A LIMNOLOGICAL COMPARISON OF TWO SMALL IDAHO RESERVOIRS

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INTRODUCTION

Most limnological studies of lakes are based on data collected only during the summer months. In this thesis I have compared selected limnological features of two reservoirs based on year around sampling.

Deep Creek and Crowthers Reservoirs located near Malad, Idaho were selected for the study. They are situated within six miles of each other but have different drainage areas.

The study was conducted for a one year period from April, 1965 to April, 1966. Periodic sampling of both reservoirs was undertaken to determine the physical-chemical aspects of the water, zooplankton concentration, and primary productivity of nannoplankton. An investigation of fish production in the two reservoirs is contained in a separate report (in press).

The information obtained should aid in fishery management of the two waters and should add to the knowledge of the structure and function of fluctuating reservoirs as ecosystems.

ABSTRACT

Some limnological aspects of two small southeastern Idaho reservoirs were studied for one year. The reservoirs selected were Deep Creek Reservoir and Crowthers Reservoir, both located near Malad, Idaho.

The study involved a comparison of the two reservoirs as to their chemical and physical features, standing crop of net zooplankton, and the primary production rates of nannoplankton using Carbon-14 isotope.

A well defined thermocline did not form in either reservoir. Annual heat budgets of 15,233 and 15,544 cal/cm^2 respectively were found for Deep Creek and Crowthers Reservoirs.

Dissolved oxygen remained relatively high in both reservoirs except on the bottom where concentrations dropped to two ppm during the summer. Total alkalinity was relatively high in both reservoirs (140-170 ppm in Deep Creek Reservoir and 175-650 ppm in Crowthers Reservoir). Both reservoirs were alkaline with the pH ranging from 7.5 to 8.9.

The mean primary production rates of nannoplankton using Carbon-14 were 9.9 mg C/m^3/hr for Crowthers Reservoir and 6.7 mg C/m^3/hr for Deep Creek Reservoir.

Standing crop of Cladocera for the year averaged 18.7 per liter

in Deep Creek Reservoir compared to 11.7 per liter in Crowthers Reservoir. Copepoda standing crop averaged 70 per liter in Deep Creek Reservoir compared to 36 per liter in Crowthers Reservoir. Rotifera averaged 34 per liter in Deep Creek Reservoir compared to 4 per liter in Crowthers Reservoir.

DESCRIPTION OF STUDY AREA

A. General Description

Deep Creek and Crowthers Reservoirs are located near Malad, Idaho in Oneida County (Figure 1). Malad City is situated in the southeastern region of the State, 15 miles north of the Utah-Idaho border. Deep Creek Reservoir, elevation 5,210 feet, lies 6 miles east of Malad. Crowthers Reservoir, elevation 5,100 feet, is located adjacent to the northern edge of the Malad city limits.

Vegetation in the area consists principally of grasses such as *Agropyron cristatum* (Crested wheat grass), *Elymus cinereus* (Giant wild rye), and sagebrush, *Artemisia absinthium*. *Juniperus* sp. (Juniper), and *Abies* sp. (Fir) are scattered at higher elevations. Dry-land wheat is the principal farm crop in the area, but some bottom land is irrigated from numerous reservoirs around Malad.

Oneida County is considered semi-arid, having a mean annual precipitation of 14 inches (Figure 2). The air temperature extremes during 1966 at Malad City were 95 F and -4 F (U.S. Dept. of Commerce, 1966).

Deep Creek Reservoir was constructed in 1952 for the purpose of storing water for irrigation. The dam is earth filled and about 100 feet high. Water is released through one outlet located at the bottom of the reservoir. An overflow is located at the southern edge of the dam. Water enters the reservoir via three small tributaries which drain an area of about 30 square miles of scattered forest, undeveloped sagebrush land and

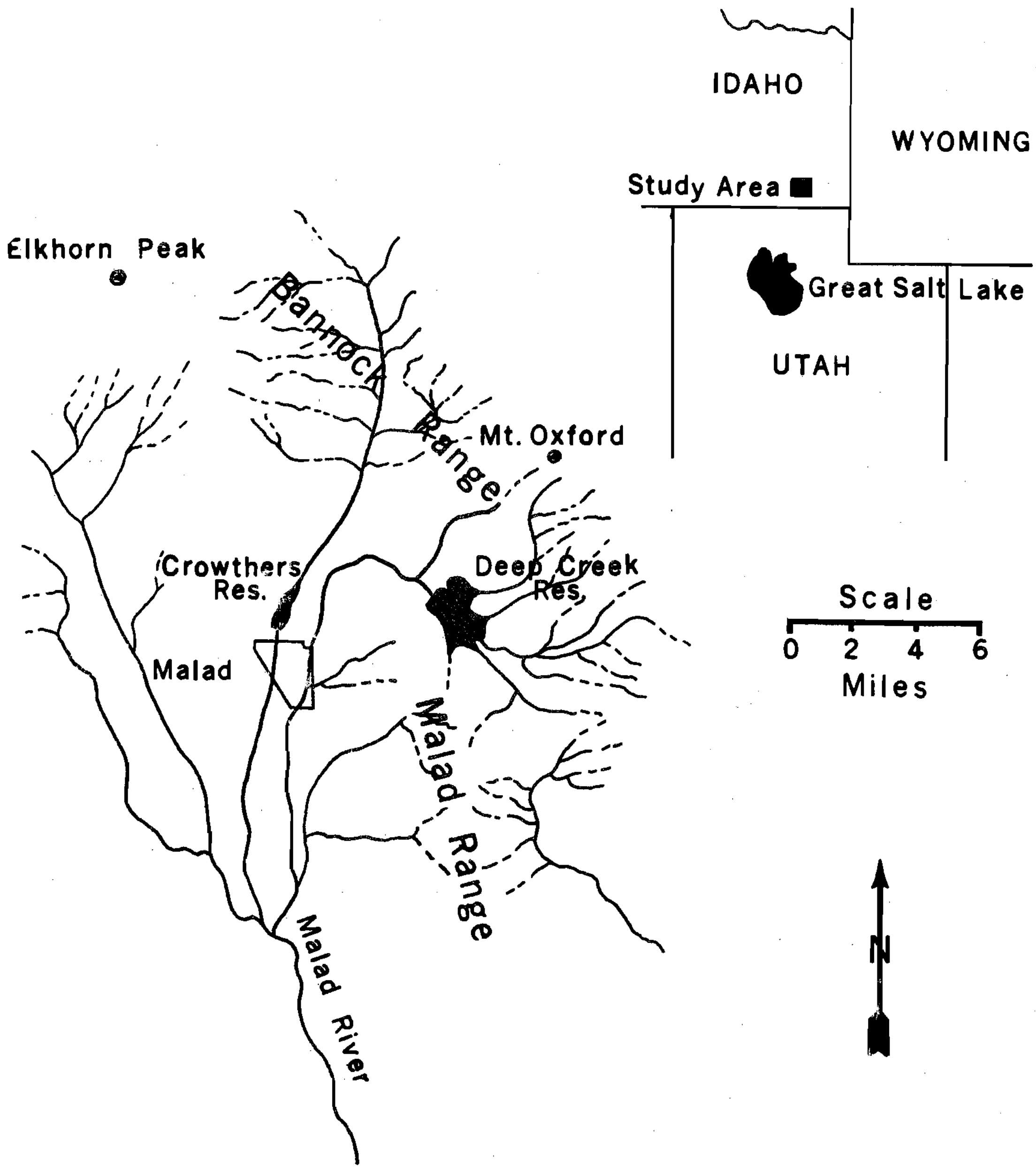


Figure 1. Locality map indicating drainage areas of Deep Creek and Crowthers Reservoirs.

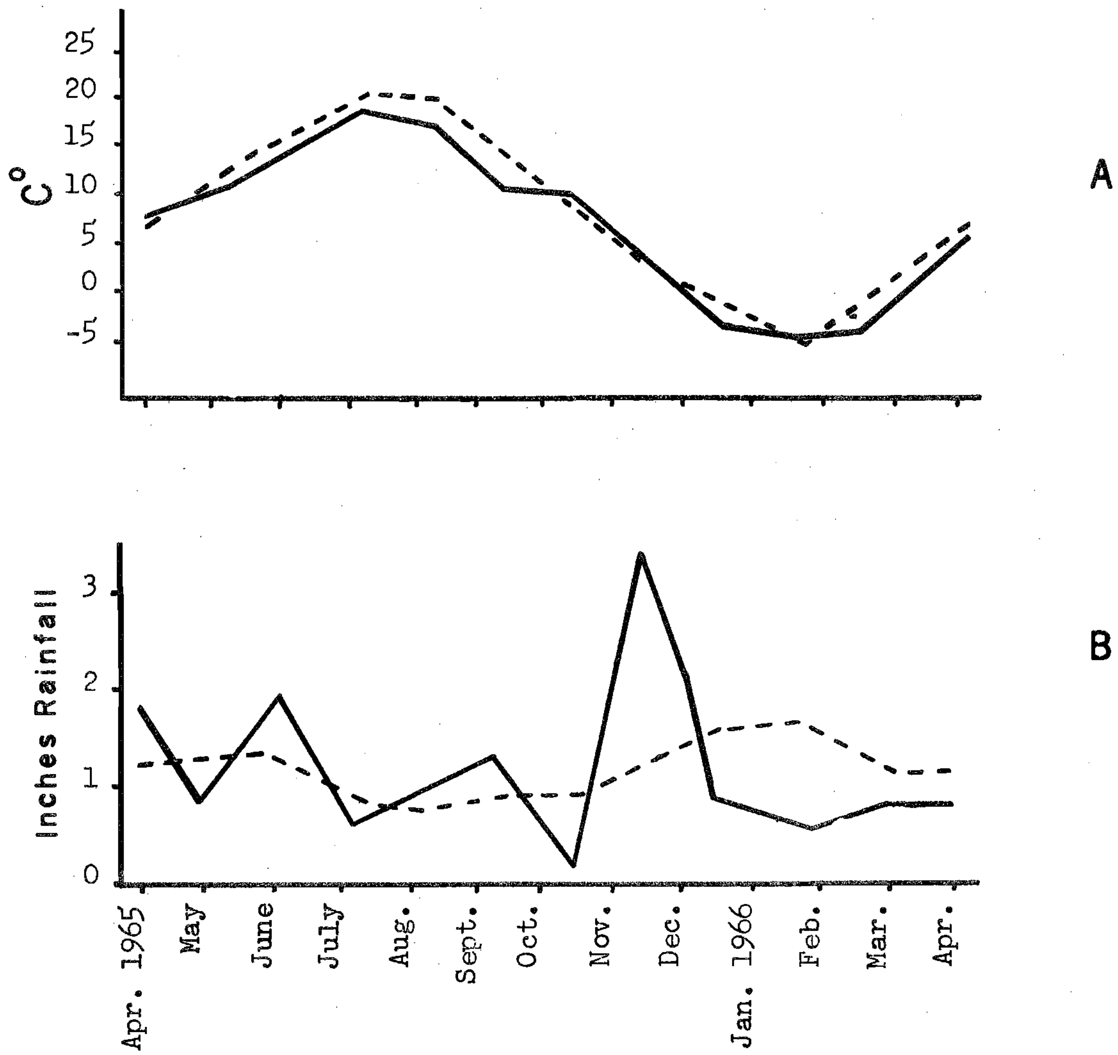


Figure 2. Average monthly air temperature and precipitation at Malad, Idaho during study period of 1965 and 1966. Solid line represents observed values and broken line represents 30 year mean values.

winter wheat farms. Discharge from the reservoir enters the Malad River which drains into the Bear River and into Great Salt Lake.

Crowthers Reservoir was constructed in 1948 for the purpose of supplying water power for a flour mill. It is also earth filled and about 100 feet high. Water is released from the bottom of the reservoir with an overflow pipe located near the top of the dam. Water enters Crowthers Reservoir through Devil Creek which drains an area of about 20 square miles. Organic matter is added to the reservoir by three cattle feed lots adjacent to the mouth of the influent. The effluent flows into the Malad River.

B. Geology

Malad Valley is surrounded by the Bannock Range of mountains and their spur, the Malad Range, which attain elevations of over 9000 feet at Mt. Oxford and Elkhorn Peak. The oldest rock of the surrounding mountains is from the Cambrian Period which shows up principally as dark gray limestone containing yellow sandy streaks. Rock from the Tertiary-Quarternary Periods shows up as various types of conglomerates, marls and limestone which produce a prevailing white soil. These beds underlie most of the Malad Valley, sloping up to the mountains (Piper, 1924).

C. Morphometry

Deep Creek Reservoir is located in a canyon that is steep on the south slope and gently inclined on the north and east slopes (Figure 3). Crowthers Reservoir is situated in a narrow ravine enclosed on both sides by steep slopes (Figure 4). Both reservoirs have widely fluctuating water levels. During the study period the water level dropped 32 feet in Deep Creek Reservoir and 50 feet in Crowthers Reservoir.

Methods for determing morphometric features (Table 1) were obtained from Welch (1948).

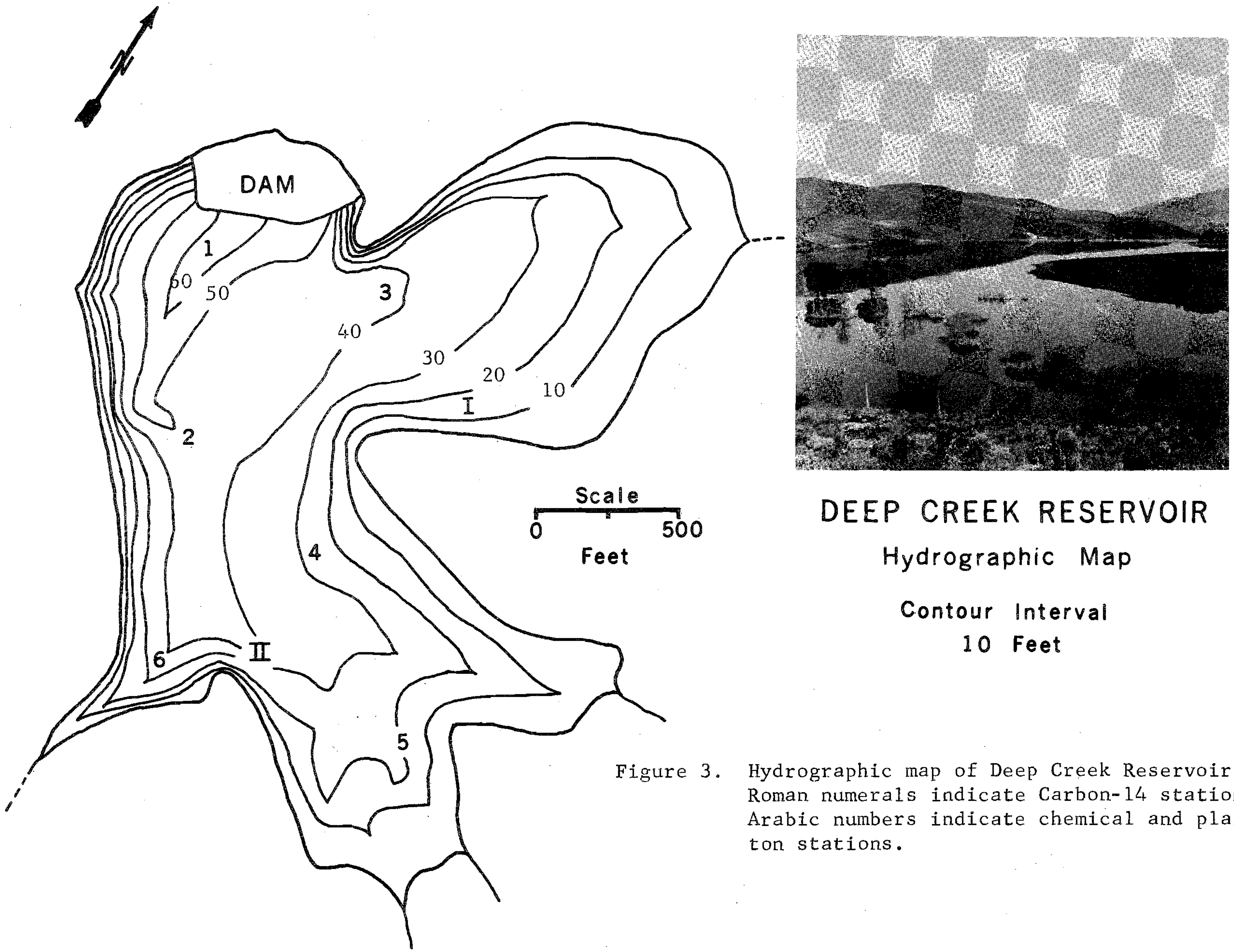
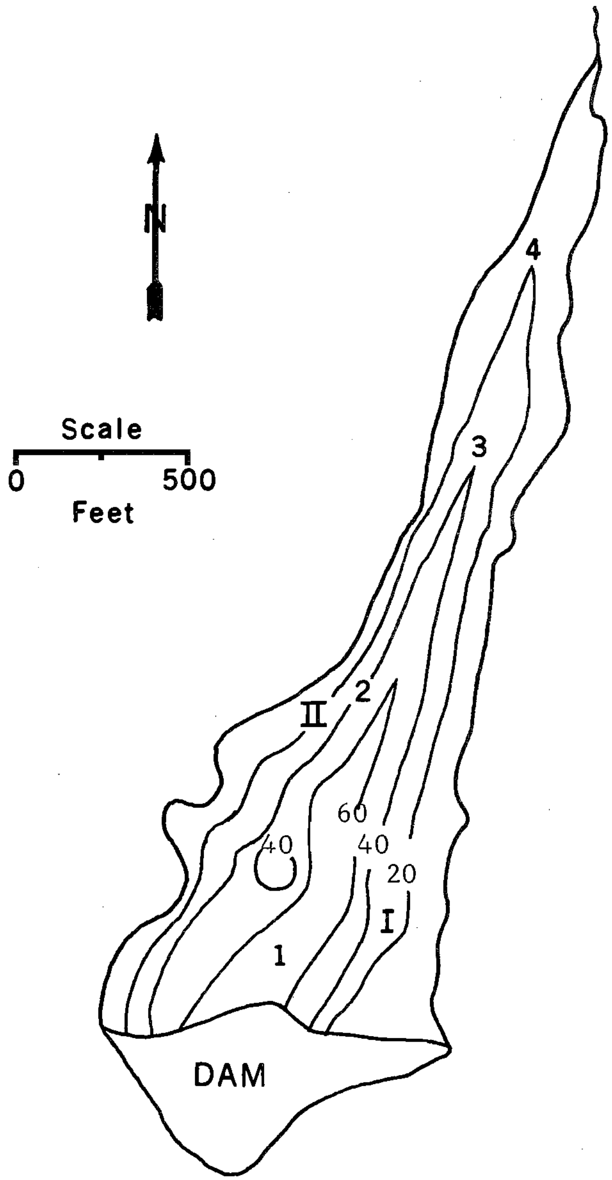
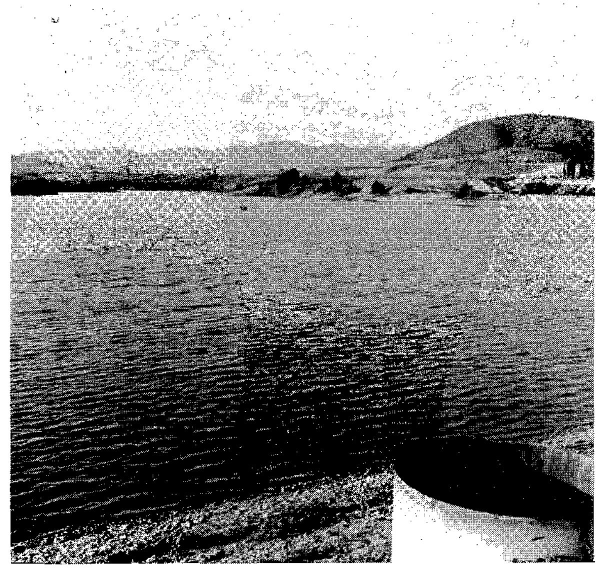


Figure 3. Hydrographic map of Deep Creek Reservoir. Roman numerals indicate Carbon-14 stations. Arabic numbers indicate chemical and plankton stations.





CROWTHERS RESERVOIR

Hydrographic Map

Contour Interval
20 Feet

Figure 4. Hydrographic map of Crowthers Reservoir. Roman numerals indicate Carbon-14 stations. Arabic numbers indicate chemical and plankton stations.

Table 1. Morphometric features of Deep Creek and Crowthers Reservoirs.

FEATURE	DEEP CREEK RESERVOIR	CROWTHERS RESERVOIR
ELEVATION		
Feet	5,210	5,100
Meters	1,615	1,601
MAXIMUM VOLUME		
Acre Feet	6,000	880
Cubic Meters	260,869,560	38,260,870
MAXIMUM AREA		
Acres	200	32
Hectares	80	13
MAXIMUM DEPTH		
Feet	60	60
Meters	18.6	18.6
MEAN DEPTH		
Feet	29.9	27.4
Meters	9.3	8.5
MAXIMUM LENGTH		
Feet	4,100	2,850
Meters	1,271	884
MAXIMUM WIDTH		
Feet	3,900	900
Meters	1,209	279
SHORE DEVELOPMENT	1.79	1.98
MEAN SLOPE OF BASIN	5.0%	8.8%

MATERIALS AND METHODS

A. Sampling Schedule

Limnological features of Deep Creek and Crowthers Reservoirs were studied from April, 1965 to April, 1966. Samples were collected weekly except for April and May of 1965 and from December, 1965 to April, 1966 when samples were taken monthly. Primary production was measured bi-monthly from May through August.

I collected plankton from six stations in Deep Creek Reservoir and four in Crowthers Reservoir. Selection of stations was based on depth, which ranged from six feet in littoral areas to 60 feet near the dams. Samples for chemical analysis were taken only from station No. 1. Two stations were selected in the littoral area of each reservoir for measuring primary production.

Collections were made in the late morning or early afternoon, alternating between reservoirs each week. Sampling was done from an outboard motor boat with the aid of a hand operated winch. During winter holes were drilled through the ice with a hand operated auger.

B. Chemical and Physical Methods

I collected water samples for chemical analysis from the surface, midway, and near the bottom to represent the epilimnion, metalimnion and hypolimnion. A two liter plastic Van Doren sampling bottle was used, and the contents transferred to 250 ml pyrex glass bottles. Dissolved oxygen was determined by the unmodified Winkler method as described by Welch (1948). The oxygen was "fixed" immediately after collection. Titration was completed several hours later in the laboratory. Alkalinity and free carbon dioxide were determined by titrating with N/44 sodium hydroxide and N/50 sulfuric acid, using phenolphthalein and methyl orange as indicators (Needham and Needham, 1962). The pH was determined by using a Hellige color comparator. Conductivity was measured with a conductivity bridge and the specific conductance calculated by the method shown in Standard Methods (1965).

I determined transparency by lowering an eight inch black and white sechii disc, recording the average depth at which it disappeared and reappeared. Temperatures were recorded at two foot intervals with an Allied Electronic Thermometer. Water level fluctuation was observed by placing marked poles in the water.

The heat content per unit surface area at any one time was determined by totaling the product of temperature times volume for declared depth intervals, then dividing by the surface area of the lake and expressing the results in cal/cm^2. The true mean temperature of the lakes was obtained by dividing the heat content by the volume. Summer heat income was arrived at by subtracting the heat content of a theoretically homothermous 4 C state from the maximum heat content during the summer. The annual heat budget was obtained by substituting the lowest heat content obtained during the winter for the homothermous

4 C state (Ruttner, 1963; Reid, 1961).

C. Plankton Methods

I determined standing crop of net zooplankton by collecting water samples from surface to bottom at two meter intervals with a two liter Van Doren sampler. I chose the Van Doren sampler because there may be less avoidance reaction by the zooplankton to a clear plastic container than to a metal container such as a Kemmerer sampler. Also, Strickland (1960) states that some organisms may be so sensitive to metal ions that they disrupt with the loss of body fluids before they are processed. Sampling levels were alternated between stations to represent vertical distribution in the reservoirs. The water was then filtered through a Wisconsin plankton net containing No. 20 bolting cloth. The organisms were washed out of the detachable bucket with a squirt bottle containing 3% formalin and collected in vials for enumeration later. Additional samples were taken for qualitative analysis.

I counted zooplankton using the modified Brodskii-Baskakov method described by Mednikov (1961). By this procedure the ratio of the field area of a dissecting scope to the area of a petri dish was determined. The plankton were then distributed as evenly as possible in the petri dish and the organisms counted in eight random fields. The mean count was multiplied by the corresponding ratio and divided by the number of liters in the sample to give the number of organisms per liter.

Organic weight of net plankton was determined by allowing the plankton to settle in crucibles. Excess water was drawn off and the crucibles were placed in a drying oven. The samples were then cooled and weighed on a Mettler balance. The crucibles were placed in a muffle furnace and ashed at 800 C for five minutes, then cooled and reweighed. The difference between the ash weight and dry weight gave the organic weight of the sample.

Zooplankton were identified using keys and techniques described by Ward and Whipple (1959) and Pennak (1953).

D. Primary Production Methods

Primary productivity of nannoplankton (phytoplankton small enough to pass through No. 20 bolting cloth) was measured using Carbon-14 isotope as described by Steeman-Nielsen (1952) and Goldman (1963). Water was drawn from a medium depth of 18 inches with a plastic Van Doren sampler and filtered through the detachable bucket of a Wisconsin plankton net. A Van Doren sampler was selected because of the possibility of increased carbon fixation caused by a brass Kemmerer bottle (Goldman, 1963). The filtrate was poured into two 250 ml pyrex glass stoppered bottles. One was transparent and the other made opaque with black tape and paint. One ml (5 microcuries) of C^{14} in the form of $Na_2 C^{14} O_3$ was introduced into each bottle with a glass syringe. The bottles were then attached by harness snaps to a cord and suspended at a depth of 18 inches from cross bars on an inner tube. The bottles were exposed during mid-day for about five hours. After the required exposure time the bottles were withdrawn and filtered through type HA 47 mm Millipore filters with a pore size of 0.5 microns. The filters were washed with distilled water to remove any unfixed C^{14} present, placed in plastic planchets and stored in a dessicator until they could be counted. The C^{14} uptake was counted at the University of Utah in an FD2 Flow Counter of a Tracermatic SD-75 Auto/Matic, utilizing an FDW2 window. The radioactivity of each sample was expressed in disintegrations per second. The following formula by Knight (unpublished) was used to determine the C^{12} assimilated.

1. $$C^{12} \text{ assimilated} = \frac{(C^{14} \text{ assimilated})\ (C^{12} \text{ available})\ (1.06)}{(C^{14} \text{ available})}$$

2. $$C^{12} \text{ available} = \frac{(\text{ml } H_2SO_4)\ (1000)\ (0.12)}{(\text{ml of sample})}$$

3. $$C^{14} \text{ assimilated} = \frac{(\text{dps LB} - \text{dps Bg}) - (\text{dps DB} - \text{dps Bg})\ (7.4)\ (\text{sample size})}{(\text{sub-sample size})}$$

4. $$C^{14} \text{ available} = (5 \text{ microcuries})\ (3.7 \times 10^4 \text{ dps})$$

1.06 = Constant correction factor which accounts for the presumed slower uptake of the heavier C^{14}.

ml H_2SO_4 = Amount of N/50 acid used in the titration for total alkalinity.

dps LB = Disintegrations per second of light bottle sample.

dps DB = Disintegrations per second of dark bottle.

dps Bg = Disintegrations per second of background count.

7.4 = Constant correction factor to account for the inefficiency of the counter.

Formula No. 1 yields C^{12} in mg C/liter. To obtain the answer in mg $C/m^3/hr$ the answer was multiplied by 1000/hrs incubation.

RESULTS

A. Physical Features

1. Transparency

Water in both reservoirs was most transparent during June and July (18 feet in Deep Creek Reservoir and 14 feet in Crowthers). The reservoirs were least transparent during the spring and late summer and fall months when plankton populations were highest (Figure 5-A). Both reservoirs were ice covered from December to April. Maximum ice depth was 12 inches, with up to eight inches of snow cover.

2. Water Level

Both reservoirs had widely fluctuating water levels (Figure 5-B). The area and volume of Deep Creek Reservoir decreased slowly from April to July, then dropped rapidly to reach a minimum area of 100 acres and volume of 1800 acre feet during late September (Figure 6). Water level then increased steadily, reaching maximum capacity in April, 1966. Water level in Crowthers Reservoir decreased steadily from April to early November, reaching a minimum area of six acres and volume of 120 acre feet. Water level then increased rapidly, attaining maximum capacity during February, 1966 (Figure 6).

3. Temperature and Heat Content

A well defined thermocline did not form in either reservoir, although a definite temperature gradient was present. Both waters

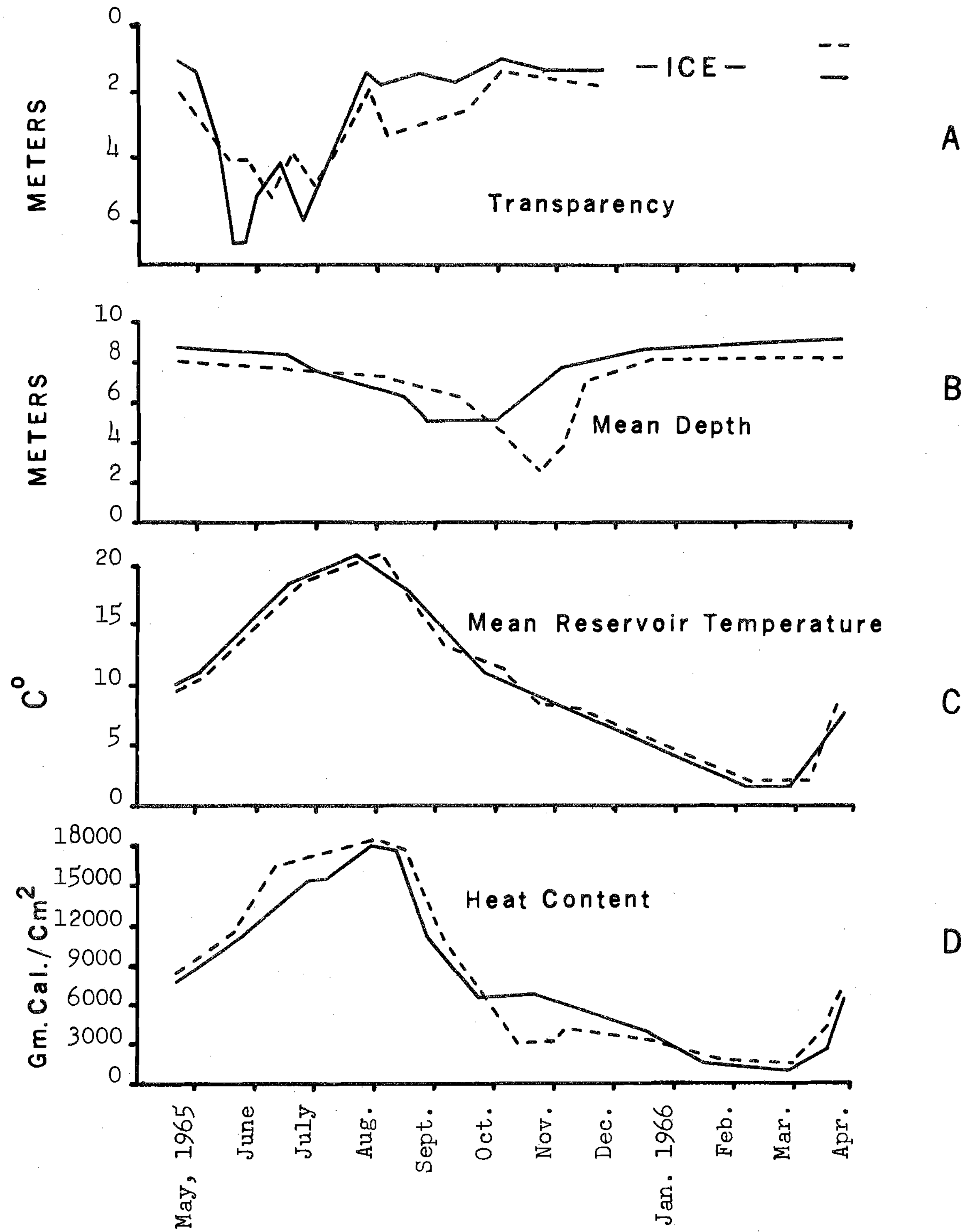


Figure 5. Physical features of Deep Creek and Crowthers Reservoirs from May, 1965 to April, 1966. Solid line represents Deep Creek Reservoir. Broken line represents Crowthers Reservoir.

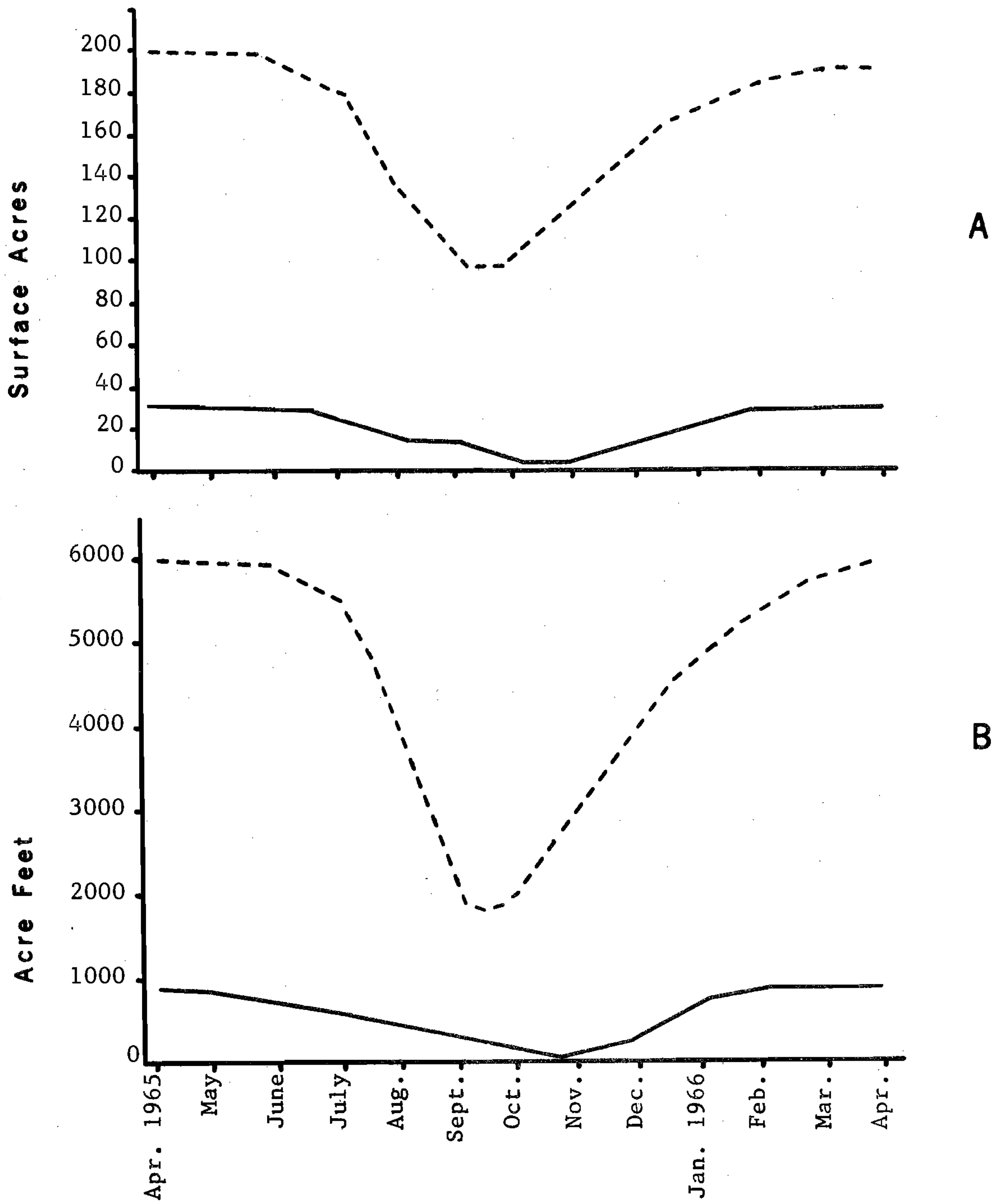


Figure 6. Area and volume fluctuations in Deep Creek and Crowthers Reservoirs from April, 1965 to April, 1966. Broken line represents Deep Creek Reservoir and solid line represents Crowthers Reservoir.

remained stratified until about August 24, followed by the fall overturn which produced homothermous temperatures until the formation of ice. Inverse stratification occurred during the winter months. Surface water temperature of both reservoirs ranged from 1 C in the winter to near 25 C during the middle of August. The mean reservoir temperature varied from 2 C to 21 C, reaching maximum values in August (Figures 5-C, 7, 8).

Heat content varied from 1,800 to 17,000 cal/cm^2 in Deep Creek Reservoir and from 2,000 to 18,000 cal/cm^2 in Crowthers. The highest heat content in both reservoirs occurred in August and the lowest during March (Figure 5-D). I found the annual heat budget to be 15,233 cal/cm^2 in Deep Creek Reservoir and 15,544 cal/cm^2 in Crowthers.

B. Chemical Features

1. Nitrate and Phosphate

One water sample from each reservoir was sent to the U.S. Geological Survey for complete chemical analysis (Table 2). Especially important are the values for nitrate (1.2 ppm for Deep Creek Reservoir and 9.2 ppm for Crowthers) and phosphate (0.07 ppm for Deep Creek Reservoir and 0.37 ppm for Crowthers).

2. Dissolved Oxygen

Dissolved oxygen in the surface water ranged from 4.5 to 12.0 ppm in Deep Creek Reservoir and 5.6 to 10.2 ppm in Crowthers

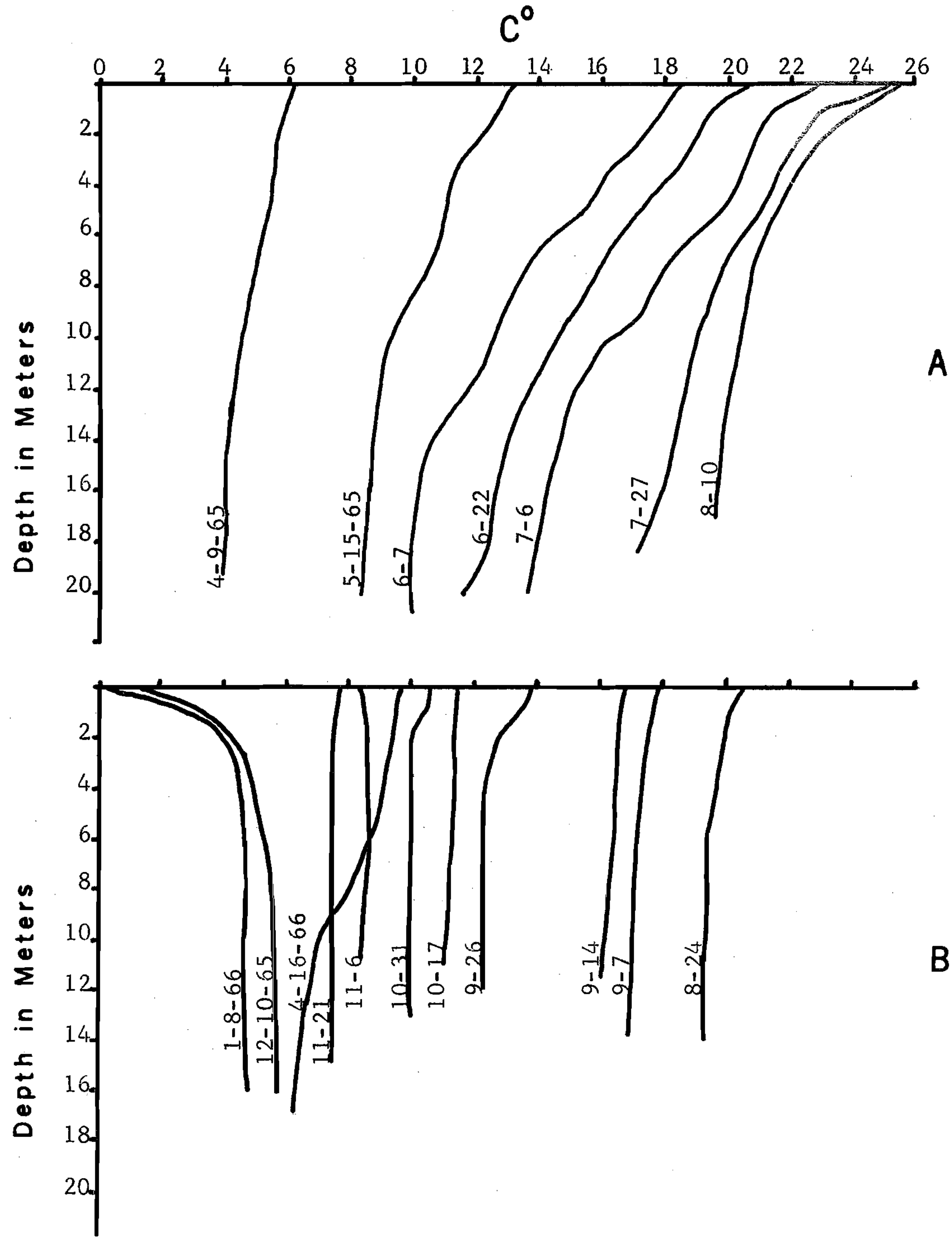


Figure 7. Water temperature profiles from selected dates in Deep Creek Reservoir.

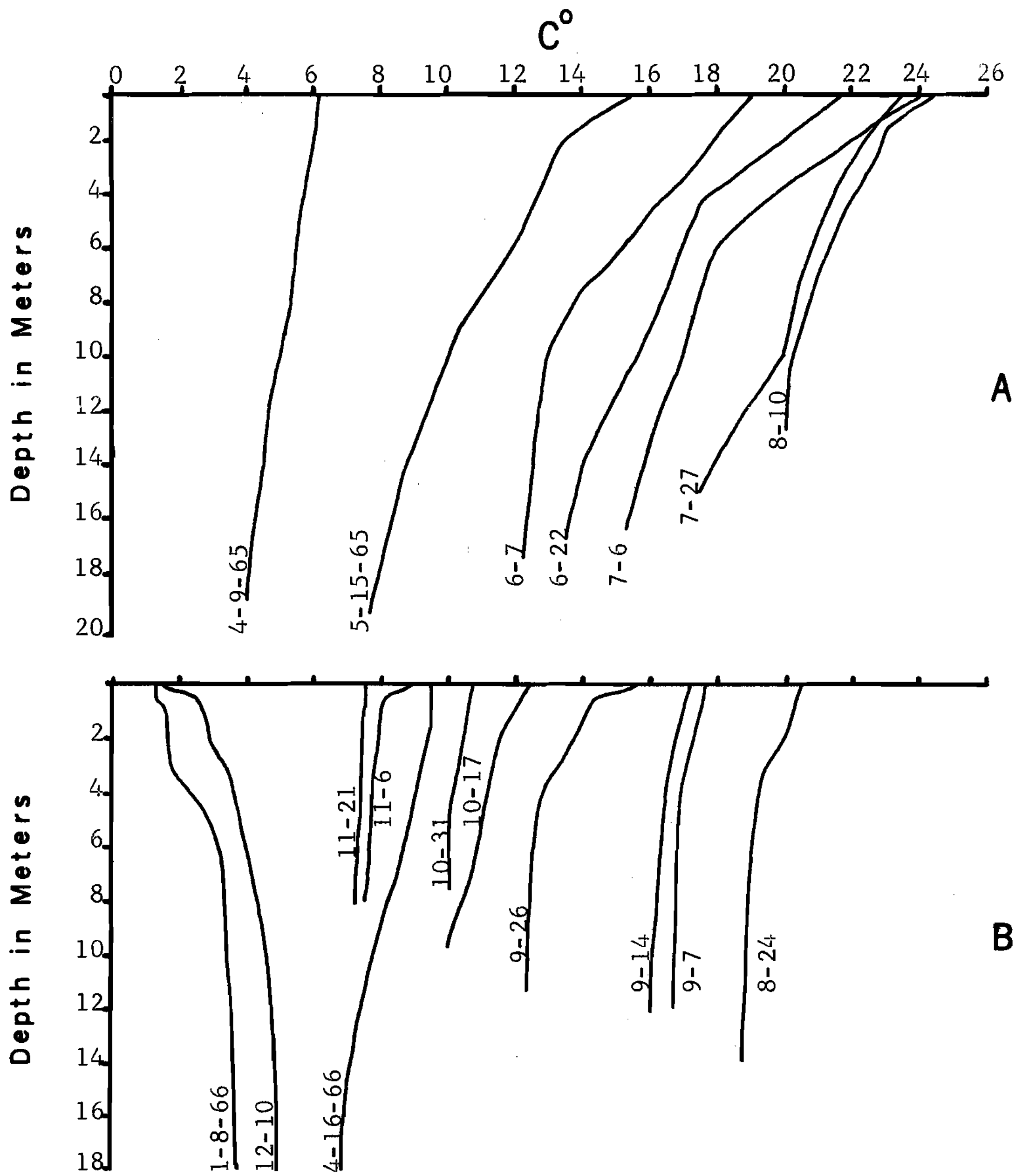


Figure 8. Water temperature profiles from selected dates in Crowthers Reservoir.

Table 2. Chemical analysis of Deep Creek and Crowthers Reservoirs.* Determined by the U.S. Geological Survey, Water Quality Board.

FEATURE	DEEP CREEK RESERVOIR	CROWTHERS RESERVOIR
Calcium (ppm)	49	57
Magnesium (ppm)	9.2	14
Potassium (ppm)	4.4	4.6
Silica (ppm)	14	17
Sodium (ppm)	13	15
Bicarbonate (ppm)	188	216
Carbonate (ppm)	0	4
Chloride (ppm)	14	21
Fluoride (ppm)	0.2	0.2
Nitrate (ppm)	1.2	9.2
Phosphate (ppm)	0.07	0.37
Sulfate (ppm)	18	15
Dissolved Solids (ppm)	215	263
Hardness as $CaCO_3$ (ppm)	160	198
Noncarbonate (ppm)	6	14
pH	8.1	8.4
Specific Conductance (micromhos)	365	440

* Collected May 15, 1965 at depth of one meter.

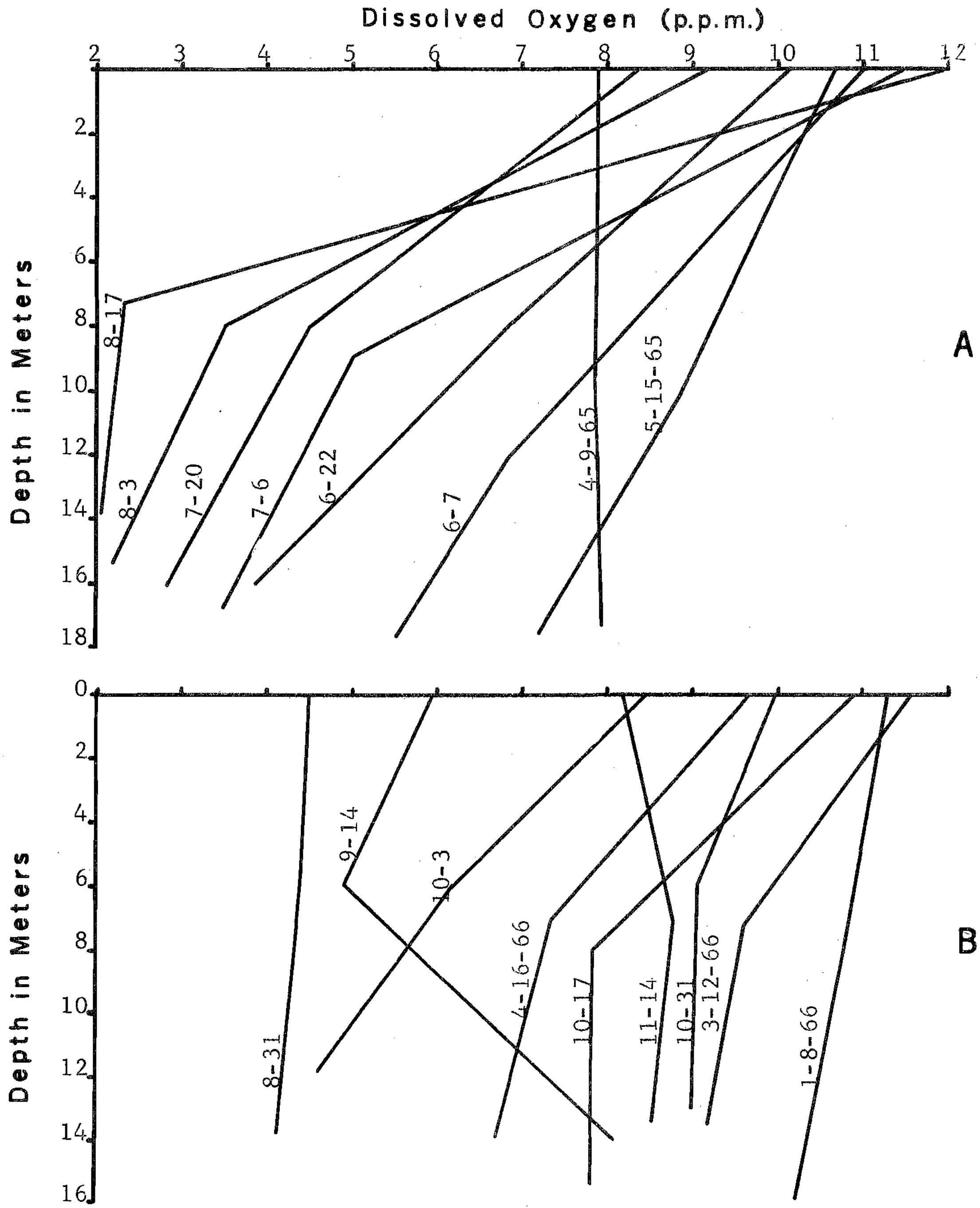


Figure 9. Dissolved oxygen profiles from selected dates for Deep Creek Reservoir.

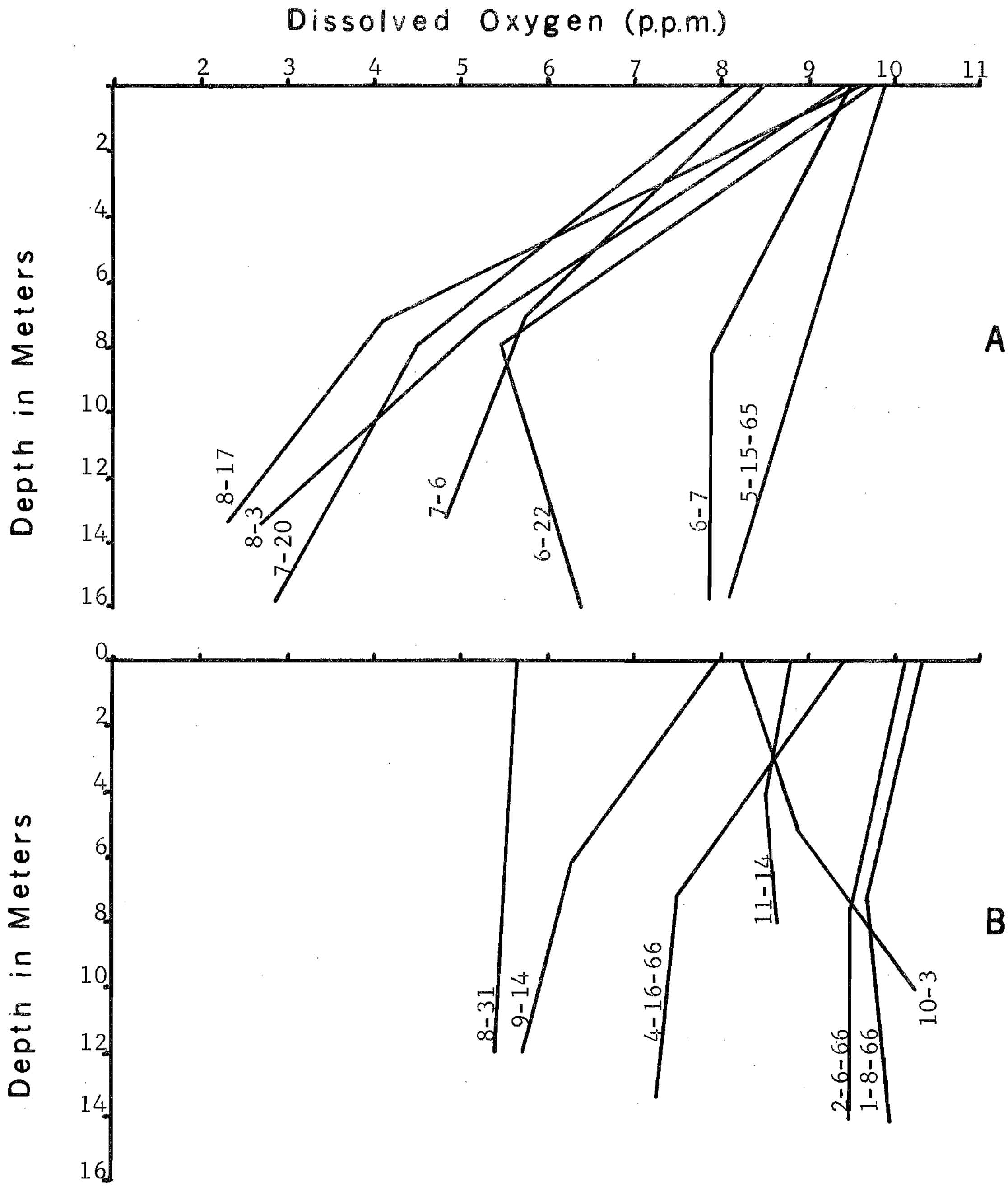


Figure 10. Dissolved oxygen profiles from selected dates for Crowthers Reservoir.

(Figures 9, 10). Values near the bottom varied from 2.0 to 9.5 ppm in Deep Creek Reservoir and from 2.5 to 10.2 ppm in Crowthers. Dissolved oxygen became increasingly stratified in both reservoirs from May to August. Maximum stratification occurred about August 17, when oxygen content ranged from 12 to 2 ppm (surface and bottom respectively) in Deep Creek Reservoir and from 10 to 2.5 ppm in Crowthers. During the following week the fall overturn caused near homogeneous oxygen content in both waters. A slight amount of oxygen stratification occurred in the winter. Percent saturation of dissolved oxygen ranged from near 120% at the surface to 20% at the bottom in each reservoir. Both high and low values occurred during August.

3. Alkalinity and Specific Conductance

Total alkalinity ranged from 140 to 170 ppm in Deep Creek Reservoir and from 175 to 650 ppm in Crowthers (Figures 11-D and 12-D).

Surface carbonates reached peaks in July, October and February (Figures 11-B and 12-B). Bottom pehnolphthalein alkalinity readings were nonexistant except for a short period in May and during the fall months.

Specific conductivity readings were highest in Crowthers Reservoir (380-650 micromhos at 25 C). Readings in Deep Creek Reservoir ranged from 325 to 430 micromhos at 25 C. Peaks were reached during October in Crowthers and January in Deep Creek Reservoir (Figures 11-E and 12-E). There was little variance with depth.

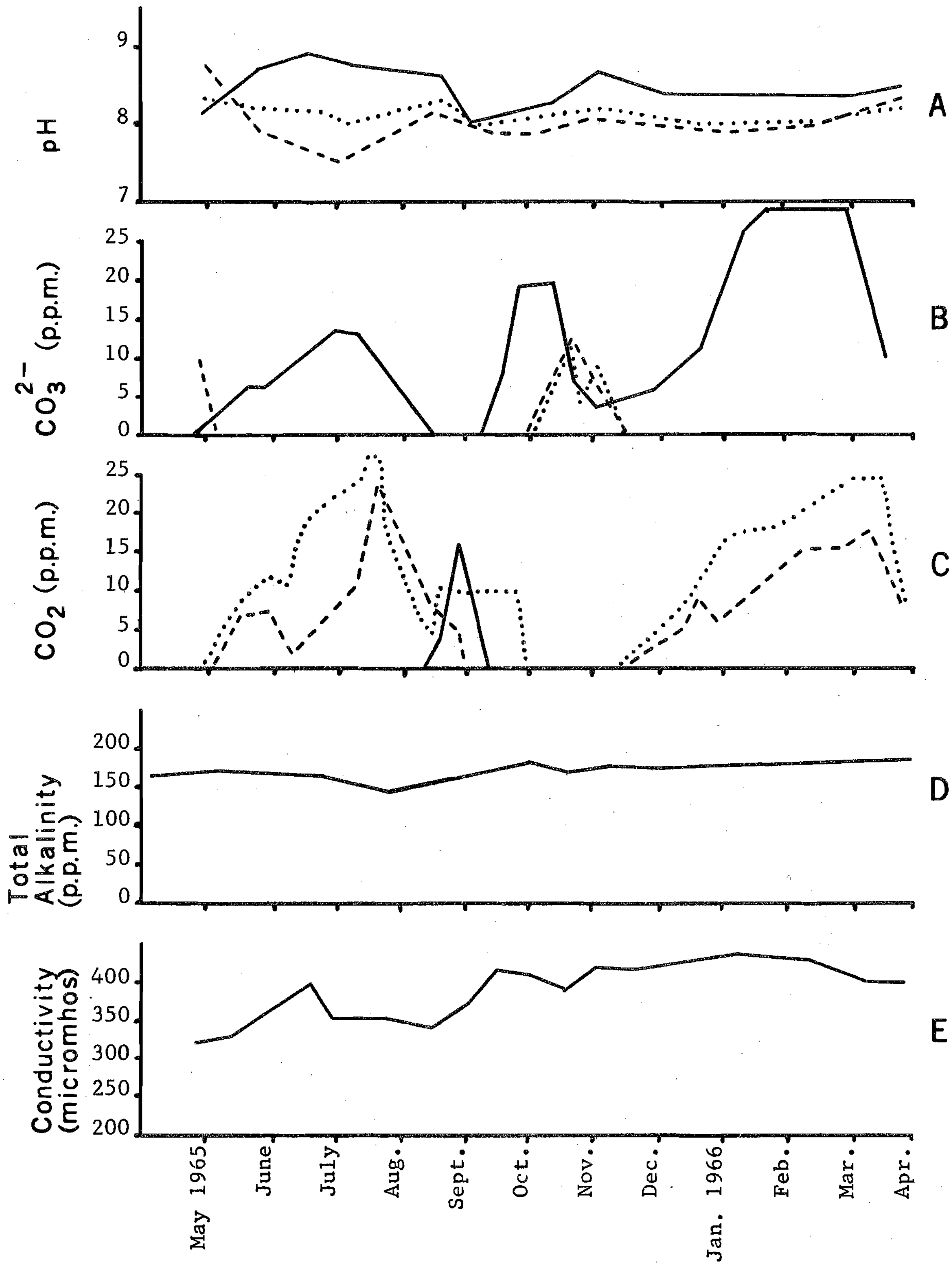


Figure 11. Selected chemical features in Deep Creek Reservoir during study period. Solid line represents surface samples, broken line represents midway samples and dotted line represents bottom samples. Samples were averaged for alkalinity and conductivity values.

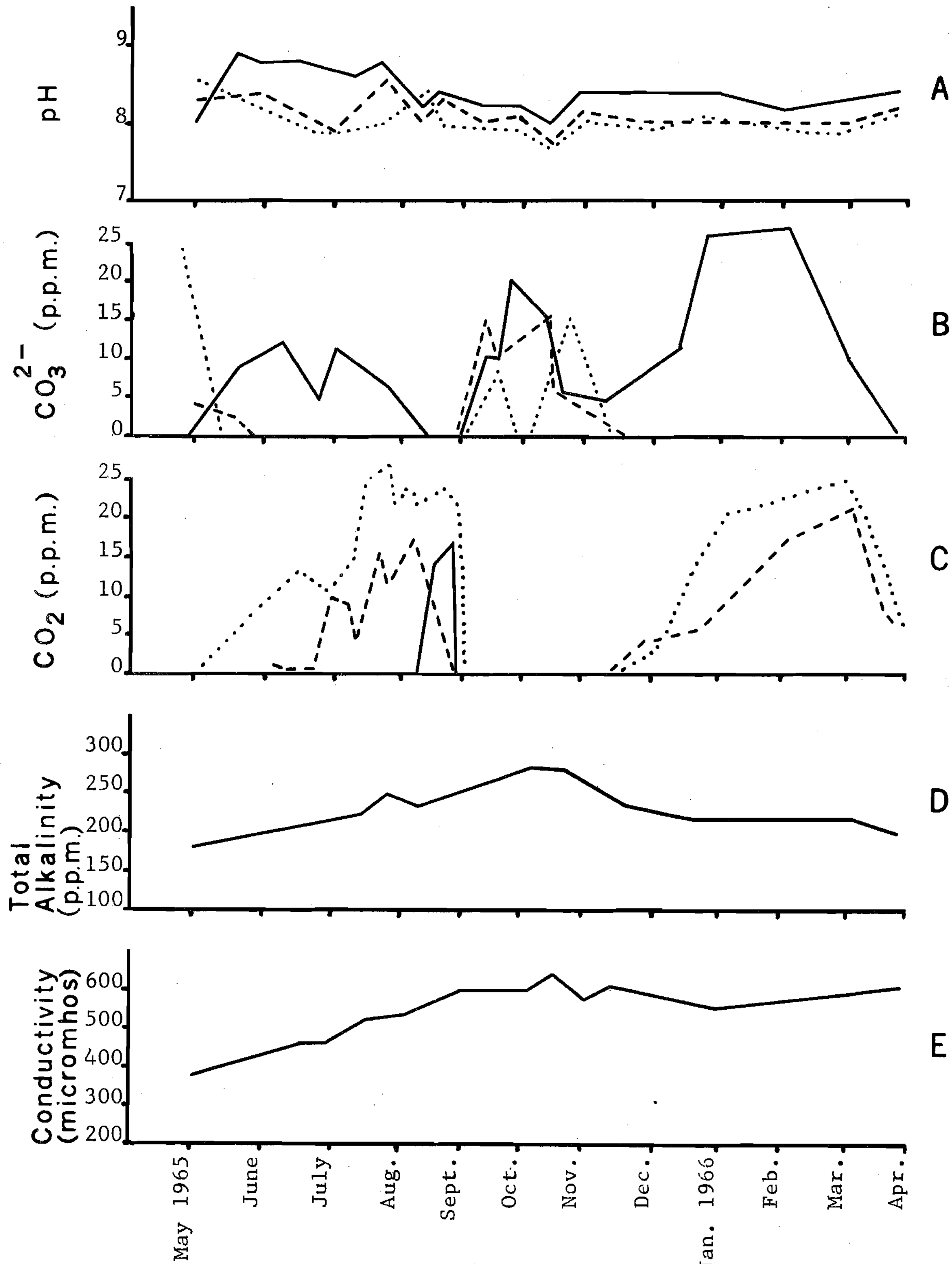


Figure 12. Selected chemical features in Crowthers Reservoir during study period. Solid lines represent surface samples, broken lines represent midway samples and dotted lines represent bottom samples. Samples were averaged for alkalinity and conductivity values.

4. Carbon Dioxide and Hydrogen Ion Concentration

Carbon dioxide was present at the surface only for a short period during the first part of September. It reached peaks at the bottom during August and again during the winter months (Figures 11-C and 12-C).

Highest pH readings occurred during the early summer months (Figures 11-A and 12-A). The pH ranged from 7.7 to 8.9 in Crowthers and from 7.5 to 8.9 in Deep Creek Reservoir. Values were generally higher at the surface than the bottom.

C. Primary Production

The mean primary production rates of nannoplankton using Carbon-14 were 9.9 mg $C/m^3/hr$ for Crowthers and 6.7 mg $C/m^3/hr$ for Deep Creek Reservoir (Table 3). Values ranged from 1.9 to 10.2 in Deep Creek Reservoir and from 1.8 to 22.6 in Crowthers.

D. Zooplankton and Organic Weight

1. Cladocera

Cladoceran species found in Deep Creek Reservoir were *Daphnia pulex* and *Daphnia rosea*. *D. pulex* was predominant. *D. rosea* appeared only during the summer months. *D. pulex* was the only cladoceran present in Crowthers.

Population peaks of Cladocera occurred several times in both

Table 3. Primary productivity measurement in Deep Creek and Crowthers Reservoirs using Carbon-14.* Expressed as milligrams of Carbon per cubic meter per hour.

EXPOSURE DATE	RESERVOIR				WEATHER CONDITIONS DURING EXPOSURE	WATER TEMPERATURE DURING EXPOSURE C^o	
	Deep Creek Reservoir		Crowthers Reservoir				
	STATION		STATION				
	1	2	1	2		Deep Creek Res.	Crowthers Res.
5-15-65	5.6	5.8	6.0	2.3	25% Cloudy	13^o	15^o
6-7-65	6.3	8.2	6.0	7.5	30% Cloudy	18^o	19^o
6-22-65	1.3	1.9	1.8	2.1	80% Cloudy - Rain	20^o	21^o
7-6-65	10.0	10.2	22.6	6.2	Clear	23^o	24^o
7-20-65	4.9	10.1	15.3	1.9	30% Cloudy	24^o	23^o
8-17-65	5.0	2.6	20.0	20.2	80% Cloudy - Rain	22^o	23^o
8-24-65	6.0	15.7	12.8	NS**	50% Cloudy	21^o	21^o
Mean Value	5.6	7.8	12.1	7.7			
Mean of stations one and two	6.7		9.9				

* One dark bottle and one light bottle were exposed for approximately 5 hours at each station at a depth of 18 inches.
** No sample taken.

reservoirs during the summer and fall months (Figure 13-A and Table 4). Counts were greatest in Deep Creek Reservoir during November (65 per liter). The greatest concentration in Crowthers Reservoir occurred during August (45 per liter). Mean annual counts were highest in Deep Creek Reservoir, 18.7 per liter, compared to 11.7 per liter in Crowthers.

2. Copepoda and Nauplii

Cyclops bicuspidatus thomasi and *Diaptomus tyrelli* were the copepod species found in Deep Creek Reservoir. *C. bicuspidatus thomasi* was most abundant. *D. tyrelli* was present in the samples only during the summer. *C. bicuspidatus thomasi* and *Diaptomus coloradensis* were found in Crowthers Reservoir. *D. coloradensis* was the dominant species throughout the year.

Large pulses of copepods occurred during May, October and November in Deep Creek Reservoir (Figure 13-B and Table 4). Numbers reached 500 per liter during October. Smaller pulses were recorded during May and August in Crowthers Reservoir (100 per liter and 75 per liter respectively).

Numbers of nauplii were consistantly higher in Deep Creek Reservoir with pulses of about 200 per liter in May and 350 per liter during August (Figure 13-C and Table 4). Smaller pulses occurred in Crowthers Reservoir, with a maximum of 75 per liter in July.

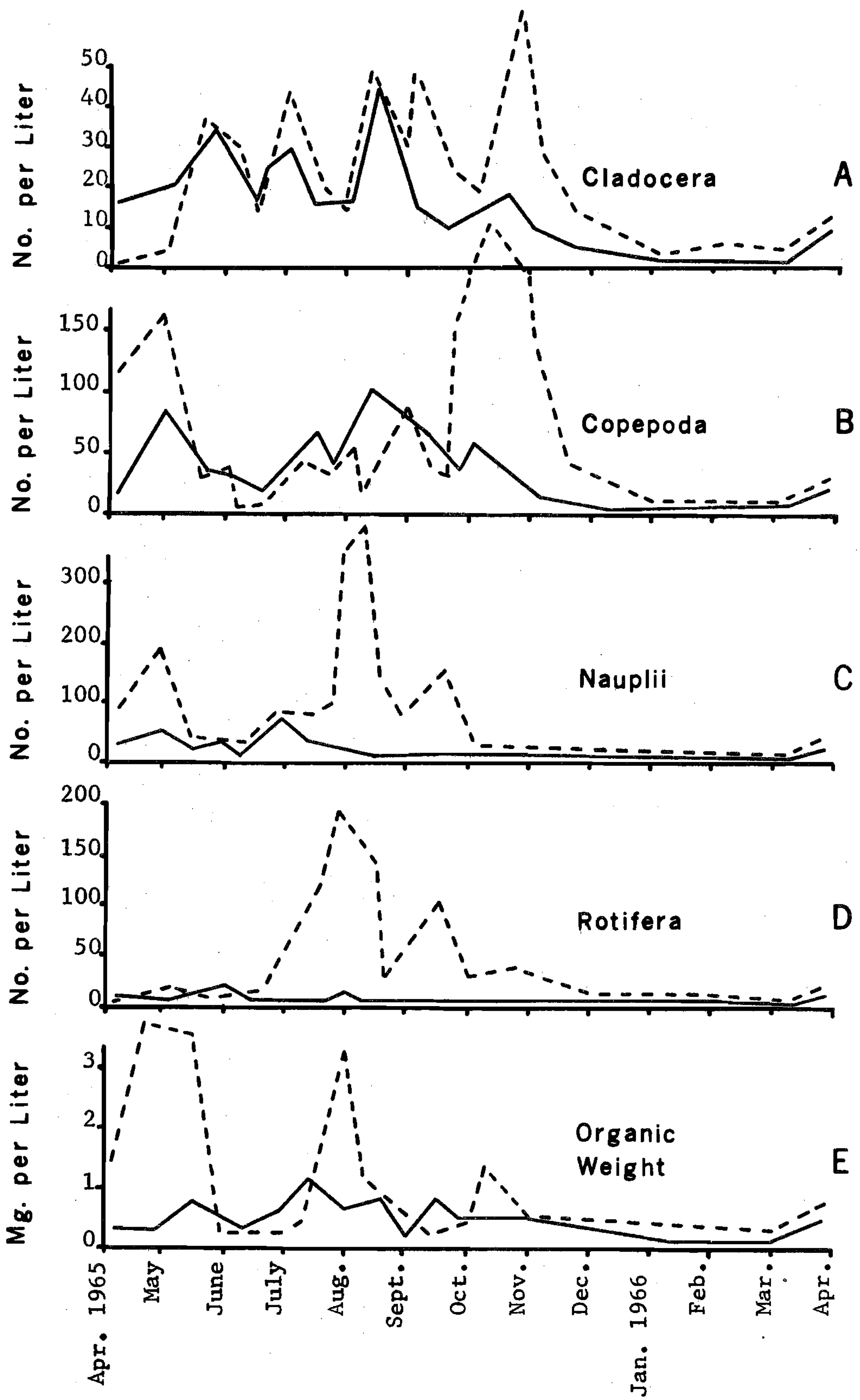


Figure 13. Zooplankton standing crop and organic weight in Deep Creek and Crowthers Reservoirs during study period. Solid line represents Crowthers Reservoir. Broken line represents Deep Creek Reservoir.

3. Rotifera

Rotifera species found in Deep Creek Reservoir were *Keratella quadrata*, *Keratella cochlearis*, *Asplancha priodonta* and *Polyarthra* sp. I found only *K. quadrata* and *A. priodonta* in Crowthers Reservoir.

A pulse of approximately 200 rotifers per liter (mostly *Polyarthra* sp.) was observed during August in Deep Creek Reservoir. Another pulse of 100 per liter (mostly *Asplancha* sp.) was recorded during October. Rotifera were found in fewer numbers (5-10 per liter) in Crowthers Reservoir.

4. Organic Weight

Net organic weight included all organic material collected with a No. 20 plankton net. This included detritus and larger algae cells together with the zooplankton. Algal blooms were observed in both reservoirs during the summer. A bloom of *Aphanizomenon flos-aquae* and *Ceratium hirudinella* appeared in Deep Creek Reservoir about July 27 and lasted until September 15. A bloom of *Microcystis flos-aquae* and *Microcystis aeruginosa* occurred in Crowthers Reservoir during the same period. Peaks of organic weight occurred during May and August in Deep Creek Reservoir, reaching a maximum of 3.5 mg per liter during August (Figure 13-E and Table 4). Values for Crowthers Reservoir remained relatively constant during the summer, reaching a maximum of about 1 mg per liter during the middle of July.

Table 4. Monthly and annual average zooplankton and organic weight per liter in Deep Creek and Crowthers Reservoirs.*

	CLADOCERA		COPEPODA		NAUPLII		ROTIFERA		ORGANIC WT.	
	Deep Cr. Res.	Crowthers Res.	Deep Cr. Res.	Crowthers Res.	Deep Cr. Res.	Crowthers Res.	Deep Cr. Res.	Crowthers Res.	Deep Cr. Res.	Crowthers Res.
May 1965	5	5	177	79	181	52	4	2	5.60	.42
June	27	26	17	23	25	23	7	17	1.40	.40
July	31	18	47	42	75	60	57	3	.88	.43
Aug.	27	21	36	69	276	22	118	7	2.00	.87
Sept.	31	17	50	69	88	18	119	3	1.00	.55
Oct.	21	9	241	58	90	10	40	3	.76	.46
Nov.	38	10	169	20	26	2	22	3	.99	.76
Dec.	6	3	17	6	8	2	4	1	.61	.46
Jan. 1966	3	5	10	5	2	0	1	3	.55	.51
Feb.	7	4	8	7	1	0	2	1	.55	.31
Mar.	5	5	7	6	1	0	0	0	.48	.26
Apr.	11	9	8	16	1	0	1	2	.68	.32
Average	18.7	11.7	69.9	35.8	69.6	17.0	33.7	4.0	.84	.48

* Zooplankton expressed as number per liter. Organic weight expressed as mg. per liter.

DISCUSSION

Deep Creek and Crowthers Reservoirs have widely fluctuating water levels, typical of small reservoirs in this area. After filling during the winter months they are drained in the summer as demand for irrigation water is increased. Extreme drawdown of water level during the late summer no doubt affects the spatial relationships of aquatic organisms. Results of the drawdown may produce erroneous conclusions in terms of productivity. For example, increase in standing crop during late summer may be due in part to concentration of organisms rather than increased production rate. The degree to which standing crop is affected by water level fluctuation appears difficult to assess, but may be substantial.

Both reservoirs exhibit seasonal thermal characteristics which would classify them as dimectic lakes, which have spring and fall turnovers typical of the temperate zone (Hutchinson, 1957). They could also be termed eutrophic lakes, which are characterized by being rich in nutrients, exhibiting a hypolimnetic loss of oxygen during the summer and having low transparency during the summer and fall (Reid, 1961).

Temperature profiles indicate only weak thermal stratification during the summer. A definite temperature gradient did exist, but the classic zones (epilimnion, metalimnion and hypolimnion) were not clearly defined. This may have been caused by a combination of two factors.

First, occasionally strong wind, typical of the region, may tend to prevent stratification from forming by continually mixing the water. Ruttner (1964) points out that spring winds may inhibit stratification until the entire lake is warmed. Secondly, the continual discharge of water from the hypolimnion tends to lower the metalimnion as cold water is withdrawn from the bottom. This results in continually warmer water on the bottom which may weaken the thermal stratification.

Temperature profiles taken during the summer in small fluctuating reservoirs may be misleading if they are to represent classic summer stratification. Enough water was withdrawn from the hypolimnion in Deep Creek and Crowthers Reservoirs to affect thermal stratification, but decomposition on the bottom was great enough to continually deplete the water of oxygen, resulting in a period of "summer stagnation".

Gorman (1964) and Reimers (1955) explain that annual heat budgets are controlled by the mean depth of lakes in the temperate zone, rather than by temperature differences. This appears to be only partially true in Deep Creek and Crowthers Reservoirs. Data shown in Figure 5 indicate more correlation between heat content and mean temperature than between heat content and mean depth. An exception to this occurred in November when the mean depth in Crowthers Reservoir dropped rapidly, also lowering the heat content. It was observed that heat content varied directly with mean temperature, affected only by extreme fluctuations in mean depth.

The annual heat budgets for both reservoirs were approximately the same, about 15,000 cal/cm^2. This compares with 65,000 cal/cm^2 in Lake Baikal, 23,500 in Lake Mendota (Reid, 1961), and 4,117 in a high mountain lake (Falter, unpublished).

Deep Creek and Crowthers Reservoirs are considered hard water lakes containing over 40 ppm bound carbon dioxide (Welch, 1952). This amount is also considered an optimum concentration for productivity (Moyle, 1946).

Free carbon dioxide followed the classic pattern in both reservoirs, reaching maximum values on the bottom during summer and winter. Free carbon dioxide was absent during the fall months as water was mixed by the fall turnover. This is believed to be due to carbon dioxide combining with water to form carbonic acid, which dissociates to form bicarbonates in the presence of calcium carbonate.

Specific conductance, which indicates ion concentration in the water, is related to total alkalinity (Hem, 1959). There is a positive correlation between hardness and conductivity in both reservoirs.

Nitrate and phosphate samples, although limited, may give some indication of productivity. Moyle (1946) points out that nitrate and phosphate may be important limiting factors in fresh water production. Reid (1961) found that the world average of nitrate in unpolluted fresh water is 0.30 ppm. Both reservoirs were above this figure (1.2 in Deep Creek Reservoir and 9.2 in Crowthers). It has been shown

(Reid, 1961) that the mean phosphate content of most lakes ranges from about 0.01 to 0.03 ppm. Deep Creek Reservoir had a value of 0.07 and Crowthers Reservoir had an extremely high value of 0.37 ppm. These high concentrations of nitrate and phosphate in the reservoirs may be explained by noting agricultural activities in the area. Nitrate and phosphate may have been leached from soil in the drainage areas which have been fertilized. Hem (1959) points out that fertilization of soil around lakes may add large amounts of nitrate and phosphate to the water. The high amount of nitrate in Crowthers Reservoir may be due in part to numerous cattle feed lots which drain into the influent. This eutrophication was not apparent in the Deep Creek drainage.

Carbon-14 has been widely used as a measurement of primary productivity since its introduction by Steeman-Nielsen (1952). For this study productivity of only nannoplankton was measured. It is believed that nannoplankton constitute a large portion of the primary productivity in lakes and is the major constituent of food for zooplankton (Ruttner, 1963). Verduin (1956) found that after filtering lake water through the finest bolting cloth, 65% of the photosynthetic activity was in the filtrate. Rodhe (1958) also found that the rate of photosynthesis in lake water samples was more closely related to the numbers of nannoplankton than with the numbers of plankton retained by the plankton net. As Fogg (1965) mentions, this is probably because of the high surface to volume ratio in the smaller forms, allowing more activity per unit mass of cell material than the algae retained by a net.

Mean primary productivity rates of nannoplankton in Deep Creek and Crowthers Reservoirs for the summer were 6.7 and 9.9 mg C/m^3/hr respectively. Assuming that nannoplankton contribute 50% of the primary productivity of phytoplankton (see above paragraph), average values of 13 and 20 mg C/m^3/hr indicate high productivity rates in both reservoirs. Knight (1962) found mean values ranging from 5.5 to 15.0 mg C/m^3/hr in four ponds in Michigan. He felt that these ponds were relatively productive. In a study of a lava sink pond in southeastern Idaho, Mollmer (unpublished) found values between 0.07 and 1.9 for nannoplankton. Falter (unpublished) found values ranging from 2.6 to 15.5 in high mountain lakes of Montana.

The 15% difference between the two reservoirs may be only slightly significant. Goldman (1963) states that experimental error may account for about 8% of the difference. The higher primary production rate in Crowthers Reservoir may be due to increased eutrophication as mentioned above.

Experiments by Pennington (1941) have demonstrated that zooplankton may have striking effects on the numbers of phytoplankton. Although enumeration of phytoplankton was not made in this study, it is believed that "grazing" by zooplankton on nannoplankton may account for an undetermined difference in primary production rates.

Studies by Carl (1940) and Pennak (1957) give evidence that a genus of Copepoda or Cladocera is seldom represented by more than one species in one body of water. This pattern was followed with Copepoda, but not with Cladocera. Only one species of Daphnia was found in Crowthers Reservoir, but two species were present in Deep Creek Reservoir. It should be noted though, that D. rosea showed up only occasionally in Deep Creek Reservoir.

It is interesting to note that a different genus of Copepoda was dominant in each reservoir (Cyclops in Deep Creek Reservoir and Diaptomus in Crowthers). This may be due to a difference in feeding habits, as Cyclops has mouth parts modified for seizing small plants and animals and Diaptomus is adapted for filtering living and dead particulate material (Pennak, 1963). Perhaps the larger Rotifera population in Deep Creek Reservoir provided more available food for Cyclops, whereas only particulate material was available in Crowthers Reservoir.

The importance of studying plankton on an annual basis is emphasized by Pennak (1949) when he states that in order to gain an adequate concept of the standing crop of plankton in a lake, sampling should be on a year around basis rather than on summer samples only. As Rawson (1953) points out, the standing crop of net zooplankton may still not be an adequate measure of production rate, but should be regarded as a balance on hand. Although standing crops may be the same in two bodies of water, rates of production may be different because of an unknown amount of predation, and different turnover rates between species.

Standing crop of zooplankton was relatively high in both reservoirs when compared to other lakes of comparable size. In a study of small lakes in Wisconsin, Pennak (1949) found mean annual averages of zooplankton to be about the same as I found in Deep Creek and Crowthers Reservoirs. He concluded that these lakes were relatively productive.

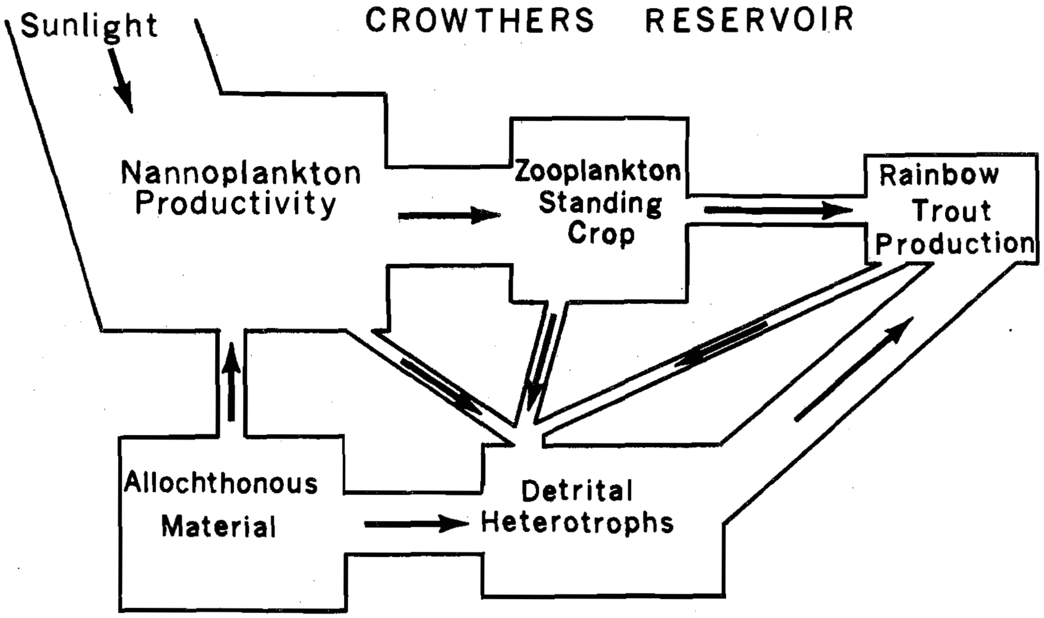
Mean annual organic weight in Deep Creek and Crowthers Reservoirs was slightly less than the lakes studied by Pennak. This may be due to a difference in phytoplankton and organic detritus which may constitute a large portion of the organic weight. Rawson (1953) points out that determination of organic weight is sometimes difficult because of large amounts of allochthanous material. The pulses of organic weight during May and August in Deep Creek Reservoir are believed a result of detritus and blooms of *Ceratium* and *Aphanizomenon*.

Pulses of Cladocera and Copepoda in the fall months may have resulted from increased nutrients caused by decomposition of algae blooms. Edmondson (1957) explains that certain algae such as *Aphanizomenon* is unsuitable as food for zooplankton but after decomposition of the algae blooms, the resulting debris and microbial population may provide ample food. Salmanov (1964) has found that bacteria may be an important constituent in the diet of zooplankton.

Predation by fish may have affected the standing crop of zooplankton in Deep Creek Reservoir. Galbraith (1967) has found that populations of *Daphnia* may be drastically reduced by fish predation, provided that the Daphnia are of large size (1.3 mm or more). It was found that the average size of D. pulex in both reservoirs was above this. D. rosea was found to average slightly below 1.3 mm. In a related study involving trout growth and fish stomach analysis, Miller and Rabe (in press) found that Cladocera made up 93% of the stomach contents of trout in Deep Creek Reservoir, compared to 15% in Crowthers Reservoir. It is believed that the standing crop of Cladocera in Deep Creek Reservoir would have been more if it had not been preyed upon so extensively by fish. It was also interesting to note that no Copepoda were found in the trout stomachs, suggesting that the trout either fed selectively on Cladocera or that the Copepoda were too small to be filtered out by the trout.

Although the study was not designed to investigate trophic levels in terms of energy transformations, the reservoirs as ecosystems may be better understood by applying the available information to a modified energy flow diagram (Figure 14, modified from Odum, 1959; 1963). The diagram is not drawn to scale, but the size of the trophic levels are roughly proportional to each other. Specific flow data or energy transfer from one level to another is not available but is shown by directional arrows.

The simplified diagram indicates that primary productivity of nannoplankton was slightly higher in Crowthers Reservoir (based on Carbon-14 data). Allochthonous material is represented by both organic and inorganic substances. It is believed that Crowthers



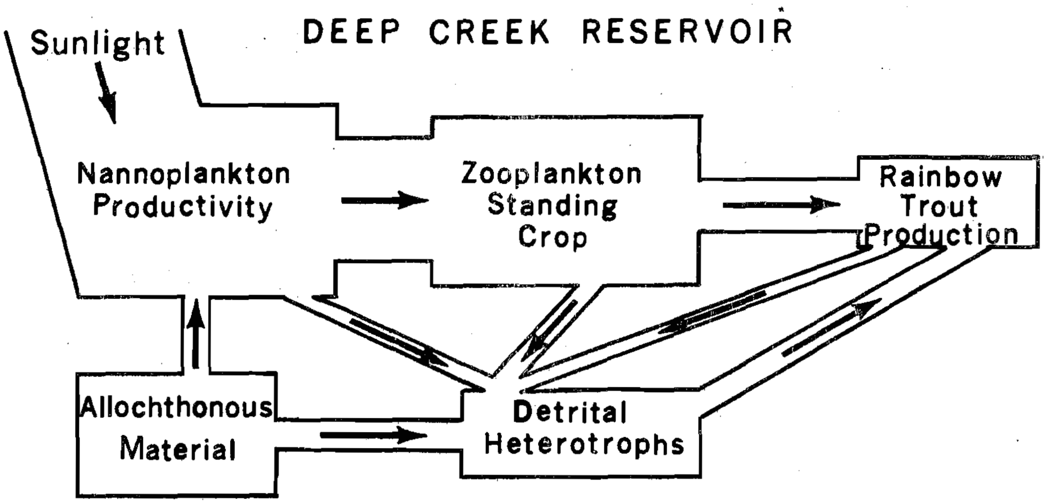


Figure 14. A simplified energy flow diagram indicating relationships of some trophic levels in Crowthers and Deep Creek Reservoirs. Arrows show direction of energy flow. Magnitude of energy flow is only relatively quantitative, based on collected data and observations.

Reservoir received more material from outside sources because of runoff from cattle feed lots and fertilized fields. This material possibly provided nutrients for nannoplankton and for the detrital heterotrophs. Quantitative data (Table 4) indicates that Deep Creek Reservoir had a higher mean standing crop of zooplankton. It is assumed that more energy flowed from nannoplankton to zooplankton in Deep Creek Reservoir than in Crowthers Reservoir. In reality this would be difficult to substantiate because zooplankton may feed on substances other than nannoplankton and because the standing crop of zooplankton may not be a reflection of the production rate, as indicated above. I believe that the standing crop of detrital heterotrophs was highest in Crowthers Reservoir. This is based on the following information: 1. A related study (Miller and Rabe, in press) has shown that Rainbow Trout stomachs in Deep Creek Reservoir contained mostly zooplankton whereas those in Crowthers Reservoir contained mostly detrital heterotrophs such as leeches and snails. 2. Deep Creek Reservoir contained large populations of Suckers and Cutthroat Trout which probably kept the bottom depleted of detrital heterotrophs. Therefore energy flow from zooplankton to trout was probably highest in Deep Creek Reservoir and energy flow from detrital feeding organisms to trout was highest in Crowthers Reservoir. The total energy flow to Rainbow Trout was believed highest in Crowthers Reservoir because of the higher assimilation rate of trout (based on the related study by Miller and Rabe). This could lead to erroneous conclusions regarding fish production though, because although the growth rate of Rainbow Trout was highest in Crowthers Reservoir, total fish production was not known because of large populations of Suckers and Cutthroat Trout in Deep Creek Reservoir. The total assimilation of organic matter per unit area by fish in Deep Creek Reservoir could have exceeded that in Crowthers Reservoir where Suckers were absent. It is difficult to determine which reservoir was the most "productive" because each reservoir was better represented by different trophic levels.

SUMMARY

Some limnological aspects of two small southeastern Idaho reservoirs were studied for one year. The reservoirs selected were Deep Creek Reservoir and Crowthers Reservoir which have maximum areas of 200 and 32 acres respectively.

Chemical and physical features of the water were determined using standard limnological methods. Standing crop of net zooplankton was determined by collecting from six stations in Deep Creek Reservoir and four in Crowthers Reservoir, using a two liter Van Doren bottle. Enumeration of zooplankton was made and organic weight of net plankton determined. Primary production rates of nannoplankton was measured during one summer using Carbon-14 isotope.

Both reservoirs were found to have widely fluctuating water levels. Deep Creek Reservoir dropped from 6,000 to 1,800 acre feet and Crowthers Reservoir from 880 to 120 acre feet.

Surface water temperature in both reservoirs varied from 1° to 25° C during the year. A well defined thermocline did not form in either reservoir. The fall overturn occurred during August in both reservoirs. Ice covered the reservoirs from December to April. Annual heat budgets of 15,233 and 15,544 cal/cm^2 respectively were found for Deep Creek and Crowthers Reservoirs.

Dissolved oxygen remained relatively high in both reservoirs except on the bottom where concentrations dropped to 2 ppm during

the summer. Surface readings were generally over 8 ppm. Total alkalinity was relatively high in both reservoirs, but highest in Crowthers Reservoir. Values ranged from 140 to 170 ppm in Deep Creek Reservoir and 175 to 650 ppm in Crowthers Reservoir. Conductivity readings were likewise high in both waters (over 300 micromhos at 25 C). Both reservoirs were alkaline, with the pH ranging from 7.5 to 8.9. Phosphate and nitrate was high in Deep Creek Reservoir (0.07 and 1.2 ppm respectively) and very high in Crowthers Reservoir (0.37 and 9.2 ppm respectively). The extremely high values in Crowthers Reservoir were believed due to runoff from fertilized fields and drainage from cattle feed lots.

The mean primary production rates of nannoplankton using Carbon-14 were 9.9 mg $C/m^3/hr$ for Crowthers Reservoir and 6.7 mg $C/m^3/hr$ for Deep Creek Reservoir.

Blooms of blue green algae were found in both reservoirs during the summer (*Aphanizomenon* sp. in Deep Creek Reservoir and *Microcystis* sp. in Crowthers Reservoir). A bloom of *Ceratium* sp. appeared with the algae in Deep Creek Reservoir.

Cladocera species were represented by *Daphnia pulex* and *Daphnia rosea* in Deep Creek Reservoir and only *D. pulex* in Crowthers Reservoir. Standing crop of Cladocera was highest in Deep Creek Reservoir with a mean annual count of 18.7 per liter, compared to 11.7 per liter in Crowthers Reservoir.

Copepoda species in Deep Creek Reservoir were *Cyclops bicuspi-*

datus thomasi and Diaptomus tyrelli. C. bicuspidatus thomasi and Diaptomus coloradensis were found in Crowthers Reservoir. Cyclops sp. were dominant in Deep Creek Reservoir and Diaptomus sp. in Crowthers Reservoir. Standing crop of Copepoda was highest in Deep Creek Reservoir (annual mean of 70 per liter, compared to 36 per liter in Crowthers Reservoir).

Rotifera were better represented in Deep Creek Reservoir, averaging 34 per liter compared to 4 per liter in Crowthers Reservoir. Species composition in Deep Creek Reservoir included Keratella quadrata, Keratella cochlearis, Asplancha priodonta and Polyarthra sp. Crowthers Reservoir contained K. quadrata and A. priodonta.

The available information was applied to an energy flow diagram which indicated that each reservoir was best represented by different trophic levels. Crowthers Reservoir had a higher standing crop of detrital heterotrophs whereas Deep Creek Reservoir had a higher standing crop of zooplankton. Because of this it was difficult to determine which reservoir was the most "productive".

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