Artificial Reservoir Destratification Effects on Phytoplankton

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CONTROLLING PHYTOPLANKTON BLOOMS that characteristically develop in the epilimnion of some reservoirs would be beneficial to many water users. As a potential solution to this problem, efforts have been made to eliminate blooms or at least reduce their severity with thermal destratification. With intermittent water column mixing [1] and with continuous destratification,[2] plankton numbers generally decreased. However, an increase in phytoplankton abundance (mainly *Anabaena*) has been observed during one destratification study,[3] and a decrease has been observed in another study.[4] A substantial increase in phytoplankton volume was observed following the pumping of bottom water to the surface in a small lake.[5]

STUDY AREA

Parvin Lake (Colo.) is a 19-ha mesotrophic reservoir that was constructed in 1927 (Figure 1). It has a maximum depth of 10 m, a mean depth of 4.4 m, and is located at an elevation of 2,500 m in the Rocky Mountains of northern Colorado. Summer surface temperature does not exceed 21°C. Oxygen deficits occur in the hypolimnion and in deep water in the winter. Ice cover lasts from November to April and reaches a 20- to 50-cm thickness. Diatoms dominate the phytoplanktonic community in autumn, winter, and spring. Blue-green algae (particularly *Aphanizomenon* and *Anabaena*) dominate during summer.

METHODS

Destratification. Two aerators * were used in Parvin Lake (Figure 1). Each aerator consisted of a one-piece polyethylene tube, 46 cm in diam, containing a helix that divided the tube into two separate longitudinal sections (Figure 2). Upwelling was created when air was released at the bottom of the aerator through several small holes. Anchored polyethylene pipe (3.8-cm inside diameter) connected aerators and a compressor. Compressed air was provided by a single-stage, air-cooled compressor mounted on shore. Maximum displacement of this compressor was rated at 2.1 cu m/min and maximum operating pressure at 4.2 kg/sq cm. Normal operating equilibrium pressure was reached at 1.0 to 1.4 kg/sq cm. Design, installation, and operation of this destratification system are described more fully elsewhere.[6]

* Polcon Corp., Montreal, Que., Canada.

Sampling. A systematic sampling program was conducted at Parvin Lake during a control year (November 1968 to October 1969) and a treatment year (November 1969 to October 1970). During the treatment year, the destratification system was in continuous operation. Five sampling stations were selected and permanently marked (Figure 1). Phytoplankton sampling consisted of straining 12 l (four 3-l hauls at each 0.5-m depth within each 2-m stratum) through a 75-mm mesh net. Contents were then preserved in 4 percent formaldehyde and enumerated in Palmer counting cells. Samples were taken on a single day near the middle of each month.

Analysis. Individual plankters were enumerated when practical, but colonies (*Eudorina, Volvox, Asterionella,* and others) and chains (*Melosira, Sphaerozosma,* and others) were treated as individuals. As one method of detecting valid count changes resulting from destratification, two statistical analyses were conducted on each phylum and on common species. A significant sign test was used to determine whether a general increase or decrease had taken place. A run test was used as a measure of the randomness of the order of the data. A significant run test meant that the data were not occurring randomly (for example, winter numbers increased and summer numbers decreased).

RESULTS

Changes in phytoplankton numbers were caused by the species present and various other environmental factors. In Parvin Lake, the abundance of phytoplankton in the treatment year (number of individuals or colonies) was only about 30 percent of that in the control year. However, this decrease was a result of a very substantial decline in winter phytoplankton coupled with a proportionally smaller increase in summer phytoplankton. Phyla differed in their response to destratification.

Chlorophyta. The abundance of chlorophyta (total numbers of four common species) significantly decreased during treatment (Table I). Summer and early autumn increases developed in the control year but not in the treatment year. *Eudorina elegans* was eliminated during the

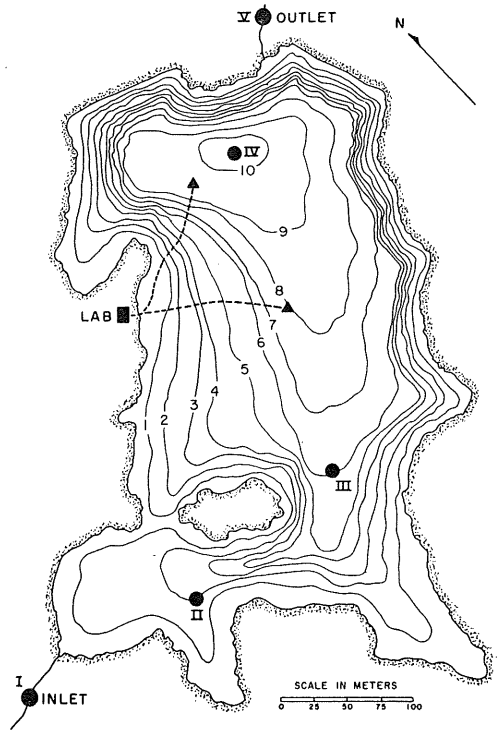

FIGURE 1.—Parvin Lake (Colo.) showing depth contours (in meters), sampling stations (circles), aerators (triangles), and air piping (dashed line).

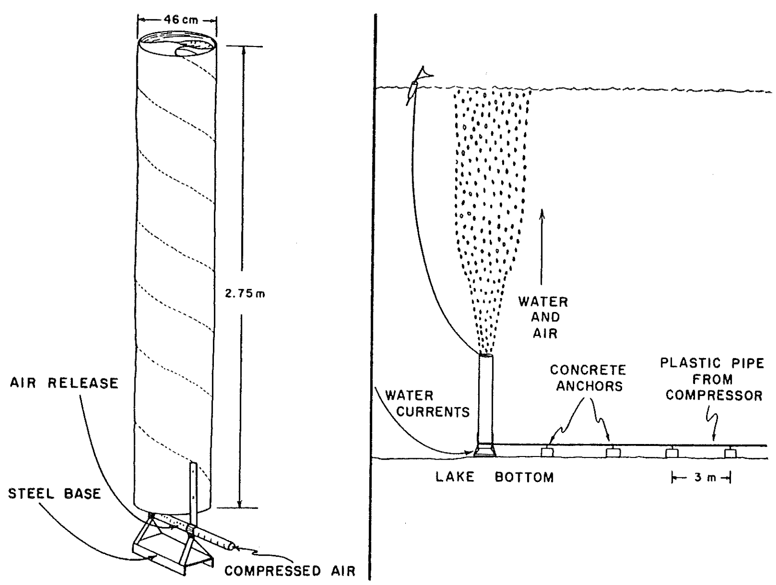

FIGURE 2.—Aerators used at Parvin Lake showing the general design and placement in the lake.

TABLE I.—Weighted Lake Means of Phytoplankters Collected in Parvin Lake

Group	Year*	Weighted Mean (organisms or colonies/l) November	December	January	February	March	April	May	June	July	August	September	October	Mean (organisms or colonies/l)	P† of Sign Test	P† of Run Test
Chlorophyta	C	51	22	63	40	4	57	64	30	62	630	176	309	126	0.04	0.07
(all spp.)	T	26	32	28	26	11	2	16	3	25	16	11	2	16		
Eudorina	C	27	18	55	34	4	32	23	290	36	2	70	57	53	0.00	0.53
	T	3	2	1	3	1	0	1	0	4	0	0	0	1		
Sphaerozosma	C	3	0	0	1	0	18	39	0	10	11	11	76	14	0.61	0.18
	T	5	17	16	9	2	1	15	3	0	0	0	0	6		
Staurastrum	C	21	4	3	2	0	2	1	9	16	590	93	170	75	0.39	0.01
	T	13	10	10	12	7	1	0	0	0	16	11	2	7		
Volvox	C	0	0	5	3	0	5	1	1	0	27	2	6	4	0.39	0.39
	T	5	3	1	2	1	0	0	0	21	0	0	0	3		
Pyrrhophyta	C	11	2	0	0	0	0	1	15	260	3,100	87	46	290	0.75	0.36
Ceratium	T	3	5	2	2	0	0	0	1	1,200	400	5	2	140		
Chrysophyta	C	0	0	0	260,000	82,000	0	0	0	0	0	0	0	28,000	0.50	—
Mallomonas	T	0	0	0	0	0	0	0	0	0	0	0	0	0		
Bacilliariophyceae	C	81,000	49,000	190,000	210,000	140,000	270,000	100,000	70	330	20	100	0	100,000	0.06	0.11
(all spp.)	T	6	19	61	110	11,000	6,000	2,400	2,200	1,100	0	0	0	1,900		
Asterionella	C	330	26,000	160,000	210,000	140,000	270,000	100,000	44	0	0	0	0	75,000	0.11	0.07
	T	2	14	26	110	11,000	6,000	2,400	2,200	850	0	0	0	1,900		
Fragilaria	C	200	2,300	3,200	300	360	200	2	0	2	2	10	0	550	0.01	0.00
	T	0	0	0	0	1	2	1	1	0	0	0	0	0		
Melosira	C	79,000	87	1,500	19	42	6	7	26	330	0	1	0	6,700	0.00	0.52
	T	4	5	35	0	1	0	0	0	260	0	0	0	25		
Cyanophyta	C	46	0	8	4	26	34	580	300	320	80	153,000	180	1,200	0.39	0.39
(all spp.)	T	2	6	0	0	0	1	0	7	2,200	310,000	140,000	2,900	38,000		
Anabaena	C	0	0	0	2	25	32	580	300	320	80	13,000	160	1,200	0.55	0.11
	T	2	6	0	0	0	1	0	7	1,100	19,000	1,800	12	1,800		
Aphanizomenon	C	0	0	0	0	0	0	0	0	0	0	150	1	13	0.12	—
	T	0	0	0	0	0	0	0	0	1,100	290,000	140,000	2,400	36,000		
Gomphosphaeria	C	46	0	8	2	1	2	0	1	0	0	38	16	10	0.26	0.14
	T	0	0	0	0	0	0	0	0	0	2	2,500	460	250		

* C = control year; T = treatment year.
† P = probability (values less than or equal to 0.05 are considered significant).

treatment year. Compared with the control year, *Sphaerozosoma aubertianum* increased during winter months but was eliminated during treatment summer months. *Staurastrum gracile* responded in a similar manner. *Volvox* sp. was nearly identical in abundance both years but, during the control year, was typically found in the upper 4 m of the lake. During the treatment year, numbers were more uniformly distributed in the water column. Other green algal species did not exhibit any pattern of vertical stratification.

Pyrrhophyta. *Ceratium hirundinella* followed a similar pattern during both years (Table I). The peak of the summer pulse was somewhat higher during the control year, and therefore the mean was higher. During both summers, this species was most abundant in the upper 2 m of water but was found throughout the water column. Data from other years showed similar annual cycles and supported the assumption that the 1968–69 control year was typical for Parvin Lake.

Chrysophyta. *Mallomonas* sp. was very abundant during February and March of the control year but was never observed during the treatment year (Table I).

Bacillariophyceae. *Asterionella formosa* decreased in abundance during treatment (Table I), but this decrease was not significant. Control winter abundance was high for November through May, while treatment abundance was low from November through February and only moderate from March to May. Maximum abundance developed in midwater during April of the control year and during March of the treatment year (Figure 3). *Fragilaria crotonensis* failed to develop a pulse during the treatment year and significantly decreased during treatment. A pattern of vertical distribution was absent in both control or treatment. *Melosira granulata* decreased during the treatment year, and the fall and winter pulse of the control year was absent during treatment. This species was most dense in deep water during the control winter, but during the treatment winter no indication of this vertical stratification was present.

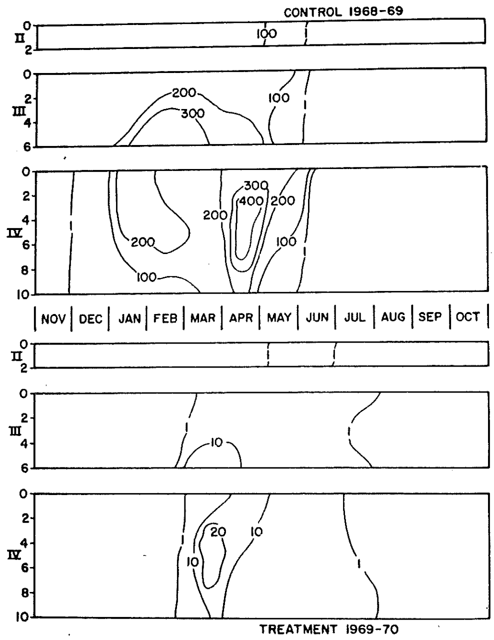

FIGURE 3.—*Asterionella formosa* (thousands per liter) found in Parvin Lake during the control and treatment years at the various stations (station depth in meters).

Cyanophyta. Representatives of this phylum bloomed in late summer, and, although monthly differences were not significantly different, abundance was much higher during the treatment year (Table I). *Anabaena flos-aquae* followed a similar pattern during both years with numbers similar in both years. Greatest numbers of *Anabaena* were found in surface water during control but were almost evenly distributed vertically during treatment. *Aphanizomenon flos-aquae* was nearly absent during the control year but bloomed during the treatment year. *Aphanizomenon* blooms are typical in Parvin Lake in late summer, and the absence of a control year bloom was unusual. This species was generally found in the top of the water column in both control and treatment. *Gomphosphaeria lacustris* increased in September and October during the control year but increased more markedly during treatment year. *G. lacustris* exhibited no pattern of vertical stratification.

DISCUSSION

Total phytoplankton abundance decreased in Parvin Lake during destratification, but not all phyla decreased. Other studies have shown a general phytoplankton decrease during forced summer circulation,[1, 2, 7, 8] but some showed phytoplankton increases during summer circulation.[3–5, 9] Destratification favors algal species that normally sink rapidly and, depending on the species present in a lake, could result in increases or decreases in overall algal abundance.[10] This is one plausible explanation to account for the diversity in findings.

Green algae declined during Parvin Lake destratification. This change was so persistent from month to month that it probably reflects the influence of destratification. Several factors may account for this decline. Water temperatures were colder in winter and warmer in summer. Changes in green algae numbers were not large in winter, so colder water temperature (1° to 3°C) was probably not critical. Warmer summer water temperature (1° to 6°C) may have been important in depressing population size. Water column stability, although possibly important, is difficult to correlate with decrease in green algae. Some research [8] has shown green algae decrease following destratification, but other work [1] found variable changes in green algae abundance with a general decrease.

Planktonic diatoms were most dominant in Parvin Lake in winter and decreased in abundance during the treatment winter. During the treatment winter, water temperature decreased, sunlight (open water) increased, and the water column was much less stable than normal. Either of these factors might account for diatom decrease. Nutrient parameters studied did not change drastically,[11] although they were identified with diatom population fluctuation.[12] Temperature and light were important determinants of population increases in *Asterionella formosa*, but a single factor was not of overriding importance.[12, 13] Winter water temperatures were 1° to 3°C colder than normal, and this may have depressed development.

Anabaena flos-aquae, a very important nuisance blue-green in water management, followed a similar pattern both years in Parvin Lake. Increases in *Anabaena* during destratification have been found by earlier researchers.[3, 4] *Anabaena* seemed to be fairly insensitive to destratification and, if true, this would seriously lessen potential benefits in reservoirs with characteristic *Anabaena* blooms. *Aphanizomenon flos-aquae* was more abundant during the treatment year in Parvin Lake. However, this species normally blooms in late summer, and the control year was somewhat unusual in that no bloom occurred. Even assuming this bloom was the normal situation, destratification did not reduce the bloom level. *Aphanizomenon* bloomed in late June and July in another artificially destratified reservoir.[4] Perhaps this is one phytoplanktonic species that is stimulated by lake destratification. *Gomphosphaeria lacustris* in Parvin Lake reached greatest abundance in late summer and early fall of the treatment year. Eliminating thermal stratification seemed to have increased the number of this species. Similar results were found with *G. aponina* with a bloom developing in September.[4]

Blue-green algae were very important from the standpoint of water quality. Blue-greens increased during destratification in one study,[5] but others [1, 14] found that blue-greens decreased in abundance during stratification. As a general rule, blue-greens usually do not reach bloom proportion unless there has been depletion of nutrients.[15] Because there seemed to be a difference in the response of blue-greens to destratification, it is recommended that the water manager carefully evaluate the effects of destratification on the reservoir under consideration.

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