HEAT TRANSFER IN OUTDOOR AQUACULTURE PONDS

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Jonathan Lamoureux
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ABSTRACT

An energy balance was developed for heated and unheated earthen aquaculture ponds to 1) determine the relative importance of energy transfer mechanism affecting pond temperature; 2) predict pond temperatures; 3) estimate the energy required to control pond temperatures, and 4) recommend efficient heating and cooling methods. PHATR (Pond Heating and Temperature Regulation), a computer program using 4th order Runge-Kutta numerical method was developed to solve the energy balance using weather, flow rate and pond temperature data.

By comparing measured and modeled pond temperatures, the average difference (the average bias) was 0.5°C for unheated ponds and 2.4°C for heated ponds. The error in warm water flow measurements explained the elevated average bias for heated ponds.

The dominant energy transfer mechanisms for unheated ponds were solar radiation (maximum: 55%), pond radiation (average: 35% to 42%) and longwave sky radiation (average: 28% to 34%). The dominant energy transfer mechanisms for heated ponds were solar radiation (maximum: 50%), pond radiation (average: 25%), longwave sky radiation (average: 19%) and the 36°C water used to heat the ponds (maximum: 60%).

The difference in biases when comparing three empirical evaporation equations ranged from 0.2°C to 1.9°C. The difference in biases when comparing two empirical convection equations ranged from 0.0°C to 2.1°C.

The average light extinction coefficient for the ponds was 0.013 mm^{-1}.

The sensitivity analysis, used to determine how variations in input data affected the model results, showed that output varied linearly with changes in average air temperature and solar radiation. The output decayed exponentially to changes in wind speed and flow rate.

Using PHATR and 40 years of weather data, the pond temperature for a 400-m^3 pond was calculated for cold, hot and average years. The average pond temperature for an average year was 21.8°C. The net energy required to maintain the pond temperature at 25°C was 3.24×10^9 J/m^3. Warming a 400-m^3 pond 2°C/day during a typical mid-January week would require 7.64×10^{10} J over 9 days.