Diel Cycles of Temperature and Dissolved Oxygen Stratification in Deep Rain-fed Ponds

Work Plan 7, Thailand Study 7

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Introduction

In regions of large seasonal differences in rainfall, particularly where no water inputs can be made to ponds during the dry season, such as the Udorn Thani region of northeast Thailand, culture ponds are constructed sufficiently deep to hold amounts of water which will sustain evaporative losses through growth cycles. The Asian Institute of Technology's Outreach Project is collaborating with the Thailand CRSP component to extend results of CRSP work to farmers in this area. The University of Michigan component constructed a set of experimental ponds on the Huay Luang Fisheries Station of the Royal Thai Department of Fisheries.

The rain-fed ponds' greater depth (2-3 m) suggests that density stratification will be more severe than is common in shallower ponds, and therefore less often dissolved by convective overturn at night or by wind-induced mixing. This makes oxygen depletion in the hypolimnion more likely. Manage-ment strategies involving artificial mixing are under consideration by the principals of the Outreach Project. This study aims to provide quantitative information on the characteristics of diel temperature stratification to be expected, which will later be used to plan mixing strategies. Similar observations can then be used to evaluate the effects of mixing methods employed.

The study of Szyper and Lin (1990) and subsequent observations at AIT have characterized the stratification patterns to be expected in ponds of 0.6 to 1.6 m depth. For example, on relatively still, sunny days during the dry season, surface warming initiates stratification within an hour after sunrise. Temperature differences between top and bottom increase through 1500 to 1600 hours, reaching 7 to 8 ^{o}C. Within 10 to 20 cm of the bottom, temperatures typically change little during day or night. This illustrates the isolation of bottom waters, which in some cases exhibited dissolved oxygen concentrations (DO) less than 1 mg/L throughout the diel cycle, with the exception of increases amounting to a few mg/L between midnight and 0600 hours due to convective mixing with the surface waters. Detailed temperature profiles showed that under these conditions, the hypolimnion, the depth layer isolated below the thermocline, constituted more than half the pond depth.

These observations dictate the need for quantitative information on ponds to be mixed artificially, because mixing, unless timed and located properly, could reduce whole-pond DO levels to markedly below optima, and possibly below tolerance limits, for cultured animals. In addition, mixing can have profound effects on primary production, which is the primary source of nourishment to the animals in fertilizer-based production strategies. The objectives of this work are: 1) to describe and quantify diel cycles of temperature and DO stratification in deep rain-fed ponds; 2) to compare these patterns with those of shallower ponds typical of CRSP experiments; and 3) to apply this information in the context of practical pond management.

Materials and Methods

Ponds of 800 m^{2} area and 2.5 m depth at the Huay Luang station were monitored during fish growth experiments designed by the University of Michigan component. Diel cycles of temperature and DO were recorded with an automated monitoring system similar to that used at AIT, and described by Szyper and Lin (1990), Green and Teichert-Coddington (1991), and Szyper and Ebeling (1993). Temperature was monitored by thermocouples deployed on a plastic pipe suspended from a float; DO was assessed in water pumped from the pond through a receiving

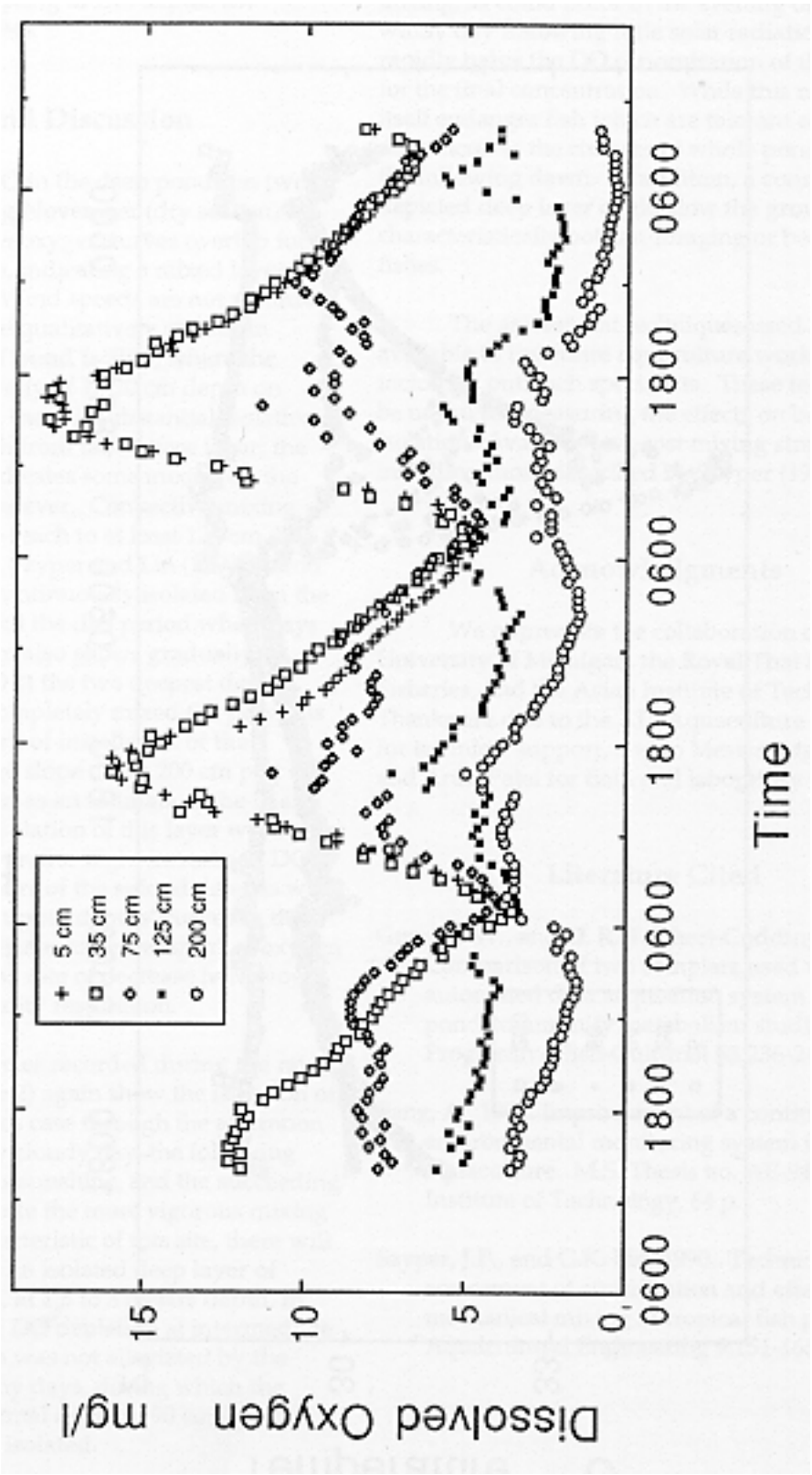

Figure 1. Several days' diel cycles of dissolved oxygen concentration at five depths in an earthen pond of 2.5 m depth at the Huay Luang Fisheries Station in Northeast Thailand during the dry season.

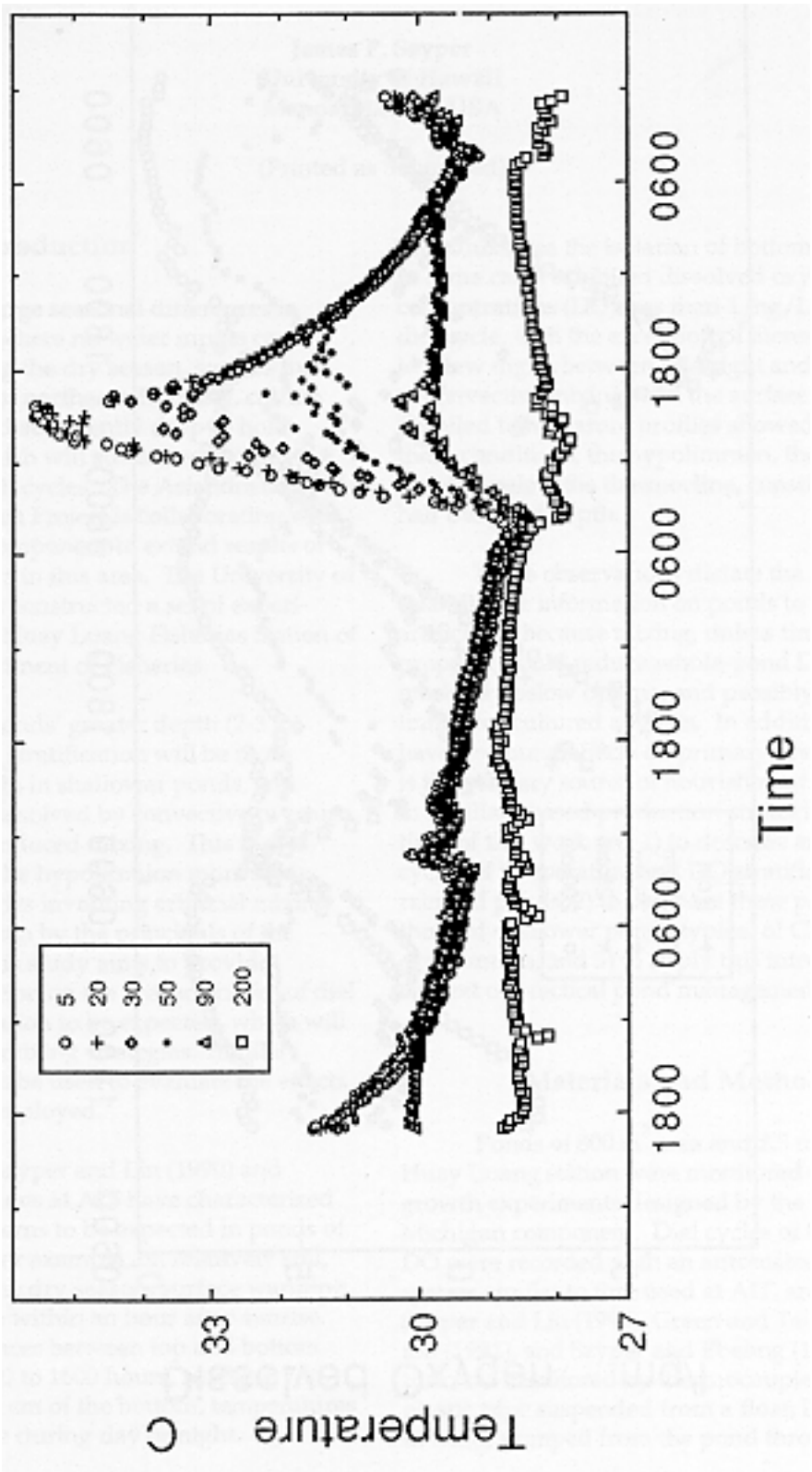

Figure 2. Several days' diel cycles of temperature at six depths in an earthen pond of 2.5 m depth at the Huay Luang Fisheries Station in Northeast Thailand during the rainy season. The center of the plot shows the cycle on a cloudy day; sun shone the next day.

chamber of plastic pipe on the pond bank at intervals of 30 minutes. The system was modified for convenient pump sampling of five depths as described by Jiang (1994).

Results and Discussion

Diel cycles of DO in the deep ponds on two successive dates during November (dry season) are shown in Figure 1. The oxygen curves overlap for the 5 cm and 35 cm depths, indicating a mixed layer of at least the latter depth. Wind speeds are not recorded at this station, but were qualitatively greater in general than at the AIT pond facility, where the mixed layers are generally of 10-20 cm depth on sunny days. At 75 cm, there is substantial isolation of this intermediate depth from the surface layer; the scatter of the points indicates some mixing on the time scale of hours, however. Convective mixing after sunset appears to reach to at least 125 cm, but not to 200 cm. At AIT, Szyper and Lin (1990) found the 1.2 m depth to be continuously isolated from the upper layers throughout the diel period when days were sunny. The figure also shows gradually declining values of DO at the two deepest depths. The ponds had been completely mixed the previous evening due to the work of installation of the apparatus. The average slope of the 200 cm plot (0.1 mg l^{-1} h^{-1}) could be taken as an estimate of the in situ respiration rate if the isolation of this layer were more nearly perfect. However, the slight increase in DO during the daylight hours of the second date, as well as the approach of the upper depths' curves to the lower one at night, indicate some transport of oxygen to this depth, and so the rate of decrease here would underestimate community respiration.

Temperature cycles recorded during the rainy season (August, Figure 2) again show the isolation of the 200 cm depth, in this case through the afternoon and night of one partly cloudy day, the following rainy day without clear sunshine, and the succeeding sunny day. Thus, despite the more vigorous mixing by wind which is characteristic of this site, there will still be, in deep ponds, an isolated deep layer of considerable thickness, at 1.5 to 3 meters depth, in addition to the cyclical DO depletion at intermediate depths. This condition was not alleviated by the occurrence of dark rainy days, during which the pond remained isothermal down to 90 cm, but the 200 cm depth was still isolated.

If a pond of 3 m depth has its deepest 1.5 m isolated and depleted of oxygen, then a complete mixing, as could occur in the evening of an unusually windy day following little solar radiation, could rapidly halve the DO concentration of the upper layer for the final concentration. While this might not in itself endanger fish which are tolerant of low DO, it does increase the chances of whole pond depletion by the following dawn. In addition, a constantly depleted deep layer could slow the growth of characteristically bottom-foraging or bottom-resting fishes.

The assessment techniques used here are now available to the entire aquaculture work group at AIT, including outreach specialists. These techniques will be useful for measuring the effects on bottom isolation of various low-cost mixing strategies, including those described by Szyper (1995).

Acknowledgments

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