Food nutrient dynamics and regulation for fertilized pond aquaculture

Li Lanhai and Amararatne Yakupitiyage

Asian Institute of Technology

P. O. Box 4, Klong Luang 12120 Thailand

Abstract

A development of a nutrient dynamic model to explain food nutrient dynamic behavior in a fertilized pond is described in this paper. The model has been used to simulate a field experiment which is designed to determine the nutritional limiting factors for fish growth in fertilized ponds. The simulation results indicate that the model can reproduce the historical behavior and that the simulated data have a good correspondence with field observations. Strategies for regulating food nutrient production and fish growth have also been evaluated.

Introduction

In a semi-intensive or extensive fish culture system, natural food plays a key role in fish growth (Chang, 1983). Its constant supply is dependent upon the primary productivity where the production rate is mainly controlled by the availability of major elementary nutrients i.e. nitrogen (N) and phosphorous (P). Pond fertilization provides an extra source of elementary nutrients to promote natural food production and enhance natural food availability for cultured-fish.

Natural food production dynamics and fish growth in an aquaculture pond are complex biological processes controlled by its indigenous structure and exogenous circumstances and management strategies. The indigenous structure includes nutrient recycling and energy flow, while exogenous circumstances consist of solar radiation and temperature. Management strategies e.g. fish stocking rate and fertilization regimes influence both food nutrient production and the availability of natural food for fish.

A number of investigators have identified the elementary nutrients types and the required doses for natural food production in fertilized ponds (e.g. references). However, a little study has been focused on qualitative and quantitative changes in natural food nutrient production of the fertilized ponds and fish growth. This study was designed to evaluate the food nutrient dynamics and its effects on fish growth in fertilized tilapia ponds using a system dynamic model.

Process of Food Nutrient Dynamics

A pond ecosystem consists of autotrophic and heterotrophic producers, and their physical environment. Autotrophic producers fix elementary nutrients into various autotrophic food nutrients by utilizing solar energy. While some autotrophic food nutrients are grazed by fish, a part converted into heterotrophic food nutrients due to its mortality. Elementary nutrient availability and grazing by fish are dominant forces to control food nutrient behavior in the pond.

Fertilization strategies improve the trophic state and adjust food nutrient dynamic behavior in a fish pond. Fertilization with chemical fertilizers increases elementary nutrient content which stimulates photosynthesis and increases autotrophic food availability. Organic fertilizers promote both heterotrophic food nutrient and autotrophic food nutrient as it is partly consumed directly by fish, and releases elementary nutrients by its decomposition to stimulate autotrophic food nutrient production, respectively.

Nitrogen and phosphorus are the most important elementary nutrients to enhance primary productivity (Liken, 1971). The food nutrient dynamic process in a pond is accelerated through pond fertilization, but there exists a maximum productivity limit for autotrophic food nutrients and a critical standing biomass of fish under a given fertilization regime. Once the fish biomass increase up to a certain limit, food nutrient deficiencies develop and high fish yield can be obtained only by providing supplementary feeds.

Model development

This study focuses monoculture of male Nile tilapia in earthen ponds. Based on the dynamic process of food nutrient production, a basic dynamic hypothesis linking pond ecosystem structure to food nutrient behavior is developed (Figure 1). The fundamental variables to control food nutrient dynamics are elementary nutrient concentration both in water and in sediment, autotrophic food amount, heterotrophic food amount and fish biomass. They are linked with other variables through nutrients and information relationships. As a key index of water quality, dissolved oxygen (DO) concentration is integrated into the model as it is affected by the photosynthesis and also influences biological activities in water column. The proposed model, therefore, is divided into five sectors: elementary nutrient sector, food nutrient sector, fish growth sector, dissolved oxygen sector and exogenous factor.. The high level map of the model using Stella II is presented in Figure 2.

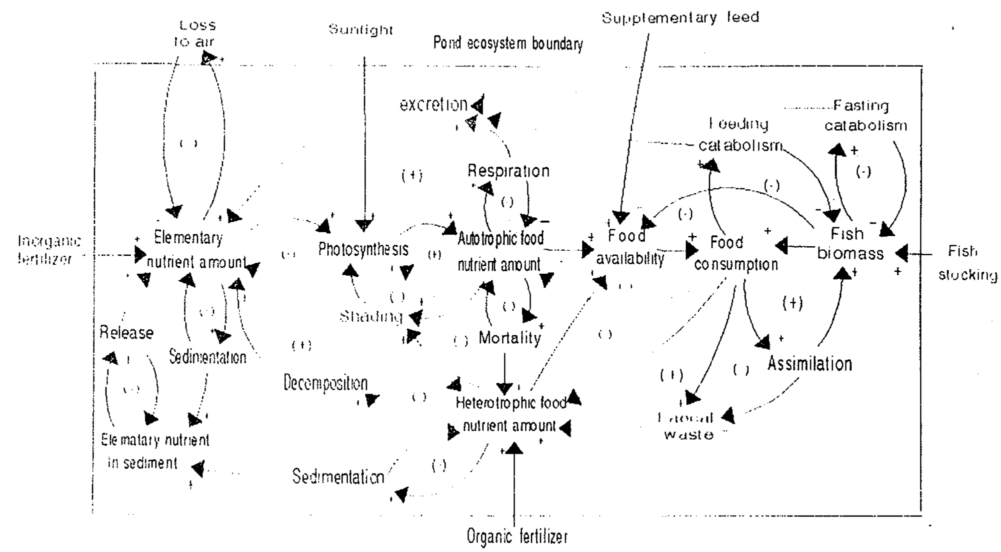

Figure 1 Basic dynamic hypothesis for food nutrient dynamics in a fertilized pond

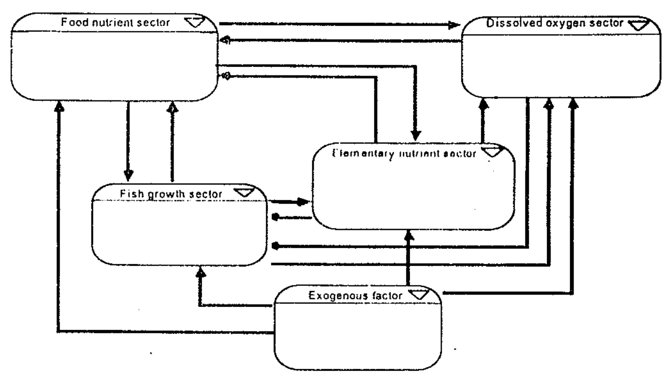

Figure 2 A high level map of food nutrient dynamic model

Simulation run of the model

After parameterization and validation, the model was applied to simulate a field experiment conducted in AIT from 6th of June to 1st of September in 1994. The experiment was designed to evaluate the nutritional limitation for tilapia growth in chemically fertilized fish ponds at a rate of 2 kg N and 1 kg P/ha/day. Fish with 6.8 g/fish were stocked in 8th of June at a rate of 3 fish m^{-2}. Water quality parameters were analyzed for every 2 weeks and fish was sampled for every 3 week intervals. The model was simulated after initial values, exogenous variables (solar radiation and temperature) and management strategies (stocked fish number and biomass, fertilization rate and dates) were fed. Simulation results are shown in Figure. 3. The results shows that simulated values are within the range of observed data from three replicates and coincide with mean values of the each sampling points (Figure. 4).

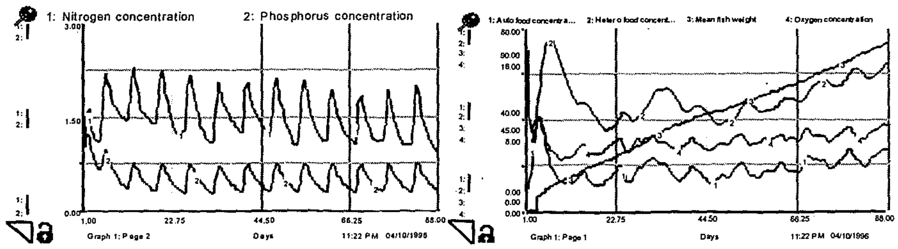

Figure 3 Responses of the elementary nutrients, food nutrients and mean fish weight to fertilization rate of 2 kg N and 1 kg P/ha/day

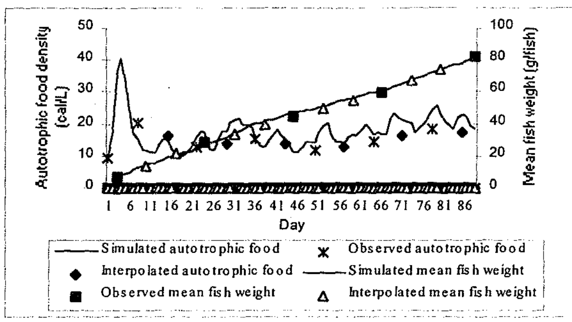

Figure 4. Comparison of simulated and observed autotrophic food density and mean fish weight

Regulation of food nutrient behavior

The management strategies to regulate food nutrient behavior and fish growth in aquaculture practice include fertilization and supplementary feeding. Figure 5 shows the responses of autotrophic food density and mean fish weight to different fertilization rates and supplementary feeding regimes. The results show that the behavior patterns of food nutrients and fish growth do not change with different strategies, but affect the numerical values. Autotrophic food density and mean fish weight increase by increasing the fertilization rate, but fish growth is limited by the autotrophic food nutrient productivity under given fertilization regime. Mean fish weight significantly increases by both the fertilization and supplementary feeding. Under the same fertilization and supplementation regimes, the feed with a higher protein content can further increase mean fish weight.

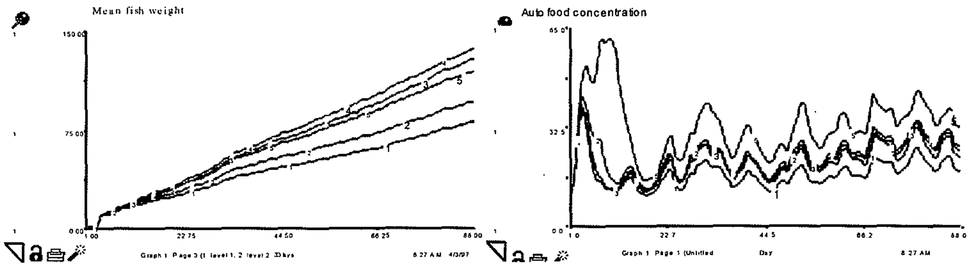

Figure 5 Responses of autotrophic food nutrient and mean fish weight to different fertilization and supplementation strategies.

Line 1: fertilization with 2 kg N and 1 kg P/ha/day; Line 2: fertilization with 4 kg N and 2 kg P/ha/day;

Line 3: fertilization with 2 kg N and 1 kg P/ha/day, plus 15 kg dry supplementary feed/ha/day with 0.03 g protein/Kcal feed.

Line 4: fertilization with 2 kg N and 1 kg P/ha/day, plus 15 kg dry supplementary feed/ha/day with 0.06 g protein/Kcal feed.

Line 5: fertilization rates are determined under expected the concentration of nitrogen (3 mg/L) and phosphorus (0.3 mg/L)

Conclusion

This study proposed a system dynamics model to describe food nutrient dynamics in a pond ecosystem. The model explains the process of food nutrient production and clarifies both the role of food nutrient production in fish growth and the limitation of nitrogen and phosphorus to food nutrient production. Pond fertilization significantly improves elementary nutrient supply for food nutrient production, which, in turn, increase fish growth.

Simulation run of the present model shows that simulated food nutrient dynamics and tilapia growth responded appropriately to the interactions of elementary nutrients with food nutrients, and food nutrients with fish growth. Food nutrient productivity and mean fish weight increase with an increase in fertilization rate. Further fish growth is significantly promoted by supplementary feeding.

Reference

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