FREQUENCY OF LOW DISSOLVED OXYGEN CONCENTRATIONS IN PONDS FOR COMMERCIAL CULTURE OF CHANNEL CATFISH

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Abstract: Data were obtained on dissolved oxygen (DO) problems in 36 ponds used for the commercial production of channel catfish (*Ictalurus punctatus*) in Tallahatchie County, Mississippi. The frequency of DO concentrations below 2 mg/liter at dawn was greatest during summer when water temperatures were above 26C. On summer days, 20% or more of the ponds often had DO concentrations below 2 mg/liter at dawn. During the 154-day period, 1 May through 1 October, emergency aeration was employed a total of 410 times in the 36 ponds. During the summer, at least 1 pond was aerated most nights, and a maximum of 9 ponds was aerated on a single night. Findings suggest that at least 1 aeration unit should be available for each 4 ponds.

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Low concentrations of dissolved oxygen (DO) are frequently a problem in pond culture of channel catfish (*Ictalurus punctatus*). Recent research on DO management in channel catfish ponds include: effects of phytoplankton die-offs on DO (Boyd et al. 1975; Tucker et al. 1979), methods for predicting the nighttime decline in DO (Boyd et al. 1978; Romaire and Boyd 1978), feeding rates and DO concentrations (Boyd et al. 1979; effects of solar radiation on DO concentrations (Romaire and Boyd 1979), evaluation of potassium permanganate, copper sulfate, and simazine as deterrents to DO problems (Tucker and Boyd 1977, 1978), and the effectiveness of different methods of emergency aeration (Boyd and Tucker 1979). These studies indicated that problems with low dissolved oxygen concentrations are generally predictable from data on plankton density, standing stocks of fish, and weather conditions. Problems with low DO concentrations increased in frequency and severity with increasing feeding rate. Mechanical aeration or the introduction of oxygenated water were the only effective techniques for preventing fish mortality.

The present study was conducted during the 1978 growing season to determine the frequency of DO problems in ponds used for the commercial production of channel catfish. These data provide a basis for estimating the emergency aeration requirements of channel catfish ponds.

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Materials and Methods

Thirty-six channel catfish production ponds located on a fish farm in Tallahatchie County, Mississippi, were employed in this study. Thirty-two ponds had areas of 6.1 ha. The other 4 ponds had areas of 2.8, 4.9, 8.1, and 8.9 ha. Average depth was approximately 1 m in all ponds. Ponds were separated by earthen dams and filled by water from wells. Fish were of 2 sizes, marketable size and small fish which were being reared to marketable size. Marketable fish were periodically removed by seining. Estimated average standing stocks of fish and ranges were: 28 May, 3,030 kg/ha (80-4,500 kg/ha); 25 June, 2,350 kg/ha (40-4, 500 kg/ha); 23 July, 2,410 kg/ha (40-5,510 kg/ha); 27 August, 3,330 kg/ha (1,600-5,100 kg/ha), and 24 September, 3,950 kg/ha (1,950-6,170 kg/ha). Fish were fed daily at approximately 2% of standing stock.

Dissolved oxygen concentration and temperature were measured at a depth of approximately 15 cm with a polarographic DO meter and thermistor (Yellow Springs Instrument Company) at 1 or 2 locations in each pond. Measurements were made at dawn and mid afternoon each day between 2 May and 1 October. The DO probe was attached to a fiber glass rod to permit readings to be taken from pond banks. A graph of dawn and afternoon DO concentrations was prepared for each pond. If the DO concentration at dawn was above 5 mg/liter and the afternoon DO concentration was as high or higher than the previous day, DO was not measured during the night. If the DO concentration at dawn dropped below 5 mg/liter or the afternoon DO concentration was markedly lower than the previous day, DO was measured at 2 to 3 hours intervals during the night. When a graph of the nighttime DO concentrations suggested that DO concentrations would fall below 2 mg/liter before dawn, emergency aeration was usually initiated.

Emergency aeration was conducted in one of three manners: paddlewheel aerators operated from the power-take-offs of tractors (Fig. 1), lift pumps which pumped oxygenated water from an adjacent pond into the pond with the DO problem, and Crisafulli pumps which sprayed DO-deficient water into the air so that it fell onto the pond surface (Fig. 2). When oxygenated water from an adjacent pond was pumped into a pond with DO-deficient water, an equal volume of water was returned to the adjacent pond after the DO crisis. Four paddlewheel aerators, 3 Crisafulli pumps with sprayers, and 2 lift pumps were used during the study.

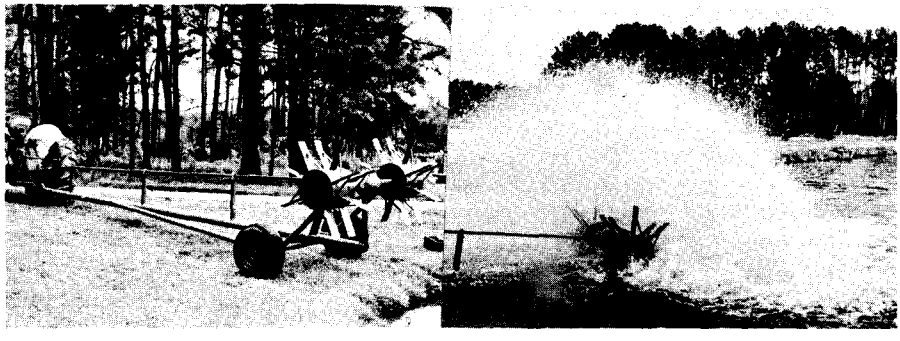

Fig. 1. A paddlewheel aerator.

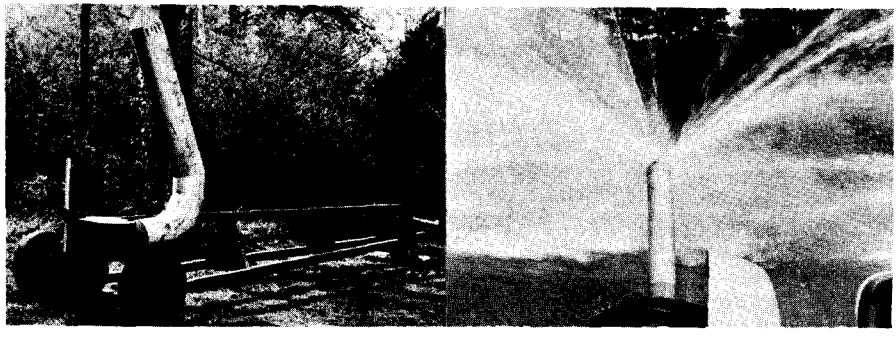

Fig. 2. A Crisafulli pump and sprayer.

RESULTS AND DISCUSSION

The average DO concentrations at dawn and dusk are summarized at approximately 2-week intervals in Table 1. Average DO concentrations in the afternoon were always above 10 mg/liter. However, the afternoon values were underestimates because the DO meter did not register concentrations above 15 mg/liter and several ponds had DO concentrations above this value on each date. Concentrations of DO at dawn averaged much lower than those for the afternoon, indicating that the ponds had a large nighttime demand for DO. Although DO concentrations at dawn always averaged above 2 mg/liter and often above 4 mg/liter, individual ponds frequently developed dangerously low DO concentrations during the night. The percentage of ponds with DO concentration below 2 mg/liter at dawn gradually increased during May and June, and from late June until mid September it was not unusual for 20% or more of the ponds to have DO concentrations below 2 mg/liter at dawn (Fig. 3). The greatest frequency of DO problems occurred on 9 September, when 75% of the ponds had less than 2 mg/liter DO at dawn. During the period 15 June through 15 September, the frequency of DO problems was greater when the preceding day had been overcast than when it had been clear or partly cloudy. The frequency of low DO concentrations at dawn declined greatly after 15 September.

TABLE 1. Average ± standard deviation for dissolved oxygen concentrations (mg/liter) on selected dates in 36 channel catfish production ponds in Tallahatchie County, Mississippi.

Date	Dawn	Mid afternoon[a]
17 Apr	5.6 ± 2.6	10.2 ± 2.4
10 May	5.7 ± 1.9	11.6 ± 2.3
23 May	4.4 ± 3.0	11.4 ± 2.3
10 June	5.4 ± 1.6	12.2 ± 2.5
24 Jun	3.7 ± 0.9	14.3 ± 1.6
10 Jul	4.4 ± 1.7	13.2 ± 2.3
25 Jul	4.5 ± 1.6	12.8 ± 3.7
10 Aug	3.8 ± 1.8	11.3 ± 3.0
24 Aug	4.1 ± 2.3	11.7 ± 2.8
10 Sep	2.7 ± 1.1	12.9 ± 2.4
24 Sep	5.8 ± 1.6	12.0 ± 2.2
1 Oct	5.7 ± 2.6	10.9 ± 2.1

[a]Afternoon values are underestimates because DO meter read only to 15 mg/liter and several ponds had higher concentrations on all dates.

When emergency aeration was initiated during the night, DO readings were made from the pond bank opposite the aeration equipment so that the DO readings were not greatly influenced by aeration.

The low frequency of low DO concentrations during spring and fall (Fig. 3) resulted because water temperatures were lower in spring and fall than in summer (Table 2) and water has a greater capacity to hold oxygen at lower temperature. Water temperatures at dawn were generally above 26C during the summer when DO problems were frequent. Boyd et al. (1979) and Tucker et al. (1979) also noted that DO problems were more frequent during summer when water temperatures at dawn were above 26C than in spring or fall when temperatures were lower.

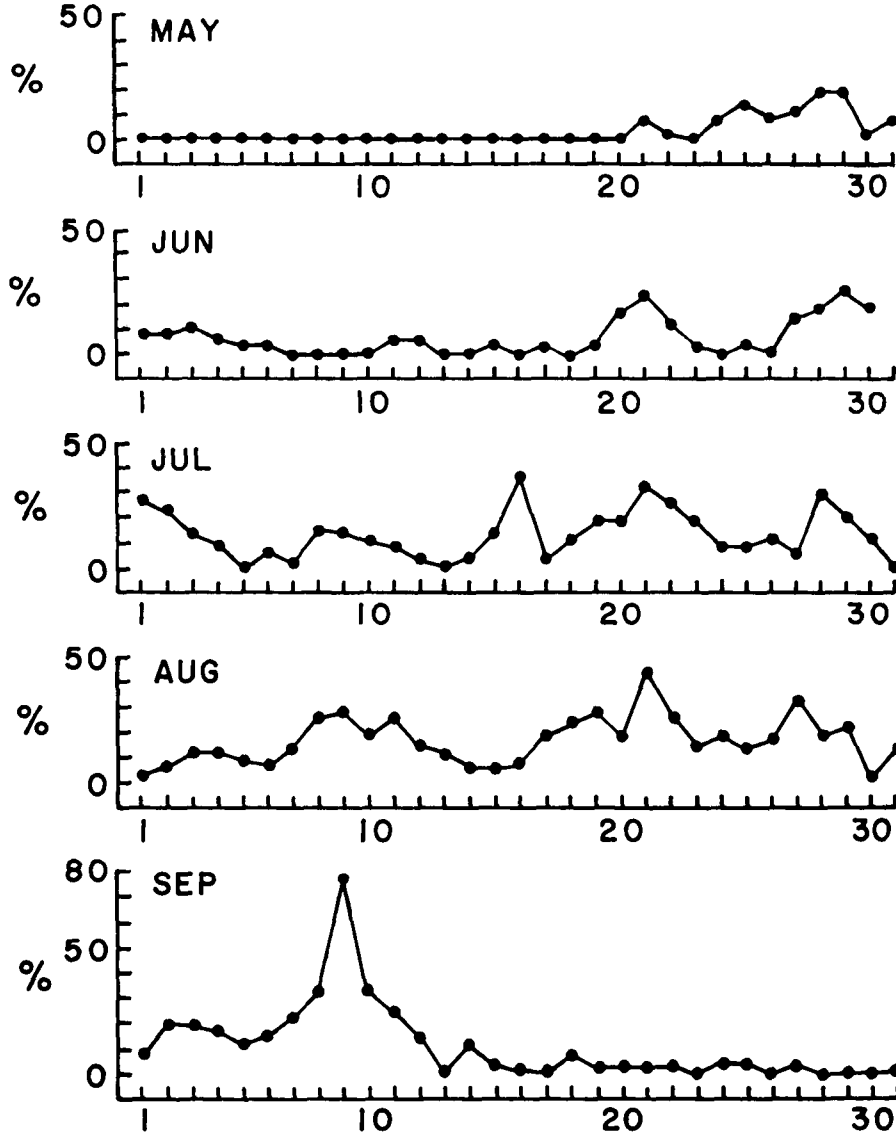

Fig. 3. Percentages of 36 channel catfish production ponds with dissolved oxygen concentrations less than 2 mg/liter at dawn during the period 1 May through 31 September, 1978. Ponds were located in Tallahatchie County, Mississippi.

Emergency aeration (pumping is also considered emergency aeration) was not required until 15 May and comparatively few ponds had to be aerated until after 15 June (Fig. 4). Between 16 June and 15 September, there were only 4 nights during which no ponds were aerated. A maximum of 9 ponds was aerated during a single night. However, on a few dates, more than 9 ponds had DO concentrations below 2 mg/liter. On these dates, only the ponds with the most rapidly declining DO concentrations were aerated.

TABLE 2. Average water temperatures (15 cm below surface) at dawn and mid afternoon in 36 channel catfish production ponds in Tallahatchie County, Mississippi.

Date	Temperature (C)		Date	Temperature (C)	
	Dawn	Mid afternoon		Dawn	Mid afternoon
10 May	22	25	25 Jul	28	33
15 May	19	23	30 Jul	28	35
20 May	24	31	5 Aug	28	29
25 May	27	33	10 Aug	27	31
30 May	27	32	15 Aug	28	31
5 Jun	26	28	20 Aug	29	31
10 Jun	26	27	25 Aug	29	33
15 Jun	26	32	30 Aug	28	32
20 Jun	27	28	5 Sep	27	32
25 Jun	28	32	10 sep	29	27
30 Jun	32	36	15 Sep	24	29
5 Jul	30	36	20 Sep	27	33
10 Jul	29	34	25 Sep	21	23
15 Jul	28	34	30 Sep	22	22
20 Jul	29	33			

Emergency aeration was generally initiated between midnight and dawn and continued during daylight until phytoplankton photosynthesis had produced adequate DO to prevent stress of fish. The duration of emergency aeration was usually 3 or 4 hours (range = 1 to 10 hours). Emergency aeration was generally effective and DO-related fish kills occurred in only 3 ponds. Fish mortality was estimated at 4,000 kg in 1 pond and 2,000 kg in the other 2 ponds. this is not a large loss of fish since the 220 ha of ponds had a maximum standing stock of about 1,000,000 kg.

During the 154 day period (1 May through 1 October) emergency aeration was used 410 times out of a possible 5,544 times (7.4% of the possible times). All ponds requried emergency aeration on at least 3 nights, but none were aerated more than 27 nights (Table 3). The number of consecutive nights of aeration seldom exceeded 3, but 1 pond was aerated on 9 consecutive nights (Table 4). In summary, most ponds required aeration less than 20 nights and aeration was seldom continued for more than three consecutive nights. Some ponds were relatively free of DO problems while others had chronic DO problems. Tucker et al. (1979) also observed that certain ponds had chronically low concentrations of DO while others treated in the same manner did not. Typical patterns of temporary and prolonged DO problems are illustrated with data from 2 ponds (Fig. 5).

This study describes an effective DO management scheme for commercial channel catfish production ponds. The procedure requires many DO measurements, but the number of measurements might be reduced by utilizing the suggestions of Romaire and Boyd (1978) to identify problem ponds.

In the present study, a maximum of 75% of the ponds had DO levels below 2 mg/liter on a single date. Nevertheless, no fish kills resulted on those dates even though emergency aeration was employed in only a portion of the pond with DO concentrations below 2 mg/liter. These were the ponds with the most rapidly declining DO concentrations. This

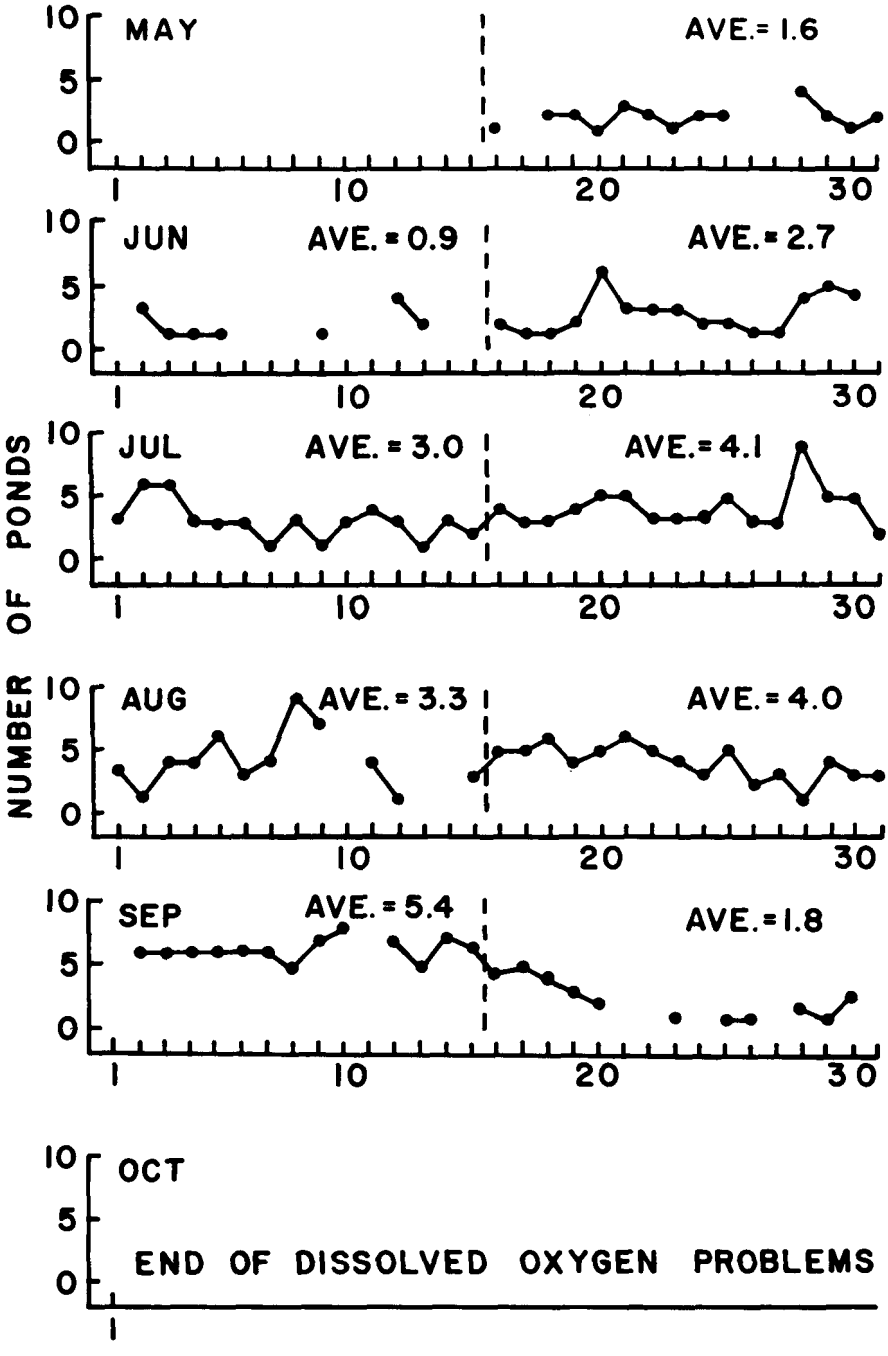

Fig. 4. Number of channel catfish production ponds per night which required emergency aeration between 1 May through 1 October, 1978. A unit of 36 ponds in Tallahatchie County, Mississippi, was used in this study.

TABLE 3. Frequency of emergency aeration in 36 channel catfish production ponds in Tallahatchie County, Mississippi.

No. of times aerated	No. of ponds	Percentage of ponds
>3	0	0.0
4- 5	6	16.7
6-10	13	36.1
11-15	7	19.4
16-20	8	22.2
21-27	2	5.6
<	0	0.0

TABLE 4. The frequency distribution of emergency aeration for different numbers of consecutive nights in individual channel catfish ponds (total of 36) in Tallahatchie County, Mississippi.

No. of consecutive nights aerated	No. of events	Percentage of events
1[a]	111	53.9
2	47	22.8
3	26	12.6
4	6	2.9
5	3	1.5
6	6	2.9
7	5	2.4
8	1	0.5
9	1	0.5

[a]For example, on 111 occasions, aeration was used in ponds 1 night, but not the next; on 47 occasions aeration was required in ponds on 2 consecutive nights; etc.

finding is in agreement with the observations by Boyd et al. (1979) and Tucker et al. (1979) that DO concentrations often fall below 2 mg/liter without harming fish. Therefore, it is more useful to base the need for emergency aeration equipment on the fact that in this study not over 25% (9 of 36) of the ponds were ever aerated on a single date. Admittedly, only 9 aeration units were available. However, the judicious use of these units prevented massive fish mortalities even on nights when more than 9 ponds had DO concentrations below 2 mg/liter. Emergency aeration units are mobile and 1 unit could often be used in 2 ponds during 1 night. This is a margin of safety if only enough aeration units are available to aerate 25% of the ponds at once and more than 25% of the ponds have DO problems during the same night.

An emergency aeration unit is quite expensive because a large tractor is required to power each unit. However, it would be possible to produce self-powered paddlewheel

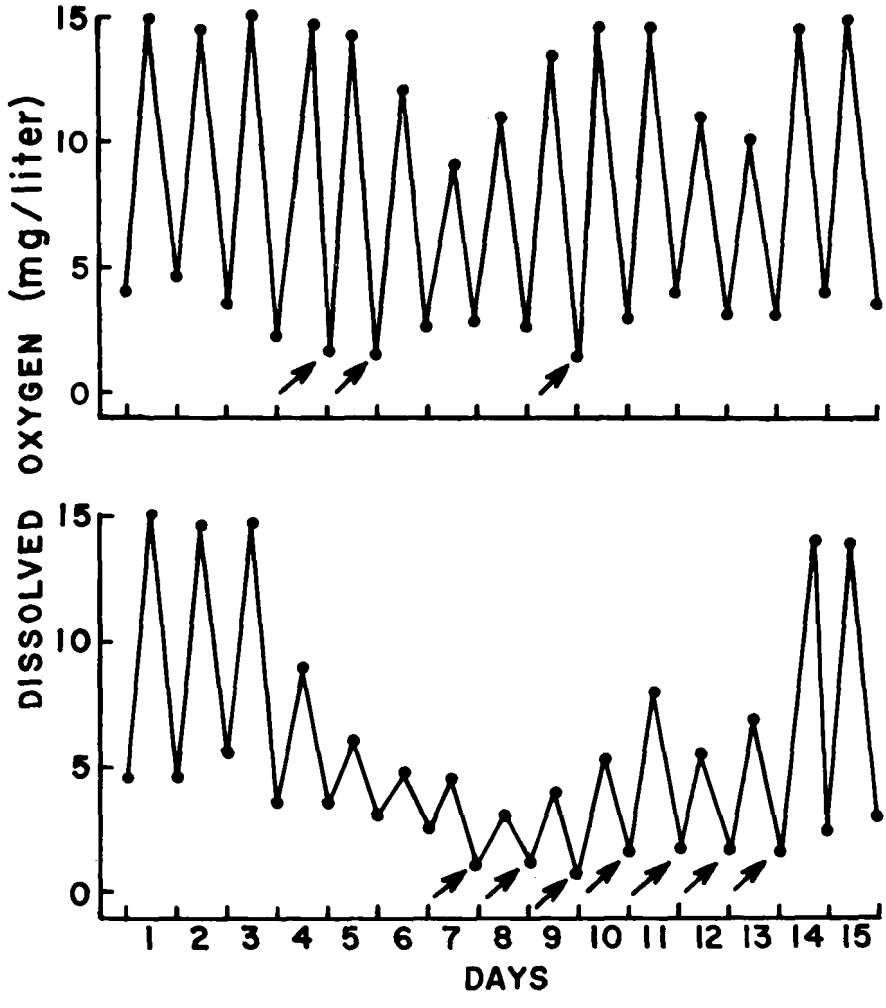

Fig. 5. Examples of dissolved oxygen (DO) problems in 2 channel catfish production ponds. The upper and lower series of dots on each graph represent mid afternoon and dawn DO concentrations, respectively. Arrows indicate emergency aeration.

aerators or pumps. A single tractor could then be used to move these units between oxygen-depleted ponds. The cost per aeration unit could be drastically reduced by use of self-powered units.

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