Comparison of Automated versus Manual Monitoring of Levels of Dissolved Oxygen in Aquaculture Ponds

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ABSTRACT

Automated water quality monitoring systems can be used to help maintain optimal levels of dissolved oxygen (DO) in aquaculture systems by continuously monitoring oxygen concentrations and immediately turning on aerators to supplement oxygen if a critical limit is reached. This study compares differences in water quality maintenance under operation schemes using manual and automated water quality monitoring of DO concentrations. A commercial automated monitoring system will be used to monitor the DO concentrations in the aquaculture ponds on the Mississippi State University campus. Data collected by this system will be used to document the amount of time that DO concentrations would have fallen below threshold levels under a manual monitoring operation scheme. Mississippi State University aquaculture facility employees will be interviewed to determine how often DO measurements are needed and how often they can be collected from the entire 75 pond complex. Data collected by the automated monitors will be used to simulate manual data collection by using the automated measurements and the sampling timeline for manual collection. Using this information will determine the amount of time that DO concentrations in the pond would have been below acceptable levels without automated monitoring. Automated monitoring systems should detect low DO concentrations more quickly than manual monitoring which will promote fish growth and facilitate the management and planning of aquaculture operations, and therefore increase overall production for catfish farms and other aquaculture industries across the country.

Keywords: Methods, Water Quality, Surface Water, Economics

Introduction

Commercial catfish farming has developed into one of the most important aquaculture industries in the United States. Growth of the industry has occurred over the last twenty years because of the expansion of facilities and area used for catfish farming. This economic success has largely been a result of low production costs and enhanced control of water quality. Maintenance of adequate levels of dissolved oxygen (DO) is critical in maintaining a functional aquaculture environment and oxygen concentration is a primary determinant of water quality (Colt, 2006). It is an important variable to consider because sufficient DO is essential to the health and survival of most aquatic organisms (Wetzel & Likens, 1991; Wetzel, 2001). Fish production in pond culture systems is often limited by DO concentrations (Drapcho and Brune 2000) and supplying adequate DO, either biologically or mechanically, is an essential management practice for pond aquaculture. Oxygen supply must be sufficient to fulfill overall respiratory demand for pond biota (microbes, algae, insects, etc.) as well as for cultured fish (Hargreaves & Tucker, 2003).

Manually measuring and monitoring DO concentrations in an aquaculture setting can become a laborious task with the high number of ponds or sampling locations, seasonal temperature changes, weather conditions, and possible depletion of oxygen during the evening. Automated oxygen monitoring systems have the potential to reduce labor and energy costs, decrease disease and mortality rates among aquaculture species, and increase production yields through constant monitoring, management, and enhancement of water quality in aquaculture systems. Measurement and control units, water quality sensors, and communication devises for relaying data and recording pond conditions combine to create a more productive and efficient aquaculture operation (Campbell Scientific, Inc., 2005).

Study Area

Research was conducted at Mississippi State University's MAFES Aquaculture Research Unit on the Mississippi State University campus during two separate time periods; September 21,2006 to October 18, 2006 and October 23, 2006 to November 17, 2006. There are 87 ponds on South Farm ranging from 0.04 to 0.10 hectares. Each pond has a water inflow pipe and an out flow standpipe to maintain water depth and water retention time. Of the 87 ponds, 75 were equipped with automated oxygen monitors and were used to conduct the outlined measurements.

Methods

Compare/Contrast Manual vs. Automatic Techniques

An Integrator Aquasystems ™ automated monitoring system was used to monitor the DO concentrations and temperature in the aquaculture ponds. The Integrator monitors were calibrated according to manufacturer's instructions as needed. Dissolved oxygen concentrations were collected daily with a handheld YSI DO probe and compared to simultaneous automated measurements in order to verify calibration. To calculate the differences between maintenance of DO concentrations by manual and automated oxygen monitors, the detection time of low oxygen concentrations under manual operation was estimated using continuous oxygen measurements from the automated monitoring system and the schedule of manual sampling (described below). The amount of time that DO concentrations would have fallen to and remained below threshold levels before being identified under a manual monitoring scheme was then summed across all ponds and tallied as the total number of ponds receiving additional aeration.

Oxygen deficits were calculated as the time between automated measurements initiated aeration and the scheduled time manual measurements taken by Mississippi State University aquaculture facility employees would have detected low oxygen conditions. Conceptually this is shown in Figure 1. This figure shows anticipated oxygen concentrations under the 3 different management schemes; automated management, manual monitoring and without aeration. When no aeration is applied to the ponds the diurnal shift in oxygen concentrations is extremely high as concentrations drop to 0 mg O2 L-1 during the night. Under an automated sampling scheme with DO triggers set at 3 mg O2 L-1 concentrations are prevented from falling below this critical level. Manual DO monitoring produces a similar result overall to the automated scheme but there are significant lag periods around dawn and dusk where the timing of manual sampling fails to detect falling DO concentrations as quickly as the automated system.

Aquaculture facility employees were interviewed to determine how often DO measurements were needed and how often they can be collected manually from the entire 87 pond complex. Employees take DO samples daily at approximately 6 AM, 2 PM, 10 PM, 2 AM, and 4 AM; collection of these samples require an hour each time. From this a model sampling schedule representative of the manual process was established staggering the samples in a systematic way to capture the time required to move between ponds. The Integrator systems were set to turn aerators on if DO reached 3 mg/L. Data that the automated monitors collected was used to simulate manual data collection by using the automated measurements and the sampling timeline for manual collection. For example if the Integrator system turned aeration on at 9 PM while oxygen would not have been checked manually until 10 PM, then this would be recorded as 60 minutes of additional aeration for this single pond. The number of additional aeration minutes was then summed across all 75 ponds. This information determined the amount of time that DO concentrations in the ponds would have been below

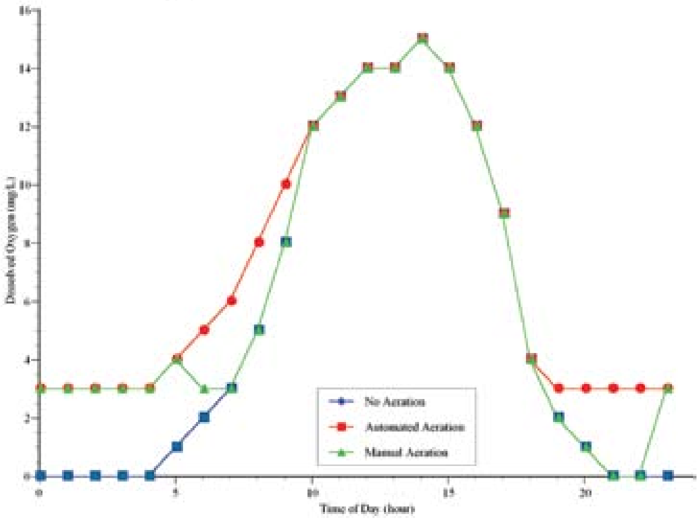

Figure 1. Conceptual representation of dissolved oxygen concentrations in aquaculture ponds under different oxygen management schemes. The blue diamonds represent oxygen concentrations if there is no management of oxygen, the red squares represent oxygen concentrations with automated control of aerators and a trigger of 3 mg O2 L-1. The green triangles represent oxygen concentrations with manual monitoring and aerator control with a trigger of 3 mg O2 L-1 and manual sampling at 2 AM, 4 AM, 6 AM, 2 PM, and 10 PM.

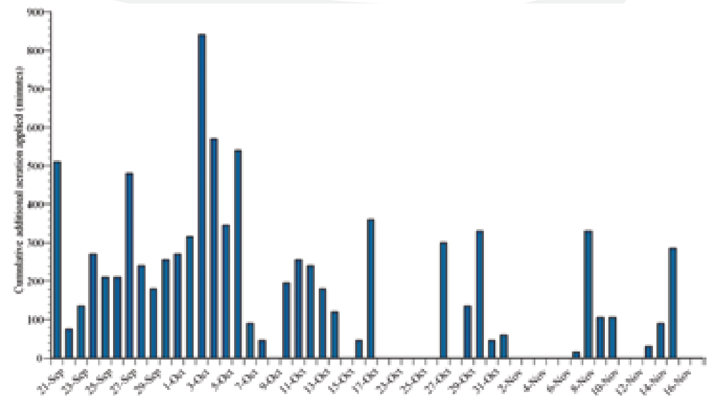

Figure 2. Cumulative additional aeration time across all 75 ponds managed under the automated aeration scheme. This data is analogous to the a summation of the amount of time that ponds would have been below the critical 3 mg O2 L-1 threshold under a manual management scheme.

acceptable levels without automated monitoring. Additionally the percentage of the 75 ponds that received additional aeration under the automated scheme was calculated to assess how widespread the under-aeration was across all ponds.

Results and Conclusions

Based on the comparison of automated measurements and estimates of manual measurements, oxygen deficits would have occurred at some point in 28 ponds over the time period that was considered using only a manual operation scheme. This totaled 8,805 minutes more aeration time than would have occurred had the automated monitors not been controlling aeration within the ponds. Of those 8,805 total minutes, 1,830 minutes (~21%) came from the later time period studied which included a period with cooler temperatures. Oxygen concentrations are not usually checked as often, if at all, during these cooling periods as it is assumed that with lower temperatures DO concentrations will not be as critical or variable. This late season aeration might not have occurred under manual operation potentially causing fish stress or death.

Figure 2 illustrates the amount of time that additional aeration would have been used each day using automated monitoring techniques. When combined with Figure 3 which illustrates the percentage of ponds receiving extra aeration each day over the 28 ponds found to have oxygen deficits a comprehensive picture of the benefits of automated oxygen management become apparent. During the early sampling period as many as 22 of the ponds received additional aeration on any given day with 300 to over 800 minutes of cumulative additional aeration. While this data does not allow us to make precise assessments of the timing of these additional aeration events, it is likely that they are occurring during the critical periods at dawn or dusk. Following the 6AM manual sampling scheme aeration would be shut off if DO concentrations were 3 mg O_2 L^{-1} or higher. This discounts

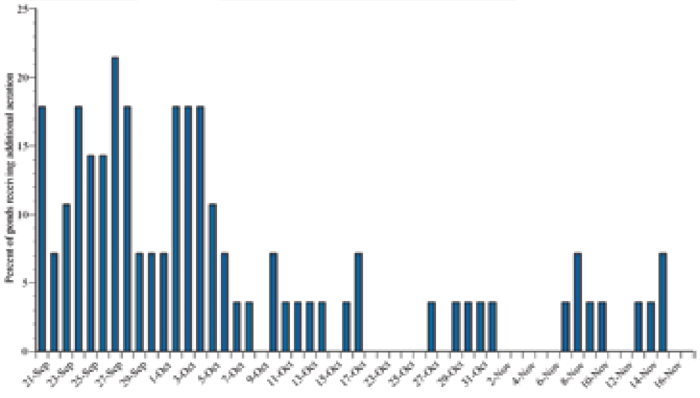

Figure 3. Percentage of the 75 total ponds that received additional aeration under the automated management scheme. This data is analogous to the percentage of ponds that would have suffered low oxygen conditions under a manual management scheme.

the possibility of cloud cover slowing the increase in light and related increases in oxygen production by photosynthesis, which would result in DO levels declining through the morning. At dusk DO concentrations are similarly subject to unanticipated declines in response to warmer than typical days, increases in cultured and resident plant and animal biomass, and the potential for microbial respiration. Under the manual sampling schedule considered in this analysis DO declines between mid-afternoon (2 PM) and 10 PM will not be detected. Declines at either dawn or dusk can result in stress or potential death if oxygen concentrations were to decline significantly.

As noted above a substantial portion of the additional aeration time occurred during the later sampling period (Fig. 2 and 3). Over 1800 minutes of additional aeration was applied to fewer ponds than during the early sampling period. This highlights a second area of potential importance for automated oxygen management. During this later sampling period the cooler temperatures correspond (intuitively) with lower oxygen consumption in response to lower metabolism. As a result of this pond managers will likely decrease the frequency of monitoring activity. While we did not account for decreased manual sampling in our scheme there were still indications of significant oxygen deficiencies (additional aeration requirements).

PCA (Principle Components Analysis) and ANOVA (Analysis of Variance) were run to try to determine other factor(s) that could have resulted in the 28 ponds needing additional aeration. PCA results concluded that the oxygen and temperature means, medians and ranges were the most important statistical measurements to consider and demonstrated the inverse physical/chemical relationship between oxygen concentrations and temperature (increasing oxygen solubility with decreasing temperatures). Results from the ANOVA illustrate that ponds with higher areas have slightly more variable oxygen concentrations. In this case further improvements might be realized through the use of several automated monitors could be more useful in collecting the representative oxygen concentrations across the entire pond, as opposed to manually checking the larger pond at only one point that may or may not be representative of the overall oxygen concentration. Also, ponds that contain catfish and prawn consumed more oxygen than ponds that contained only plants or only water, signaling the importance in considering species composition and biomass when designing oxygen sampling approaches. No other significant differences were observed in either analysis, but this analysis did not include stocking and feeding rates, which have the potential to be confounding factors. Regardless of the cause of DO variability, the use of automated oxygen monitoring and aerator control can simplify operations and provide an added level of confidence in water quality management.

An increase in net return on investment is a primary motive in the continuously growing catfish industry, and all catfish operations want to increase their productivity (Hargreaves & Tucker, 2003). Automated water quality monitoring and control systems have the potential to contribute to an increase in production and profit. Aerators are only activated when DO decreases below a desired level, reducing energy and night labor crew expenses to a minimum. Automated monitors also detect those outlier ponds that could potentially fall to fatal DO concentrations in cooler/cold months when DO is not manually checked at all or as frequently as it is in warmer/hot months. These unpredicted occurrences could have a significant effect on total net returns, an effect the producer would not have anticipated without the help of automatic monitors. Implementation of the automated oxygen monitors could profoundly impact water quality management and reduce production losses due to low DO fishkills.

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