Bottom Fauna Changes During Artificial Reservoir Destratification

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BOTTOM FAUNA CHANGES DURING ARTIFICIAL RESERVOIR DESTRATIFICATION

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Abstract—A 19 ha montane reservoir was kept vertically isothermal by aeration all year round. Four macrobenthic species were abundant during the study: *Asellus intermedius* (isopod), *Chaoborus sp.* (phantom midge), *Hyalella azteca* (amphipod), and *Lumbriculus inconstans* (annelid). Several species of Chironomidae were present and treated collectively. *Hyalella* significantly increased in abundance in shallow water during destratification. Chironomid larvae declined in abundance in the profundal zone during destratification in Winter and Summer. *Asellus, Chaoborus*, and *Lumbriculus* were not significantly altered in abundance during destratification.

INTRODUCTION

OPTIMUM management of reservoirs is often hindered by thermal stratification. Treatment problems of consumptive-use water (for domestic or industrial use), limited recreational activity, and fish die-offs have been identified, directly or indirectly, with thermal stratification. Several approaches to solving these kinds of water management problems have been used, but water quality deterioration is relatively expensive to treat. One potentially economical solution to improving water quality in certain situations is to control or eliminate thermal stratification.

The principle of artificial destratification for water quality improvement involves eliminating areas of the lake where oxygen depletion develops and iron, manganese, and hydrogen sulfide increases may occur. Most destratification studies have shown improvements in water quality associated with chemical problems (DERBY, 1956; RIDDICK, 1957; NICKERSON, 1961; KOBERG and FORD, 1965; BERNHARDT, 1967; FAST, 1968; SYMONS, CARSWELL, and ROBECK, 1970). Reduction in evaporation rate by cooling surface water with thermal destratification is another potential benefit in water management (STREIFF, 1955).

The influence of thermal destratification on biological components is not clearly defined. Fisheries scientists have often attempted aeration of lakes to eliminate fish mortality caused by Winter oxygen loss. Results have not been uniformly successful, but HEMPHILL (1954), RASMUSSEN (1960), and HALSEY (1968) were reasonably successful in preventing winterkill. On the other hand, PATRIARCHE (1961), WOODS (1961), and SEABURG (1966) found their attempts unsuccessful with small scale aeration. LACKEY and HOLMES (1972) showed that commencing Winter aeration when dissolved oxygen was low caused an immediate decrease of dissolved oxygen and an increase in iron.

Another biological problem attributed in part to thermal stratification is nuisance plankton growth that characteristically develops in the epilimnion of some reservoirs. As a potential solution to this problem, efforts have been made to eliminate blooms or at least reduce their severity with thermal destratification. Intermittent water column mixing (ROBINSON, IRWIN, and SYMONS, 1968) and continuous destratification (WIRTH *et al.*, 1970) have been successful in decreasing phytoplankton abundance, at least on a temporary basis. However, increase in phytoplankton abundance (mainly *Anabaena*) was noted by RIDLEY, COOLEY, and STEEL (1966). Other studies (KNOPPERT *et al.*, 1970; HOOPER, BALL, and TANNER, 1953) have also shown general increases in phytoplankton abundance during destratification.

Bottom fauna response to artificial destratification is perhaps the least understood biological aspect. Research on El Capitan Reservoir, California, showed that some benthic species, including midge larvae and pupae, oligochaete worms, nematode worms, and freshwater clams, rapidly invaded the profundal zone following destratification (INLAND FISHERIES BRANCH, 1970). WIRTH *et al.* (1970) also noted habitation of profundal muds by invertebrates following destratification of Cox Hollow Lake, Wisconsin. Both of these lakes were highly eutrophic and contained typical warm-water fish species. The purpose of this paper is to describe the effects of artificial destratification on the bottom fauna of a high altitude, mesotrophic reservoir supporting trout.

STUDY AREA

Parvin Lake, Colorado, was selected for study to evaluate effects of destratification (FIG. 1). This 19 ha mesotrophic reservoir, constructed in 1927, has a maximum depth of 10 m and a mean depth of 4·4 m. Parvin Lake is dimictic and located at an

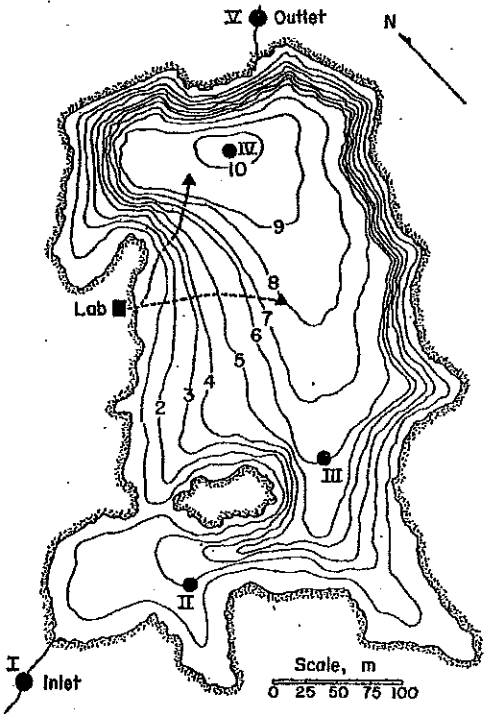

FIG. 1. Parvin Lake showing depth contours, sampling stations (circles), Helixors (triangles), and compressors (square). Dashed line indicates location of plastic pipe.

elevation of 2500 m in the Rocky Mountains of northern Colorado. Summer surface temperature usually does not exceed 21°C. Dissolved oxygen loss occurs in deep water during Summer and Winter. Ice cover lasts from November to April and reaches 20–50 cm thickness.

METHODS

Aerators used during this study were manufactured by the Polcon Corporation, Montreal, Canada. Each aerator consists of a one-piece polyethylene tube 46 cm in diameter containing a continuous coiled structure, which divides the tube into two longitudinal sections. Air, released at the bottom of the aerator through several small holes, creates upwelling by bottom water rising in the tube. Design, installation, and operation of this destratification system is described in detail in LACKEY (1972).

An identical sampling program was carried out at Parvin Lake during a *control year* (November, 1968–October, 1969) and a *treatment year* (November, 1969–October, 1970). During the treatment year the destratification system was in continuous operation and the lake was completely destratified (LACKEY, 1972). At the three lake stations (FIG. 1), four Ekman dredge grabs were combined in the field to form a single sample covering 0·093 m^2 of bottom area. Contents were sieved through a wash bucket (0·515 mm mesh screen) and sugar flotation and rose bengal dye used to separate organisms from debris (LACKEY and MAY, 1971). Preliminary sieving trials revealed large amounts of fine sediment in Parvin Lake, so mesh 0·515 mm was as small as could be effectively used. Samples were taken on a single day near the middle of each month.

Previous studies and preliminary sampling were used to select sampling stations representative of the lake. Station II (2 m) represented the bottom area between 0 and 4 m, Station III (6 m) between 4 and 7 m, and Station IV (10 m) between 7 and 10 m (FIG. 1). Selection of the exact location of a station was made in areas of homogenous bottom. Data from each station were weighted in accordance with its proportion of the total lake bottom. General population increases or decreases were evaluated by a sign test (DIXON and MASSEY, 1969). A significant run test means that data are probably not occurring randomly (e.g. Winter abundance increased and Summer abundance decreased). Both tests are nonparametric in that they do not assume data follow a distribution.

RESULTS AND DISCUSSION

Four macrobenthic species were abundant during the study: *Asellus intermedius* (isopod), *Chaoborus sp.* (phantom midge), *Hyalella azteca* (amphipod), and *Lumbriculus inconstans* (annelid). Chironomidae (midges) were treated collectively. Four or five chironomid species were present, but positive identification could not be made.

Asellus abundance was not significantly different between years (TABLE 1). The annual cycle at Station II was similar in both years, except for the drop in April and May. Abundance at Station III and IV was irregular and differences, if any, were obscure. BUSCEMI (1961) found maximum number of *Asellus* in Parvin Lake in June and July, 1954, but this situation was not observed in either 1969 or 1970. ELLIS

(1961) found that *Asellus* generally breeds in April and May, after which the adult population becomes much less abundant. A life cycle like this would account for the population decline in Parvin Lake in May.

Chaoborus was not greatly affected by destratification (TABLE 2). However, WIRTH *et al.* (1970) found that two species of *Chaoborus* were affected differently following destratification of a Wisconsin lake. *C. punctipennis*, a species that thrives in stratified lakes and is protected from fish during daylight hours because it rests in unoxygenated water, declined during Summer aeration. *C. albatus* became the dominant species during aeration.

Hyalella increased in abundance in shallow water (Station II), but did not significantly change at the other two stations (TABLE 3). BUSCEMI (1961) found these animals to be most common in Parvin Lake in Autumn, Winter and Spring, which is roughly similar to control year results, except for the lack of amphipods in Spring. However, during destratification *Hyalella* was also abundant during the Spring and Summer. Since amphipods are important in the diet of several Parvin Lake fishes, this additional Spring and Summer food may have a beneficial effect, especially on younger game fish and forage fish species.

Lumbriculus did not significantly change in abundance during destratification (TABLE 4). Station II generally supported increased numbers of *Lumbriculus* during treatment for no apparent reason. The number of dramatic monthly shifts in abundance during the control year was reduced during destratification. This is perhaps due to eliminating anaerobic conditions in the profundal zone in Winter and Summer. NICKERSON (1961) noted an increase in worms with Summer destratification. Studies at El Capitan Reservoir, California, showed an oligochaete population increase and a distribution extention following destratification (INLAND FISHERIES BRANCH, 1970). Both papers attribute the increase in abundance to improved dissolved oxygen concentration.

Chironomid larvae generally declined in abundance during the treatment year (TABLE 5). All stations exhibited a decrease in all but Autumn months. One of the most dramatic decreases took place in the profundal zone in Winter and Summer. This might be due to abnormally high dissolved oxygen concentrations at the mud–water interface during destratification. Water temperature alteration is also a possible explanation. During the treatment year, water in the profundal zone was colder (1–2°C) in Winter and warmer (4–6°C) in Summer than normal. Midge larvae are capable of migrating away from unsuitable environments (BAY, INGRAM, and ANDERSON, 1966). It is also possible that certain species responded to environmental stress with emergence at unusual times. Chironomid response might be totally different in the long run if certain species were able to colonize new areas. The results reported here are different from those reported by WIRTH *et al.* (1970) and the INLAND FISHERIES BRANCH (1970), when chironomid abundance increased following destratification and normally anaerobic areas were colonized.

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TABLE 1. ABUNDANCE (NUMBER m^{-2}) OF *Asellus intermedius* COLLECTED IN PARVIN LAKE BEFORE AND DURING DESTRATIFICATION

Year	Station	Month													Probability (a)	
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Year	Sign test	Run test
Control	II	—	—	5900	2900	1700	0	250	320	290	1100	1100	1100	1500	—	—
	III	—	—	200	180	11	390	22	130	120	22	75	33	120	—	—
	IV	330	0	65	0	0	11	0	0	0	0	0	0	34	—	—
	Average (weighted)	—	—	2400	1200	690	150	110	180	160	440	470	440	630	—	—
Treatment	II	1400	1000	1500	2000	1200	2100	0	1000	410	1900	1000	930	1200	0.34	0.40
	III	1200	54	33	43	230	43	0	200	440	410	440	380	290	0.75	0.19
	IV	0	0	22	22	0	0	0	22	0	0	0	22	7	0.65	0.70
	Average (weighted)	1000	420	6200	800	560	840	0	480	330	920	580	520	1100	0.34	0.58

TABLE 2. ABUNDANCE (NUMBER m^{-2}) OF *Chaoborus* COLLECTED IN PARVIN LAKE BEFORE AND DURING DESTRATIFICATION

Year	Station	Month													Probability (a)	
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Year	Sign test	Run test
Control	II	—	—	110	110	0	22	0	0	0	0	0	0	24	—	—
	III	—	—	11	22	3800	11	32	75	32	150	0	110	420	—	—
	IV	120	22	1000	810	700	330	300	120	65	11	700	830	420	—	—
	Average (weighted)	—	—	270	230	1600	87	79	55	27	61	160	220	280	—	—
Treatment	II	0	0	0	0	22	22	0	11	65	0	0	0	10	0.50	0.20
	III	86	54	22	22	11	22	0	43	11	0	0	22	24	0.20	0.64
	IV	1500	960	680	2100	2000	1300	230	460	200	65	330	290	840	0.39	0.53
	Average (weighted)	360	230	160	470	450	310	50	120	75	14	74	73	200	0.75	0.88

TABLE 3. ABUNDANCE (NUMBER m^{-2}) OF *Hyalella azteca* COLLECTED IN PARVIN LAKE BEFORE AND DURING DESTRATIFICATION

Year	Station	Month												Year	Probability (α)	
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.		Sign test	Run test
Control	II	—	—	280	160	0	0	0	11	0	0	120	180	75	—	—
	III	—	—	11	0	0	54	32	11	0	0	0	0	11	—	—
	IV	0	0	0	0	0	0	0	0	0	0	0	0	0	—	—
	Average (weighted)	—	—	120	64	0	21	12	9	0	0	47	72	34	—	—
Treatment	II	660	290	300	720	340	470	0	620	65	200	500	420	380	0.00*	0.00*
	III	0	0	0	0	0	11	0	0	0	0	450	22	4	0.69	0.13
	IV	0	0	0	0	0	0	0	0	22	0	360	0	32	0.50	1.00
	Average (weighted)	260	120	120	280	140	190	0	250	30	81	250	170	160	0.02*	1.00

* Significant at $\alpha = 0.05$.

TABLE 4. ABUNDANCE (NUMBER m^{-2}) OF *Lumbriculus inconstans* COLLECTED IN PARVIN LAKE BEFORE AND DURING DESTRATIFICATION

Year	Station	Month												Year	Probability (α)	
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.		Sign test	Run test
Control	II	—	—	11	0	11	0	43	160	520	110	320	1000	220	—	—
	III	—	—	65	43	22	120	220	570	0	4800	1600	0	740	—	—
	IV	110	43	970	0	1900	1100	0	0	1800	7500	430	0	1200	—	—
	Average (weighted)	—	—	230	17	420	280	100	280	580	3500	830	420	750	—	—
Treatment	II	1200	11	43	440	850	2000	0	3400	6000	1000	300	2210	1500	0.11	1.00
	III	75	1400	480	510	280	460	0	1200	3400	1800	200	2300	1000	0.34	0.58
	IV	460	1100	6000	0	2400	580	500	110	420	810	460	600	1100	0.07	0.53
	Average (weighted)	590	770	1500	370	940	1100	110	1900	3800	1300	300	1900	1200	0.11	0.22

TABLE 5. ABUNDANCE (NUMBER m^{-2}) OF *Chironomidae* COLLECTED IN PARVIN LAKE BEFORE AND DURING DESTRATIFICATION

Year	Station	Month												Year	Probability (α)	
		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.		Sign test	Run test
Control	II	—	—	780	1200	890	2600	2300	700	710	590	700	970	1100	—	—
	III	—	—	1200	3100	3800	2500	3700	1200	970	1200	660	1300	2000	—	—
	IV	86	11	390	330	500	610	720	250	310	340	220	32	320	—	—
	Average (weighted)	—	—	880	1700	1900	2100	2500	800	720	760	580	900	1100	—	—
Treatment	II	870	2000	560	1900	1800	950	0	160	380	310	2200	2600	1100	0.75	0.19
	III	940	1200	1200	1200	1100	1600	0	1000	480	330	470	1600	930	0.04*	0.03*
	IV	220	120	180	22	110	140	86	11	0	11	470	1100	210	0.39	0.02*
	Average (weighted)	760	1300	750	1200	1200	1000	19	460	340	130	1200	1900	850	0.11	0.04*

* Significant at α = 0.05.

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