J.C. Headwaters, Inc.

Diamond Lake
Aeration Experiment

A Report to the
Umpqua National Forest
Roseburg, Oregon

By
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A. SUMMARY

A one-day test of an aeration device was tested in Diamond Lake on August 12, 2002. The purpose of the test was to evaluate the potential for aerating Diamond Lake on a major scale to control the cyanobacteria populations, which have reached levels causing the lake to be closed to recreational contact in 2001 and 2002. Aeration is an accepted strategy for the control of cyanobacteria in a number of lakes, but its success depends on the size and depth of the lake. A 1-m diameter disk with perforated plastic tube was lowered into two areas of the lake and a portable compressor was used to generate air pressure to the aeration device. The aeration device worked well in producing a vertical current from the lake bottom without any detectable disturbance of the bottom sediments. Water samples collected before and during the aeration test showed no detrimental effect of the aeration on the water quality parameters measured. The zone of apparent influence of the aeration device was limited to approximately 25 to 30 m in diameter based on drogue movements at the surface. The test indicated that aeration may be a viable measure for controlling cyanobacteria populations in relatively confined areas such as swimming beaches, but the estimated number of aeration units required to achieve control of the cyanobacteria on a lake-wide basis appears prohibitive.

B. INTRODUCTION

Diamond Lake has experienced major blooms of cyanobacteria in 2001 and 2002 causing the lake to be closed to recreational contact during each of these last two summers. The primary taxon present during the blooms has been *Anabaena flos-aquae*. In addition to the noxious conditions associated with the bloom, the cyanobacteria have produced significant concentrations of the toxin anatoxin-a, a serious neurotoxin.

A number of approaches have been proposed for restoring the water quality and fisheries in Diamond Lake, however it appears that a long-term solution will require considerable effort, resources, and time to implement. Efforts are underway to pursue long-term solutions, but in the interim short-to medium-term solutions have been proposed to maintain beneficial uses in the lake while longer-term solutions are pursued. One of the more rapid response measures that was proposed was aeration. Aeration, the artificial introduction of large amounts of air or oxygen into a lake, has been used in a number of cases world-wide to control cyanobacterial populations. It has been used to aerate lake waters that have been depleted in oxygen because of high rates of decomposition and also to destabilize lake waters, thus making it more difficult for cyanobacteria to compete with more desirable algae. Although the hypolimnetic waters of Diamond Lake have become anoxic for limited periods in the summer, the primary purpose for considering aeration in Diamond Lake is to promote rapid circulation of lake waters and develop a more favorable habitat for competing algae such as diatoms.

There were several concerns expressed in implementing an aeration project in Diamond Lake. The lake has soft, flocculent sediments and there was concern that if these sediments were disturbed it would generate a substantial oxygen demand by introducing these organic-rich materials into the water column. A major disturbance of the sediment could introduce considerable particulate matter into the water column and cause the lake to exceed water quality standards for turbidity. A second concern was that the amount of aeration required to suppress the cyanobacteria would require are large physical infrastructure in the lake which would be costly to install and maintain.

As a first step in evaluating the efficacy of aeration for Diamond Lake, we conducted a day-long test of a single aeration unit in the deepest area of the lake and in a shallower area containing macrophytes. The methods and results of the test are described in the following sections.

C. METHODS

A 1m –diameter aeration unit (Figure 1) produced by Air Diffusion Systems and deployed by Paradise Northwest was attached to a distribution line and lowered to the lake bottom approximately 200m south of the DEQ buoy. The coordinates based on the Garmin *etrex* GPS unit was identified and weather data were recorded with a Brunton Sherpa. Water temperature and conductivity was measured with a YSI Model 30 meter. A YSI Model 550 DO meter was calibrated, but the unit failed to operate correctly and the data were not retained.

Figure 1. Aeration disk produced by Air Diffusion Systems being lowered into Diamond Lake.

Prior to turning on the air compressor, surface water samples were collected from the site and placed in Nalgene® containers and stored in coolers prior to shipment. Surface samples were also collected for analysis of phytoplankton community composition. Unfiltered water samples were shipped via overnight courier to Aquatic Research, Inc. in Seattle and phytoplankton samples were preserved with Lugol's solution and shipped to Aquatic Analysts in Portland. Two 12 m-long vertical plankton tows were collected, combined, preserved in denatured ethanol and shipped to ZPs Taxonomic Services in Kaiser, Oregon for analysis of zooplankton community composition. The zooplankton net was a Seattle Net with a 10 cm opening and 80 µ mesh with a modified Wisconsin bucket.

Triplicate benthic samples were collected at each site using a Petite Ponar (Wildco) and strained on-site using a benthic sieve bucket equipped with a #30 mesh (~580 µ). These samples were preserved in denatured ethanol and shipped to Aquatic Biology Associates, Inc. in Corvallis for identification.

The compressor was turned on and allowed to operate for one hour. Water samples were collected from within the aeration zone at the surface after 25 minutes of operation. An underwater infrared camera (Sea Viewer) was lowered to the lake bottom to provide visual evidence of possible bottom disturbance associated with aeration.

D. RESULTS

Field information recorded at the two aeration test sites is shown in Table 1. The weather conditions during the testing were highly favorable with calm, warm conditions. This allowed us to view the affected area easily and to measure surface turbulence with drogues. The water quality data showed modest decreases in turbidity and chlorophyll *a*, a small increase in Total N, and a significant increase in ammonia (Table 2). Other parameters showed little change.

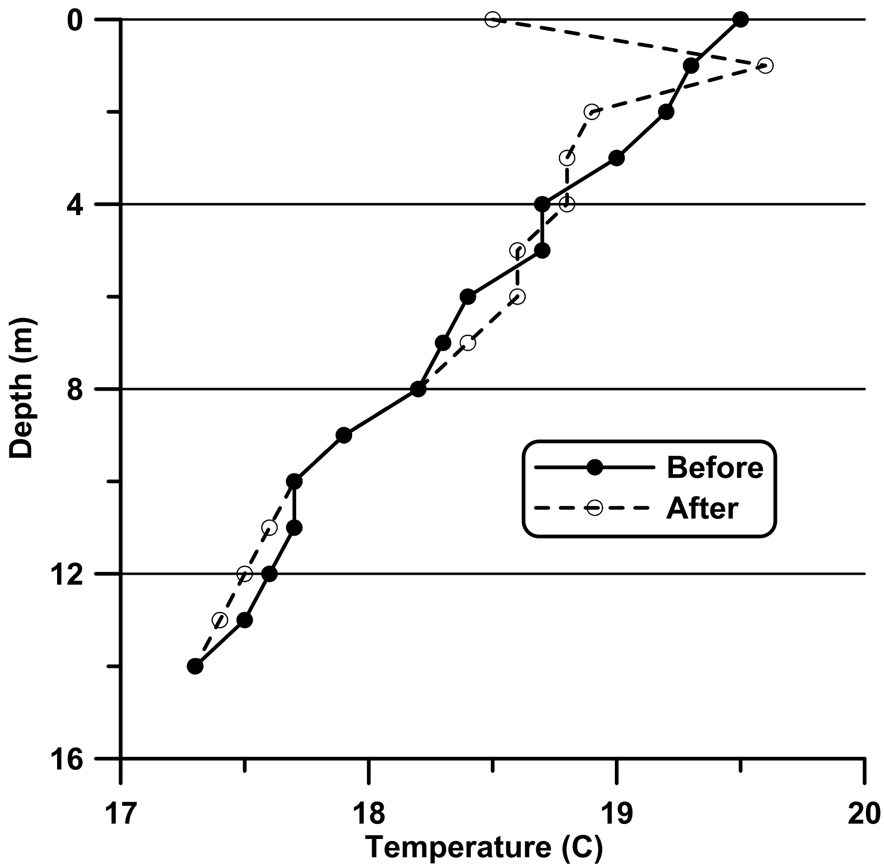
Table 1. Field Notes, August 12, 2002

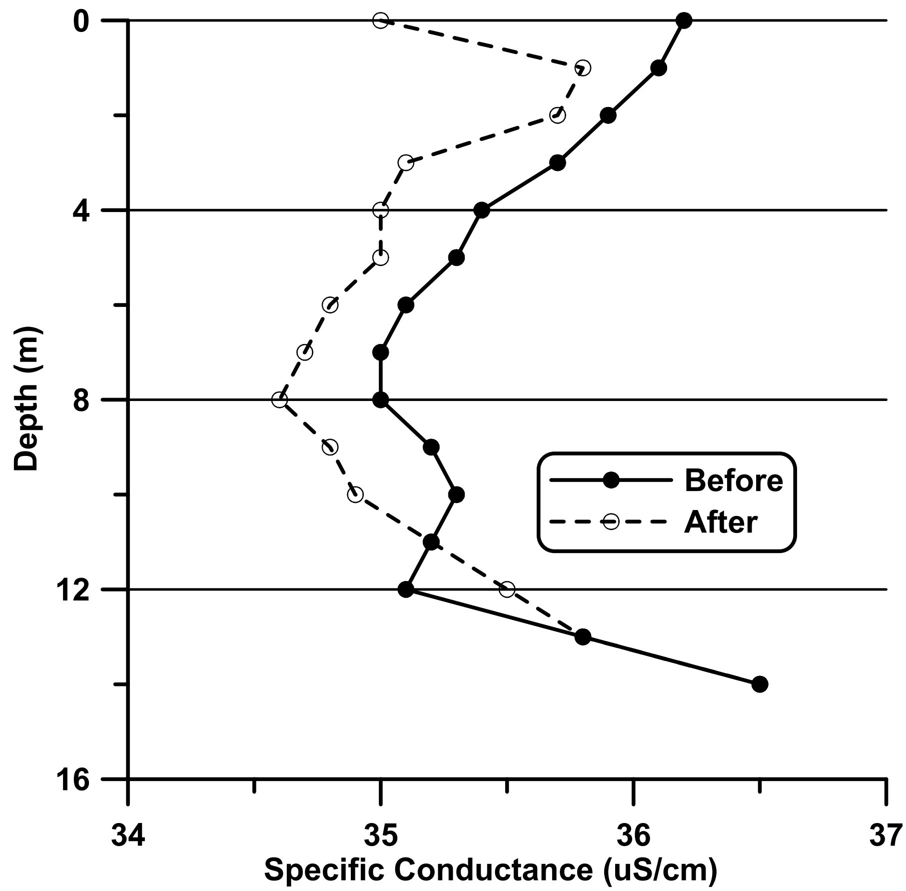
SITE 1		**Aug 12, 2002**		
Site Name	DLA	Sample labels	DIA_01	
Time	1000	Location	Lat 43 10.251	Long 122 09.066
Air Temp	27 C	Secchi Disk = 2.3m		Depth = 14 m
Wind Speed	0 to 1.5 m/s			Substrate = bare
SITE 2				
Site Name	________		DIA_02	
Time 1300			Lat 43 09.215	Long 122 08.316
				Depth = 7 m
				Substrate = weeds

Table 2. Analytical results from sampling at Site 1 (DLA) before and during aeration.

Parameter (unit)	Before	After
	DIA_01 before	DIA_01 after
Turbidity (NTU)	4.5	3.4
Total P (ug/L)	12	14
Ammonia (ug/L –N)	59	124
Nitrate (ug/L – N)	12	12
Total N	485	529
Chlorophyll a (ug/L)	7.5	6.9
Phaeophytin (ug/L)	3.7	4.6

The aeration caused a slight decrease in surface temperature and a small shift in specific conductance (Figures 2 and 3).





Indication of the spatial extent of the zone of aeration influence was determined based on movement of drogues placed in the center of aeration and observations on the movement of algae away from the emergence of the bubble pattern. These observations indicated that the zone extended in a radius of approximately 10 m (and no more than 15 m) from the center of the aerator (Figure 4).

Underwater video images of the aerator in operation indicated that there was very little disturbance of the bottom sediments at either site, despite the flocculent nature of the sediment (Attachment A). Zooplankton data indicated a population similar to that observed in recent years – namely a community dominated by rotifers and small cladocerans. The zooplankton data are archived in the Diamond Lake data base under development by JC Headwaters, Inc. (under contract with DEQ). The phytoplankton data collected on August 12 showed that the *Anabaena flos-aquae* population had declined considerably from July, although *Anabaena circinalis* was an important component of the biovolume (Table 3).

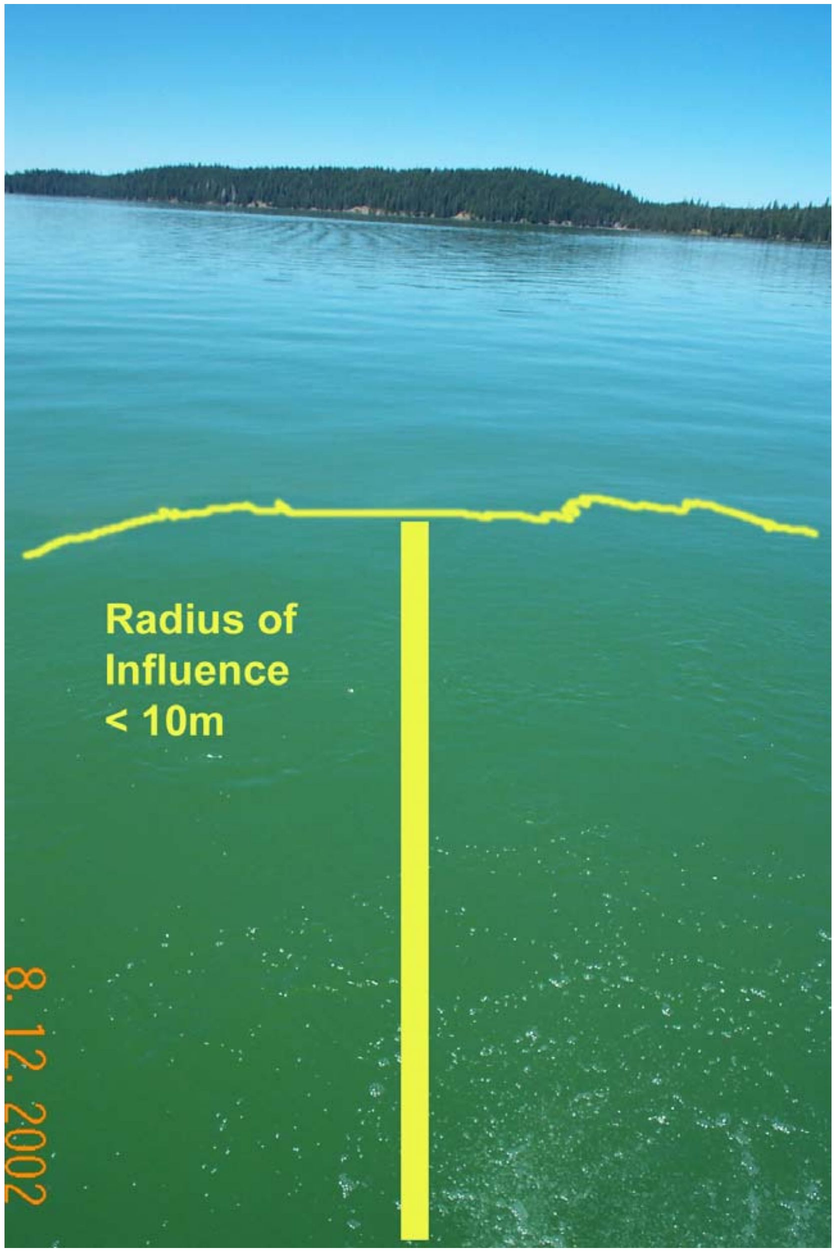


Figure 4. Aerator in operation demonstrating apparent zone of surface movement of water in Diamond Lake, August 12, 2002.

Table 3. Phytoplankton community composition in surface waters of Diamond Lake prior to aeration.

Phytoplankton Sample Analysis

Sample:	Diamond Lake
Sample Station:	DLA
Sample Depth:	0
Sample Date:	12-Aug-02
Total Density (#/mL):	1,286
Total Biovolume (um3/mL):	502,663
Trophic State Index:	44.9

	Species	**Density #/mL**	**Density Percent**	**Biovolume um3/mL**	**Biovolume Percent**
-	-	-	-	-	-
1	Anabaena flos-aquae	527	41.0	35,342	7.0
2	Cryptomonas erosa	220	17.1	114,288	22.7
3	Mougeotia sp.	99	7.7	24,508	4.9
4	Anabaena circinalis	99	7.7	189,895	37.8
5	Gloeocystis ampla	88	6.8	19,693	3.9
6	Rhodomonas minuta	77	6.0	1,538	0.3
7	Unidentified flagellate	44	3.4	879	0.2
8	Tetraedron minimum	33	2.6	11,868	2.4
9	Ankistrodesmus falcatus	22	1.7	824	0.2
10	Synedra radians	22	1.7	15,825	3.1
11	Achnanthes linearis	11	0.9	1,451	0.3
12	Fragilaria crotonensis	11	0.9	73,848	14.7
13	Synedra delicatissima	11	0.9	7,253	1.4
14	Fragilaria construens venter	11	0.9	4,220	0.8
15	Achnanthes exigua	11	0.9	1,231	0.2

Anabaena flos-aquae cells/mL =	4,800
Anabaena flos-aquae heterocysts/mL =	275
Anabaena flos-aquae akinetes/mL =	121

Aquatic Analysts **Sample ID:** GE63

All six benthic samples were low in macroinvertebrates. The number of macroinvertebrates visible with the unaided eye during the sieving process ranged from 1 to 2 organisms. These were all chironomids (Figure 5).

Figure 5. Benthic sample from Diamond Lake following sieving. The red worm-like organism is a chironomid.

E. DISCUSSION

The aeration test conducted on August 12, 2002 revealed several important aspects that would be useful in a more extensive testing of aeration should that prove useful. First, the changes in water quality observed during the brief testing indicated that the aeration would cool the epilimnetic waters. The brief testing showed a decrease of about 1º C, but we would anticipate a greater degree of cooling during a longer-duration operation of the aerators. Other anticipated changes in water quality that would likely occur with aeration would be an initial increase in ammonia in the epilimnion as lower DO hypolimnetic waters are brought to the surface. The increase in free ammonia and decrease in surface temperature would favor growth of green algae, such as diatoms, and a corresponding decrease in cyanobacteria. We observed no increase in turbidity during the aeration test. Turbidity actually declined in the aeration zone as algal cells were pushed aside to the outer edges of the disturbance area created by the rising bubbles. The lack of bottom disturbance was confirmed by visual inspection of the aerator during operation.

Although the aerator worked well in that it caused water circulation and aeration with no perceptible disturbance of the bottom sediments, the zone of influence was relatively small. If we assume that the eventual zone of influence for a given aeration disk was a diameter of 30 m then it would require about 13,000 disks lake-wide to achieve the same degree of surface turbulence as observed in the field ([30m X 30m = 900 m^2]; lake area = 11902885; # disks = 11902885/900 = 13,225). A deployment of this magnitude would cost in excess of $10,000,000, would require the use of hundreds of compressors onshore, and would seriously disrupt use of the lake for fishing and other forms of recreation.

Aeration may be feasible for limited sections of public beaches to control cyanobacteria, but it does not appear feasible to consider for a lake-wide application in Diamond Lake.