Optimal Harvesting Strategies for Farmed Fish and Shrimp in Hawaii, Year 2

General Information

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Funding Level

Year	Amount
1	$34,994
2	**$35,053**
TOTAL	$70,047

Participants

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Objective

Develop, test, and make operational a quantitative management model to assist shrimp and finfish producers in Hawaii in determine the stocking and harvesting strategies that optimize profitability.

Anticipated Benefits

Shrimp and fish farmers ultimately will use these models to increase production and improve profitability.

Work Progress and Principal Accomplishments

The first phase of this project refined and tested a multi-pond and multi-cycle harvesting/stocking scheduling model for shrimp growout operations. This work was conducted in close collaboration with Paul Bienfang, Ph.D., using data from the former Ceatech operations. The mathematical structure of the model is documented in Yu and Leung (2005). In addition, we have attempted to use an artificial neural network as an alternative method to predict shrimp growth. The results are promising and are documented in Yu, Leung, and Bienfang (2006c).

Using an extended version of the optimal scheduling model developed, we investigated the impact on the optimal production schedule and its resulting economic performance of shrimp farming from variability in survival rate, growth rate, price seasonality, and labor force constraints. The influence of these factors is described quantitatively within the context of the operating parameters of the then Ceatech USA Inc. The managerial objective under consideration is to project a scheduling scenario that maximizes net revenue from a 40-pond farm during a two-year planning horizon, subject to a set of biological and economic conditions. The practical results indicate that these factors can be managed to substantially improve the profitability of such a shrimp farm. It is apparent that continued development and application of this capability can have profound implications for the profitability of many multi-pond, multi-cycle farming operations. Detailed results of this investigation are documented in Yu, Leung, and Bienfang (2006b).

A more layman document summarizing the operations of the model as a decision support system has also been prepared (Yu, Leung and, Bienfang 2006a). The general framework of the Scheduling Decision System (SDS) is divided into five modules: (1) an input module contains general information on farm production, operating, and market conditions; (2) a biological module models the growth and survival functions appropriate for the farm setting using NeuralWare's Neuralworks Predict; (3) an economic module models the economic outcomes associated with variations in biological production and/or market fluctuations; (4) a scheduling module incorporates constraints on harvesting and planting that are conditions precedent and subsequently solves the scheduling model for maximum overall net revenue (and profit) from all growout ponds over a planning horizon using Frontline's Linear Programming Solver; and (5) a result module then facilitates presentation of optimal production schedule as charts and tables.

On-farm implementation of this model was hindered due to the close-down of the former Ceatech USA Inc. Instead, we have attempted to scale down the present model for implementation for other operations. We have presented a demonstration of this scaled-down version to Mitch Smith with the idea that Smith will entice some of his clients (local shrimp farmers) to look into the possibility of adopting this scheduling system. However, due to their busy schedules, we have not yet been successful in obtaining a chance to demonstrate the system to these shrimp operations.

In the second phase of this project, we have attempted to modify for finfish culture the model developed in Year 1 for shrimp operation. We have put together a prototype spreadsheet model for single-cage scheduling of offshore finfish culture. A copy of the spreadsheet has been provided to both Kona Blue Water Farms and Cates International for their evaluation and testing. However, due to many immediate issues that they have to attend to, both companies felt that it is not the right time to tackle scheduling at this time.

Instead, we continued to modify and extend the system's framework to model a "partial harvesting" scheme. It has generally been recognized that partially harvesting the standing stock of cultured animals (fish or shrimp) over the course of their growing season will decrease competition and thereby increase individual growth rates and total yield. Although this general paradigm has been well-documented in literature, we found that existing harvesting management models are still rather restrictive in nature and generally not suitable for practical on-farm applications. In particular, no practical model can be found in the literature that is able to address the "discrete" partial harvesting strategy consisting of several discrete harvests along the growout process. We have therefore developed an optimal harvest model using impulsive control theory that is capable of addressing "discrete" partial harvesting for a single cohort of farmed fish (or shrimp and other cultured species) represented by uniform and density-dependent growth. Preliminary results indicate that in the presence of density-dependent growth, partial harvesting could outperform single-batch harvesting. We used a numerical example to illustrate how a well-managed discrete partial harvesting can outperform single-batch harvesting and thus enhance profitability. The results of this numerical example also suggest that an economic model of partial harvesting is rather vital in using partial harvesting as an avenue of improving profitability. This theoretical model is documented in Yu and Leung (2006).

We have also been working with the shrimp program at the Oceanic Institute to evaluate the economics of partial harvesting using experimental data they have been collecting. Initial investigation suggests that partial harvesting can be beneficial under certain conditions and the results are documented in Moss, Otoshi, and Leung (2005). However, we will need to develop growth curves and feeding rates for various stocking densities under different partial harvesting scenarios in order to test the impulsive control model for identifying optimal harvest strategies.

Working closely with Dr. Bienfang, we have developed a set of baseline biological parameters for testing and refining a more general spreadsheet model based on the general analytical framework developed so far. A practical model of partial harvesting has been developed using the network-flow approach so that it can be readily implemented and solved in Microsoft Excel. We demonstrated the use of this spreadsheet model with data from a commercial shrimp farm in Hawaii. The results indicate that the model is capable of identifying an efficient harvest policy as well as assessing the viability of partial harvesting under a variety of managerial conditions and objectives. Detailed documentation and results of this practical partial harvesting model are documented in Yu, Leung, and Bienfang (forthcoming).

Using the developed framework, we have also worked with Dr. Bienfang in devising several potential partial harvesting schemes for Sunrise Capital Inc., the company that took over the previous Ceatech operation on Kauai.

Finally, we have developed the necessary interface to improve usability of this spreadsheet-based partial harvesting model for farmers and other non-programming end users. The eventual decision support system (DSS) will be accessible to all users who have access to MS Excel. Visual Basic for Applications (VBA) programming is used to automate and execute commands through a menu. This menu-based interface will permit end users to navigate and use this decision support system with minimal knowledge of MS Excel. A prototype DSS has been completed and is currently being tested. A User Manual has also been developed and includes views (screenshots) of the user interface (Yu, Kam, Leung, and Bienfang 2007).

Work Planned

To finalize the partial harvesting DSS and publish the user manual for distribution.

Impacts

Ultimately, these models will be used by shrimp and fish farmers to increase production and improve profitability.

Publications in Print, Manuscripts, and Papers Presented

Manuscripts

Moss, S. M., C. A. Otoshi, and P. S. Leung. 2005. Optimizing strategies for growing larger *L. vannamei*. *Global Aquaculture Advocate* 8(5):68–69.

Otoshi, C. A., C. Whitehead, F. Falesch, S. Naguwa, P. S. Leung, and S. M. Moss. Production of broodstock-size pacific white shrimp litopenaeus vannamei in a biosecure system using a partial harvest strategy. In *Book of Abstracts Aquaculture America 2006*, 219. Baton Rouge: World Aquaculture Society.

Yu, R. and P. S. Leung. 2005. Optimal harvesting strategies for a multi-pond and multi-cycle shrimp operation: a practical network model. *Mathematics and Computers in Simulation* 68(4):339–354.

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Yu, R., P.S. Leung, and P. Bienfang. 2006a. A decision support system for efficient scheduling of multi-pond and multi-cycle commercial shrimp culture. In Chapter 21, *Shrimp Culture: Economics, Market and Trade*, eds. P. S. Leung and C. Engle, 315–327. Oxford, United Kingdom: Blackwell Publishing.

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Yu, R., L. E. Kam, P. S. Leung, and P. Bienfang. 2007. Shrimp partial harvesting model decision support system: User manual. An unpublished manuscript, 28 pp.

Papers Presented

Yu, R. and P.S. Leung. 2005. Integrating an artificial neural network model with the optimal scheduling model: application to a commercial shrimp farm. Paper presented at the Triennial International Federation of Operational Research Societies (IFORS), Honolulu, Hawaii.

———. 2005. Optimal harvesting strategies for a multi-pond and multi-cycle shrimp operation: a practical network model. In *Book of Abstracts World Aquaculture* 2005, 330. Baton Rouge: World Aquaculture Society.

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Yu, R., P. S. Leung, and P. Bienfang. 2007 Modeling partial harvesting in intensive shrimp culture: a network-flow approach. Paper presented at the North American Association of Fisheries Economists (NAAFE) Conference, Merida, Mexico.