Chapter 18
A Decision Support System for Scheduling Partial Harvesting in Aquaculture

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ABSTRACT
The implementation of partial harvesting for intensive aquaculture is a difficult undertaking for the aqua-farmers, due to the complex nature of tracking the effects of reducing density on growth, survival and eventually on productivity and profitability. In this chapter, we describe the partial harvesting decision support system (PHDSS) developed by Kam et al. (2008). The PHDSS is designed to assist aqua-farmers in determining the best harvesting strategy for a production cycle. Potential harvesting strategies include both partial harvest and single-batch harvest. The chapter navigates the readers through the system, using shrimp culture as a case study.

INTRODUCTION
Aquaculture is a risky and potentially lucrative business venture. Seasoned aqua-farmers recognize that choosing an appropriate harvesting strategy is imperative to remain competitive and profitable in this business. A variety of computational models have been developed to assist aqua-farmers in determining the optimal harvest schedule in aquaculture operations (Yu & Leung, 2005; 2009). Bjorndal (1988) developed the first theoretical harvest model for aquaculture, using
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the optimal control framework. Arnason (1992), Heaps (1993, 1995) and Hean (1994) extended this model to take into account the effects of feeding, density-dependent growth and potential culling, and release cost, respectively. Shaftel and Wilson (1990) proposed a harvesting model using the mixed-integer linear programming approach. Forsberg (1996, 1999) developed an alternative multi-period linear programming approach. Leung and Shang (1989) employed the Markov decision approach for solving the harvesting problem in shrimp culture. Yu and Leung (2005, 2006) and Yu et al. (2006, 2009) developed an array of harvest models, primarily for shrimp aquaculture, using the network-flow modeling approach. These or similar models/modeling methods have been applied to a variety of aquacultural crops, including farmed salmon (Bjorndal, 1988), Nile tilapia (Springborn et al., 1992), giant clam (Leung et al., 1994; Hean and Cacho, 2002), carp (Talpaz and Tsur, 1982), catfish (Cacho, 1991), sea bream (Pascoe et al., 2002), crab (Figueiredo et al., 2008), prawn (Leung and Shang, 1989; Pascoe et al., 2002), shrimp (Karp et al., 1986; Hochman et al., 1990; Spaargaren, 1999; Tian et al., 2000; Pascoe et al., 2002; Yu and Leung, 2005; Pathumnakul et al., 2007; Yu et al., 2006; Kam et al., 2008) among others. Generally speaking, continuing research efforts have been made to closely mimicking the operations management of actual aquaculture enterprises. Interested readers could refer to Yu and Leung (2005, 2006) for a comprehensive review on the current status of research on optimal harvesting in aquaculture. The purpose of this chapter is to describe a decision support system for the determination of optimal partial harvesting strategy recently developed by the authors. The partial harvesting decision support system (PHDSS) is designed to assist aquaculture enterprises utilizing partial harvest (i.e., partially harvest the crop during the growout cycle) in their operations. The system automatically solves for the best partial harvesting scheme and compares it to the corresponding single-batch harvest to help aqua-farmers evaluating and implementing partial harvesting. The system is designed with great flexibility. It can be readily tailored to reflect the specific bio-economic characteristics of the aqua-farms and meet different management objectives. Single-batch harvest can be viewed as a special case of partial harvest. The PHDSS indeed could evaluate the financial implications of both single-batch harvest and partial harvest for aquaculture operations. The PHDSS is implemented in a spreadsheet form, using Microsoft Excel. It requires the use of the Solver add-in, which is available freely in Microsoft Excel.

BACKGROUND

Harvest decision, (i.e., deciding on when to gather the reared aquatic organisms and how many, is a key operations management problem for any aquaculture enterprise). Harvest decision of course is subject to the underlying physiological relationships of the cultured species. In intensive aquaculture farming systems density-dependent growth and survival are the key physiological relationships (Cheng & Chen, 1990; Arnold, Sellars, Crocos & Coman, 2006). Growth (and survival rate) likely will decline as density (biomass in the growout facility) increases over the growout season. Slow growth would incur more feed and maintenance costs; and low survival could incur more losses due to mortality. In the extreme case where density reaches the carrying capacity of the growout facility, the farmed animals might even stop growing and their survival rates could drop dramatically. Therefore, the strategy of partial harvesting (i.e., partially harvest the standing stock of cultured species over the growout cycle to reduce competitive pressure due to increased biomass) could potentially be a better alternative to single-batch harvesting (i.e., harvest the entire crop at the end of the growout season).

A number of pilot experiments have demonstrated the promising potential of partial harvesting