ALLIANCE™

(https://debug.globalseafood.org)

Responsible Seafood ADVOCATE

Health & Welfare

Computer modeling helps grow fish

2 May 2012

By Joao G. Ferreira

Models that simulate cycles can provide data for certification

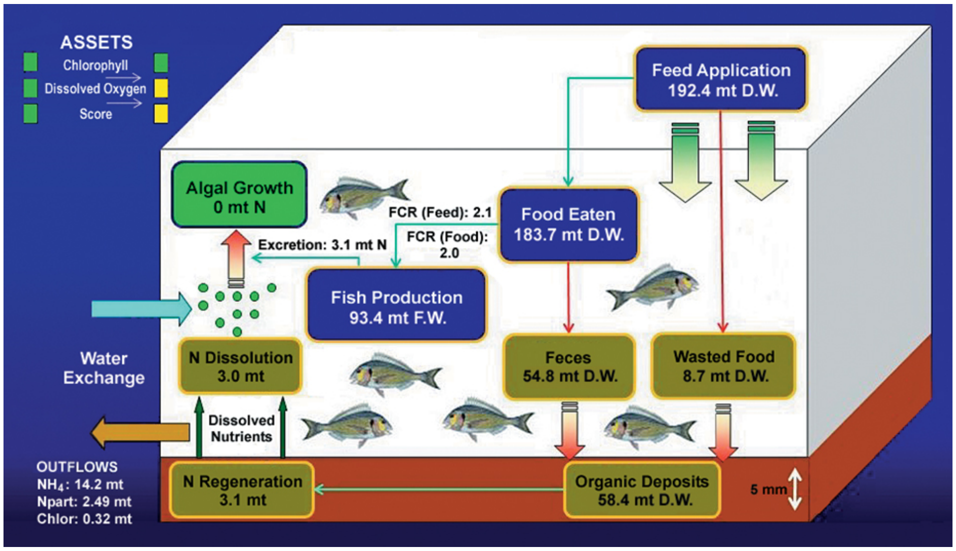

Fig. 1: Simulated production of gilthead seabream at a 1-ha onshore farm. Such modeling can help guide current and future aquaculture

development.

Aquaculture has been practiced in Asia for thousands of years. Aquaculture in Southeast Asia historically developed on land – not just with aquatic species, but as part of an agro-aqua economy that variously combined, for instance, rice, tilapia, ducks, pigs, shrimp, razor clams and macroalgae. It is easy to understand that in the centuries before the advent of electric aeration, monoculture of finfish in ponds would be viable only at very low densities or with plentiful water renewal due to oxygen requirements.

Over the last 100 years, the biology of many cultivated species has become well understood, and life cycles have been closed for a significant number of these – a key factor in aquaculture development, just as it was in agriculture.

Key data

According to the latest figures from the Food and Agriculture Organization (FAO) of the United Nations, over 70 percent of the freshwater aquaculture in China takes place in ponds that cover an area corresponding to the size of the U.S. state of New Jersey and annually produce over 15 million metric tons (MT) of seafood. This number is triple the total aquaculture production of America, Europe and Africa combined, which suggests that substantial emphasis should be placed on site selection, optimization of carrying capacity and evaluation of the negative environmental externalities of pond culture.

Just as history gave way to biology, many new tools can now help promote the growth and sustainability of aquaculture. Computers have come of age in the analysis of shellfish and finfish culture, helping to optimize production, predict financial outcomes such as turnover and profit, and evaluate the environmental effects of cultivation.

Models in aquaculture

Whether cultivating fish or shrimp in ponds, or bivalves in bottom culture or on longlines, every grower uses a model. That mental model is often based on tradition, the historical knowledge of “what works.” The right choices with respect to siting, timing of seeding and harvest, cultivation densities and other factors are key ingredients for a successful business.

All aquaculture is in fact a physical model of a natural ecosystem, providing environmental conditions for successful growth of the target organisms to market size. The degree to which the physical environment is artificialized varies, from placing tilapia in cages in a reservoir to excavation of shrimp ponds on land.

Computers have allowed many of the processes that are key to successful culture – including physical ones such as water circulation and biological ones such as the physiology of animal growth – to be translated into a simulation of the cultivation cycle itself.

In parallel, the combination of satellite remote-sensing geographic information systems (GIS, of which Google Earth is a popular example) and other tools has allowed the simulation of the larger-scale environment in which aquaculture takes place. For instance, a satellite image can be processed with GIS to estimate the areas occupied by shrimp ponds. The overall changes to the drainage patterns of the catchment could be analyzed by land use and hydrology models. The pollutant loading of the farms could be projected based on shrimp growth and environmental impact models. The sum of the parts provides a valuable toolset for integrated coastal zone management.

For farmers, models are important to analyze crop production and environmental effects. For managers, they assist with the assessment of carrying capacity and licensing issues.

Improved culture management

In the last decade, better regulatory frameworks have led to more-stringent licensing, most notably in the European Union, United States and Canada. The E.U.'s Water Framework Directive, together with FAO guidelines for an ecosystem approach to aquaculture, highlight the ecological component and aim to optimize production without compromising ecosystem services. Part of the challenge of determining carrying capacity is the quantification of negative externalities as a first step toward improved management.

In Brazil, for instance, where aquaculture has grown very rapidly over the past decade, environmental permitting for new tilapia farms in reservoirs is determined through the application of the Dillon and Rigler phosphorus-loading model, a rather simplistic view of carrying capacity. Fish farms are licensed sequentially based on the contribution to phosphorus loading of their declared production.

Although this approach does address carrying capacity at the whole water body scale, it does not consider any variation in space and time, nor does it account for factors such as organic enrichment, disease or impacts on biodiversity – all of which can be linked.

By contrast, a detailed model of fish culture such as Farm Aquaculture Resource Management (FARM) can provide many more insights into aquaculture operations. This is illustrated in Fig. 1, which shows a simulation of a 400-day gilthead cultivation cycle in ponds with a culture density of 50 fish per square meter. The growth of individual fish is modeled together with water exchange, algal production, pond aeration and several other processes.

The simulated yield is about 9.3 kg fish per square meter. Of the U.S. $141,000 in total marginal costs, 36 percent is spent on feed, 62 percent on fry and the rest on energy. Despite artificial aeration, a water renewal of almost 650 L/second is needed to maintain acceptable oxygen concentrations. In the simulation, 190 MT of feed are supplied, of which about 58 MT are lost to the sediment as uneaten food or fish feces.

The environmental impact translates into discharge outflows of 14.2 MT of ammonia and 320 kg of chlorophyll (phytoplankton algae). Impacts can also be measured using the Assessment of Estuarine Trophic Status (ASSETS) water quality index, in which the environmental score of the ponds changes from good (green) to moderate (yellow).

Perspectives

Models can help explain production cycles and their environmental consequences, and therefore be used to test different scenarios. Additionally, their more formal descriptions of the culture process can help establish regulatory compliance and reduce monitoring costs.

Finally, models that simulate aquaculture cycles can help in providing data for product certification, which in turn increases consumer acceptance and contributes to a more sustainable business model for people, planet and profit.

(Editor’s Note: This article was originally published in the May/June 2012 print edition of the Global Aquaculture Advocate.*)*

Author

JOAO G. FERREIRA

Professor of Environmental Engineering
New University of Lisbon
Quinta da Torre
2829-516 Caparica, Portugal

joao@hoomi.com (mailto:joao@hoomi.com)