven, or is it? If it is, why haven't we seen more of it? Vegetables require high nutrient levels, but do they really? Can vegetables thrive in low nutrient environments if the water velocity in the root zone is increased?

Then there are the growth vessels, which is a fancy way to say tanks, ponds and raceways. Do we know how to design them? Should ponds be big and elongated, or small and round? If they are to be small and round, do we need ponds at all?

Many of us think we can argue on both sides of these issues, and here is an opportunity for you to do exactly that.

On November 4-5, 1999, come and join your fellow engineers for two days of serious discussions (designs, formula, and data), laughing, and beer (wine for more cultured persons, and rum for those with exotic tastes, uh?). The AES Issues Forum will be hosted at North Carolina State University's Jane S. McKimmon Conference Center for Extension and Continuing Education in Raleigh, North Carolina, USA. On November 6, 1999, optional tours will be run at the Carolina Power & Light Fish Barn at North Carolina State University and possibly at a commercial recirculating farm.

Thomas Losordo is the local host (Tel: 919- 515-7587; Fax: 919-515-5110; and Jaw-Kai Wang, and David Brune are the Program Chairs for this Issues Forum.

There will be a registration fee of only \$100 for AES Members (registration will be \$185 for non-AES members), which includes two lunches, dinners, a wine and beer social on November 4th, and coffee/soft drinks during the breaks. Use the AES Issues Forum registration information on page 12 of this Newsletter. Registration will be limited to 135 and your registration material must be received by October 20, 1999. 

Preliminary Program

Session Title

- 1) Water distribution, mixing and hydrodynamics
- 2) Water treatment and reuse: bacterial systems
- 3) Water treatment and reuse: photosynthetic systems
- 4) Systems and component design
- 5) Sludge and particulate management

Moderator

- Bamby Watten
David Brune
Jaw-Kai Wang
Kelly Rusch
Paul Hundley

Logistics

LOCATION:

The Jane S. McKimmon Conference Center
North Carolina State University
1101 Gorman Street
Raleigh, NC 27695-7401 USA

DATES:

Issues Forum: November 4-5, 1999
Optional Tours: November 6, 1999
Carolina Power & Light Fish Barn at North Carolina State University Commercial Recirculating Production Facility

TRANSPORTATION:

Raleigh/Durham International Airport (airport code RDU). RDU is served by American, Delta, Northwest, United, Air Tran, US Airways, Midway and Southwest Airlines.

Free shuttles are available from RDU to the Ramada Inn and the Velvet Cloak Inn.

LODGING:

Ramada Inn/Blue Ridge
1520 Blue Ridge Road
Raleigh, NC 27607
Telephone: (919) 832-4100

The Ramada Inn is the preferred hotel for the conference (free transportation to the conference site). Conference Room Rate: \$69.00/night.

Velvet Cloak Inn
1505 Hillsborough Street
Raleigh, NC 27605
Telephone: (919) 818-0333

SOCIAL AGENDA:

Break service, lunch and dinner will be provided on November 4th and 5th as part of the registration package. On November 4th, we will gather before dinner for a social hour; beer and wine are included in the registration

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REGISTRATION

Registration will be limited to 135. [Deadline for registration is October 20, 1999.](#) Registration will not be available at the door.

	AES Members	Non-Member
Conference registration	\$100 per person	\$175* per person
Tours on November 6	TBA	TBA

*Non-member registration includes membership in the AES for one year, which includes a years subscription to Elsevier's journal *Aquacultural Engineering* and the *AES News*.

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The AES is looking for sponsors within the aquaculture industry to support the increased cost of producing the *AES News*. The sponsors listed below have donated generously to support the AES. For this donation, the AES will be inserting a one-page product literature sheet in one of the newsletter mailings, and list the vendor as an AES supporter in four consecutive newsletters. Please contact one of the *AES News* Co-Editors if you would like to be a sponsor.

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Highest Degree _____ Major _____ Institution _____ Year _____

_____ \$75 (US) Individual Member; _____ \$75 (US) Student Member ; _____ \$25 (US) Student Member

Master Card _____ Visa _____ Credit Card No. _____ Exp. Date _____

Exact spelling of name on credit card: _____