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

This study deals with development of decision support tools for warmwater pond aquaculture. Efforts are directed at refining the POND software. Refinements to POND discussed here include development of tutorials and user interaction enhancements to facilitate the use of POND in educational and extension environments, and the development of a shrimp growth and development model incorporated into the POND framework. A POND tutorial has been developed, addressing problems relating to fertilization and liming calculations and to simulation setup. A new set of tutorial databases have been developed to facility the use of POND in these environments. In the interest of familiarizing the user with POND, discussions of how to create new ponds, fishlots, and other database objects have been expanded. The development of a marine shrimp model in POND is complete. It was developed using the BIOE bioenergetic model built into POND, and calibrated using the results from twenty six datasets related to shrimp production in the CRSP database.

INTRODUCTION

Decision support systems for pond aquaculture can aid in the analysis and understanding of the dynamics of pond production. The PD/A CRSP has been involved with the development of decision support software for aquaculture systems for a number of years, resulting first in the PONDCLASS software (Lannan, 1993), and then the POND software (Bolte et al., 2000). POND provides the ability to simulate pond dynamics and fish growth for warmwater pond aquaculture facilities, and to compute enterprise budgets relating various cost and returns from a particular facility to determine short- and long-term profitability. The growth and waters quality models embedded in POND have been widely validated using data from both PD/A CRSP sites and other warmwater aquaculture sites. Previous efforts at developing POND have focused primarily on developing the underlying model used by POND for decision support, and these efforts have been largely successful.

Recently, under the PD/A CRSP program, POND has been extended in several significant ways. Feedback from POND users indicated that refinements to POND where needed in the areas of 1) improved flexibility in enterprise budget capabilities; 2) provision of more extensive tools for helping users take advantage of the analytical tools available in POND, and 3) extension of POND's bioenergetic model to include analysis of shrimp production. These capabilities have been added to POND. The improvements in the enterprise budgeting capabilities are largely focused on providing more flexibility in scheduling periodic and non-periodic costs, and improvements in the user interface designed to increase ease of use. Overall usability improvements and a detailed characterization of the shrimp production models are described below.

POND USABILITY IMPROVEMENT

The POND user's manual has been revised and updated to reflect the major changes which were implemented in POND version 4.0. The most important change in the software is the addition of an application 'wizard', which guides the user through a step-by-step process to accomplish a number of basic tasks, such as creating new fish ponds and fish lots, calculating the fertilization and liming requirements for a pond, and setting up and running a simulation. The updated manual includes a chapter which documents the eight wizard-mediated tasks.

Other changes included the addition of installation instructions for Windows 95/98 operating systems, as the POND 3.0 manual was written for a Windows 3.x environment. The interface for the weather database was significantly revamped, and minor changes in other databases were also reflected in the documentation revision.

The POND manual was converted to a file library for use in AuthorIT, a help authoring program which can create Microsoft Word documents, Windows Help files, and HTML files from the same source files. The manual is thus being made available in any of these formats, facilitating flexible use on individual machines or via the Internet.

The existing POND tutorial has been reworked in accordance with the updated software. In some cases, particularly in problems relating to fertilization and liming calculations and to simulation setup, the basic tasks are now accomplished using a completely different method than in version 3.0. A new set of tutorial databases has been developed to support these new methods, as the default databases distributed with POND no longer include the necessary objects for the tutorial. In the interest of familiarizing the user with POND, discussions of how to create new ponds, fishlots, and other database objects have been expanded and incorporated into the tutorial and help systems.

The POND tutorial has been added to the same AuthorIT library which contains the user's manual files, so that information may be shared between the two documents. This enables us to distribute the tutorial as a Microsoft Word document, Windows Help file, or as HTML pages.

DEVELOPMENT OF A GROWTH AND FEEDING MODEL FOR MARINE SHRIMP

Methods

A total of 26 datasets from the CRSP Database (http://biosys.bre.orst.edu/crspDB/) were utilized for model development (Table 1). These datasets consisted of raw data from individual experimental treatments for the production of Penaeus vannamei (Pacific white shrimp) and P. monodon (tiger shrimp) in ponds. These ponds received various water exchange rates, various application rates of inorganic and organic fertilizers during pre-conditioning and/or culture periods, and some use of supplemental feeds. Additional datasets of raw, experimental data for laboratory and intensive tank culture of P. vannamei were obtained from the Oceanic Institute (Leonard Obaldo, personal comm.).

The bioenergetic model for finfish and shrimp (BIOE model) available in the POND software was utilized for the development and application of growth and feeding models for shrimp production. The BIOE model is a comprehensive, unified modeling approach, with respect to the multiple environmental and food-resource variables impacting shrimp performance (Nath, 1996). POND provides functionality for calibrating model parameters using shrimp production datasets, as well as functionality for the application of these calibrated models to the simulation of shrimp production. This methodology has been fully explained by Nath (1996).

Prior to regression procedures using the BIOE model in POND, datasets were analyzed using the double-log specific growth

Table 1. Shrimp production datasets (26 total) in the PD/A CRSP Central Database used to calibrate a shrimp growth model for POND. Given study and treatment codes can be used at the Database web site for additional information on experimental protocols. Given here are culture period, use of fertilizers and feeds, and shrimp species and stocking density.

Study	Treatment	Per. (days)	Inorg. Fert.	Org. Fert.	Supp. Feed	Species	Shrimp/m2
A_01_01	A	102	false	true	false	P. vannamei	5
A_01_02	A	140	false	true	false	P. vannamei	5
A_02_01	A	93	false	false	false	P. vannamei	4
	B		false	false	false	P. vannamei	4
A_02_02	A	153	true	true	true	P. vannamei	4
	B		true	true	true	P. vannamei	4
A_03_01	A	73	false	false	false	P. vannamei	4
A_03_02	A	132	false	false	true	P. vannamei	4
G_02_01	H	164	true	true	true	P. monodon	4
	I		true	true	true	P. monodon	4
	K		true	true	true	P. monodon	4
G_02_02	H	196	true	true	true	P. monodon	4
	I		true	true	true	P. monodon	4
	K		true	true	true	P. monodon	4
G_03_01	A	129	true	true	true	P. monodon	4
G_03_02	A	71	true	true	true	P. monodon	4
J_08_HR3A	A	138	false	false	true	P. vannamei	16
	B		false	false	true	P. vannamei	16
J_08_HR3B	A	119	false	false	true	P. vannamei	16
	B		false	false	true	P. vannamei	16
J_08_HR4	A	242	false	false	true	P. vannamei	16
	B		false	false	true	P. vannamei	16
	C		false	false	true	P. vannamei	16
J_INT_1B	A	87	false	false	true	P. vannamei	30
	B		false	false	true	P. vannamei	30
	C		false	false	true	P. vannamei	30

rate model (DSGR model) (Hepher, 1988; Ernst 2000). The DSGR model is:

$$SGR = SGR_c\, W^{-SGRe}$$

or $$GR = SGR_c\, W^{(1.0 - SGRe)}$$

by integration

$$W_t = [W_o^{SGRe} + (SGR_c\, SGR_e\, t)]^{(1.0 / SGRe)}$$

where

SGR = specific growth rate (1/day)
GR = growth rate (g/day)
SGR_c = coefficient (intercept of log transform regression)
SGR_e = exponent (slope of log transform regression)
W = shrimp body weight (g) (subscripts 0 and t denote time zero and current time)
t = time (days)

SGR_c is a function of (1) water temperature, using a second-order polynomial scalar function (Miao and Tu, 1995), (2) additional water quality scalars, and (3) food availability (Ernst, 2000). Model parameters can be determined by log-transform linear regression. Geometric-mean fish weight (W_{gm}, g) and SGR values are calculated for each growth interval of the sample fish weights (W_o and W_t), and their natural logs are used:

where

$$W_{gm} = e^{\{ [\log_e(Wo) + \log_e(Wt)] / 2.0 \}}$$

$$SGR = [(\log_e(W_t) - \log_e(W_o)] / t \text{ and}$$

$$\log_e(SGR) = \log_e(SGR_c) - [SGR_e \log_e(W_{gm})]$$

RESULTS AND DISCUSSION

Calibration (regression) procedures for the BIOE model in POND can variably consider a number of environmental and food-resource variables. All significant driving variables of shrimp performance must be included in model regressions in order to achieve meaningful results. Drivers of shrimp growth include (1) body weight, (2) daily feed intake (natural food resources and prepared feeds), (3) water temperature, and (4) any limiting water quality (e.g., dissolved oxygen and un-ionized ammonia). In addition, assessment of calibration results for the BIOE model is enhanced by excluding independent variables that are not significant drivers of shrimp performance. Therefore, the DSGR model was used to first check datasets for expected behavior and to identify constraints to shrimp growth, prior to BIOE calibration procedures.

Under excellent culture conditions of water quality and food availability, P. monodon are reported to achieve a weight of 30 g in about 100 days (Rosales, 1995). Under commercial culture in SE Thailand for average conditions, P. monodon are reported to grow from postlarval stages (PL 15-20) to 22 g in 124 days at an FCR of 2.0 (Briggs and Funge-Smith, 1994). Recommended daily feeding rates for shrimp (% body weight per day) range from 20 to 30 %/day for postlarval stages to 3 to 4 %/day for shrimp weights above 20.0g, with initial feeding crude protein contents ranging as high as 40% (Lovell, 1988).

Montoya et al. (1999) reported that Pacific white shrimp (Litopenaeus vannamei) reached 25 g in about 6 months, showing exponential and linear growth stanzas but no inflection point in growth rate or asymptotic stanza for the culture conditions used. Tian et al. (1993) reported growth from 1.0 g (53 days from hatching) to 16 – 18 g (winter, < 26 C) and to 20-21 g (summer, > 26 C) in 140 days. The asymptotic weight of P. vannamei is reported by Tian et al. to be about 80 g under non-limiting conditions. Under production conditions, Tian et al. report approximate asymptotic weights of 50 g at 5 shrimp/m2, reducing further to 30 g at higher densities (50 – 150 shrimp/m2). Some additional production benchmarks reported by Tian et al. include shrimp weights at 15 to 20 g for a growth period of 5 to 6 months (Hawaii), 23 g at 5.8 months (Texas), and 20 g at 5.3 months (South Carolina).

Laboratory culture of P. vannamei at the Oceanic Institute (Leonard Obaldo, personal comm.; control treatment) was assumed to represent non-limiting conditions of water quality and feed availability (Figure 1). In this study, shrimp were fed three times daily to satiation over the entire culture period. Water quality parameters were measured once a week and mean values were: water temperature 26 C, dissolved oxygen 6.3 mg/L, pH 7.6, unionized ammonia 0.002 mg/L, and salinity 33ppt. Growth data showed an expected good fit to the DSGR model.

Given this background information, and regression results of the DSGR model for each of the 26 CRSP datasets, it was determined that a number of the CRSP datasets showed that shrimp growth was limited by food availability and not by

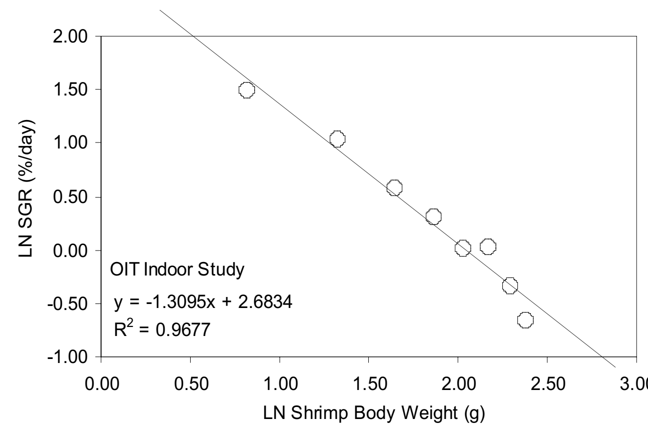

Figure 1. Regression of the double-log specific growth rate model for shrimp growth data from the laboratory culture of P. vannamei at the Oceanic Institute (Leonard Obaldo, personal comm.; control treatment).

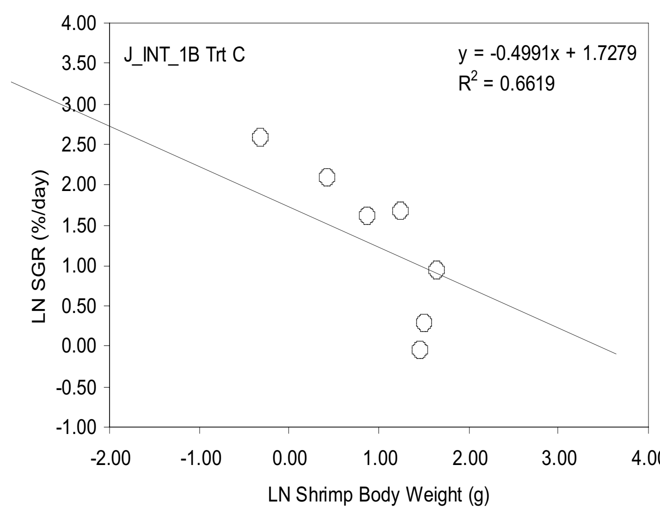

Figure 2. Regression of the double-log specific growth rate model for shrimp growth data from CRSP study J_INT_1B treatment C, illustrating a food resource limitation towards the end of the culture period.

water quality or maximum shrimp size. In all of the CRSP studies, shrimp body weights were less than half of reported maximum (maturation) asymptotic weights. Therefore, the catabolic term in the bioenergetic model (as opposed to the anabolic term) was determined to be a negligible factor with respect to observed asymptotic growth patterns. In addition, reported water quality for the CRSP studies did not indicate that water quality (e.g., dissolved oxygen and unionized ammonia) was a significant constraint to growth. To illustrate these trends with a specific example, the data and regression results shown in Figure 2 indicate a food resource constraint to shrimp growth and resulting poor fit of the DSGR model when declining natural food resources are not considered. In contrast, Figure 3 shows relatively non-constrained shrimp growth and a good fit of the DSGR model.

Natural food resources for shrimp in fertilized ponds are comprised of a number of benthic organisms and substrates, and as a result are difficult to quantify through purely mechanistic modeling. POND is able to consider various natural food resources, including phytoplankton, zooplankton, and bacteria. This food resource model is mainly intended for application to omnivorous finfish (e.g., tilapia and carp). For applications of the BIOE model to shrimp, a much simplified, empirically based approach to natural productivity was used. This method utilizes critical standing crop (CSC, kg shrimp/ha) and carrying capacity (CC, kg shrimp/ha) biomass density parameters with respect to food availability (Hepher, 1988). At shrimp densities less than CSC, the availability of natural food resources exceeds maximum consumption rates and does not limit growth. As shrimp density increases above CSC due to growth, natural food resources are utilized beyond their sustainable yield and depleted, causing a decline in natural productivity. When shrimp density achieves FBDcc, natural food resources are depleted to a level at which net growth is no longer supported and natural productivity is reduced to zero. Use of natural productivity without supplemental feeding yields sigmoidal fish growth curves, as natural food resources are initially unlimiting, then overwhelmed, and finally exhausted.

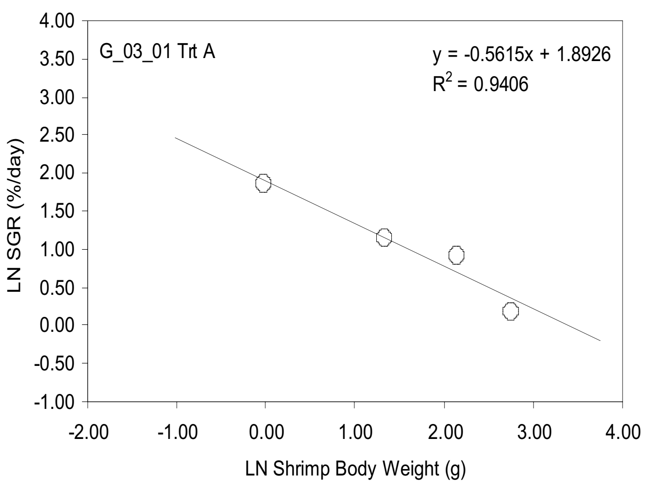

Figure 3. Regression of the double-log specific growth rate model for shrimp growth data from CRSP study G_03_01 treatment A, illustrating the availability of sufficient food resources throughout the culture period.

In conclusion, the BIOE and CSC/CC models available in POND were successfully calibrated for applications to marine shrimp culture. Results are available in the component databases of POND, available at the POND web site.

CONCLUSIONS

The POND decision support tool continues to evolve. Recent efforts, documented in this report, have focused primarily on increasing the useability of the software through incremental improvements in the user interface, enhanced online and offline help support, and better tutorial support. Further, the BIOE model has been adapted for use in simulating marine shrimp production, allowing POND to be used to incorporate marine shrimp production schemes into it facility analysis. With these additions, POND has become a mature, robust pond facility decision support tool. It is available for download from the POND website at http://biosys.bre.orst.edu/pond/pond.htm.

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