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Limnological Study of Lower Columbia River, 1967-68

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Limnological Study of Lower Columbia River, 1967-68

By

SHIRLEY M. CLARK and GEORGE R. SNYDER

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ABSTRACT

Limnological data were collected from late July 1967 through December 1968 at seven sampling stations from above the mouth of the Willamette River to below Puget Island. Items studied were: physical (water temperature, turbidity, conductivity, and salinity), chemical (pH, dissolved oxygen, phosphate, silicate, calcium, magnesium, and sodium), and biological (chlorophyll *a* and zooplankton). Dissolved oxygen was lower in 1967-68 than it had been in previous studies in 1954-55 and 1960; water temperature was higher in 1967-68 than in the other two periods.

INTRODUCTION

The Columbia River has been very important to the fishing industry of the Pacific Northwest for more than 100 years. The limnological characteristics of the lower river (from Bonneville Dam to the estuary) are therefore of interest to fishery agencies. Although these characteristics are being altered by hydrological projects, some of the effects of these changes on stocks of fish are not known. A few observations were made in the lower river during 1954-55 (Sylvester, 1958), and an extensive water quality study was made there in 1960 (Sylvester and Carlson, 1961). BCF (Bureau of Commercial Fisheries) made the present limnological survey (July 1967-68) following proposals that thermal nuclear powerplants be installed along the lower river. This report summarizes the data collected on the physical (water temperature, turbidity, conductivity, and salinity), chemical (pH, dissolved oxygen, phosphate, silicate, calcium, magnesium, and sodium), and biological (chlorophyll *a* and zooplankton) conditions.

STUDY AREA

The authors selected seven stations from just above the mouth of the Willamette River to below Puget Island which is above the present extent of salt-water intrusion. The locations of the stations (fig. 1) were:

Station	River kilometer
1	166
2	140
3	135
4	118
5	106
6	78
7	54

The lower Columbia River has four major tributaries within the area studied. The Willamette River (the second largest tributary of the Columbia River) enters just below station 1; Lewis River, at station 2; Kalama River, between stations 3 and 4; and Cowlitz River, between stations 4 and 5. Various creeks and sloughs also flow into the lower Columbia River.

MATERIALS AND METHODS

We collected physical, chemical, and biological data at 3-week intervals from November through March and at 2-week intervals during the rest of the year. Each survey required 2 days; stations 1 through 4 were sampled the first day, and stations 5 through 7 the next. Samples were taken from the middle of the channel at all stations.

Physical Data

BCF personnel measured water temperature, turbidity, conductivity, and salinity at the sampling site. Water temperature was taken near the surface with a laboratory thermometer. Turbidity was measured with a Hach CR Low Range Turbidimeter, Model 1720, and recorded in JTU (Jackson Turbidity

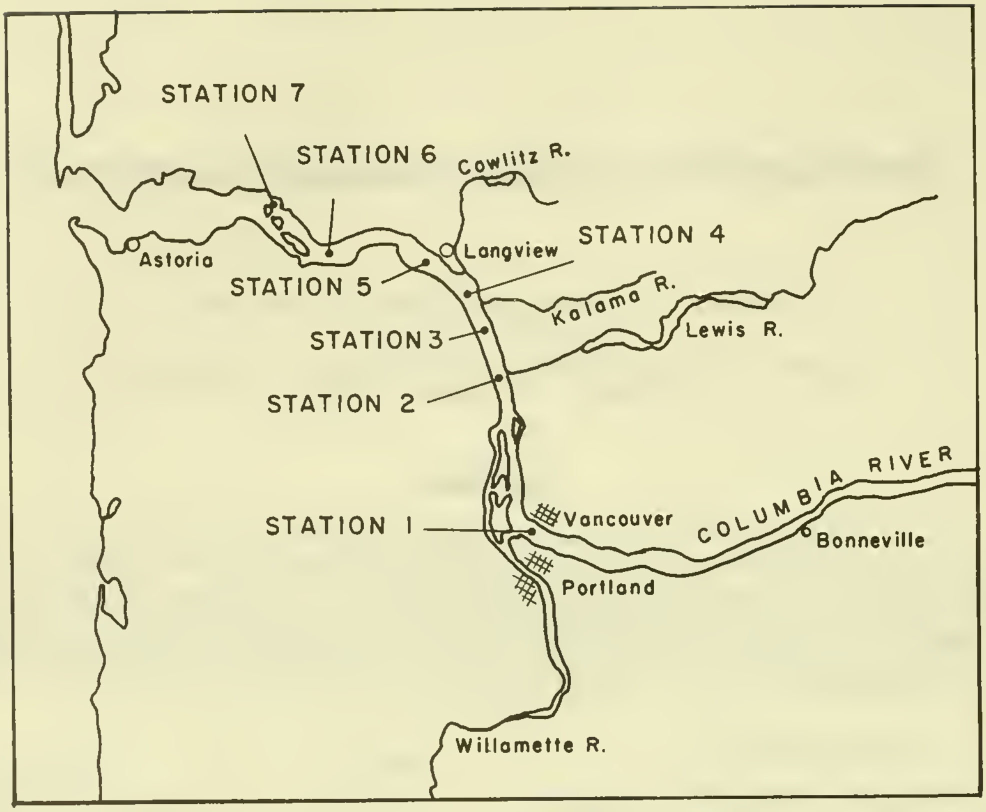

Figure 1.--Sampling stations in the lower Columbia River.

Units.[1] Conductivity and salinity were measured at 3-m. intervals from the surface to 15 m. with a Beckman Model RS 5-3 Portable In-Situ Salinometer.

Chemical Data

pH and dissolved oxygen were measured at the sampling site; other chemical determinations were made in the laboratory. A Beckman Model N pH meter and Hach colorimetric narrow-range pH test kits were used. Dissolved oxygen concentration (determined by the Alsterberg modification of the Standard Winkler Method) and pH were measured only at the surface.

Samples (500-ml.) of surface water were filtered through Millipore HA filters (0.45 μ) at the sampling site. The filtrate was returned to the laboratory in polyethylene bottles for measurements of phosphate, silicate, calcium, magnesium, and sodium concentrations. Total soluble phosphate concentration was determined by a modification of the Hach Meta Phosphate Test and silicate concentration by a modification of the Hach Silicomolybdate Method (Hach Chemical Co., 1967). Calcium and magnesium concentrations were measured on an Atomic Absorption Spectrophotometer Eel 140 by the methods recommended by Evans Electroselenium Limited (no date). Sodium concentration was determined with the Eel Emission Unit.

[1]Trade names referred to in this publication do not imply endorsement of commercial products by the Bureau of Commercial Fisheries.

Biological Data

Chlorophyll a concentration was determined in the laboratory from samples prepared on site by filtering 500-ml. samples of surface water through Millipore HA filters (0.45 μ). The acetone extraction method of Strickland and Parsons (1965) was used with substitution of the equation for chlorophyll a recommended by UNESCO (United Nations Educational, Scientific, and Cultural Ortanization) (1966).

Zooplankton was collected by making 10-m. vertical hauls with a 1/2-m. Nansen-type net, constructed of No. 10 monofilament nylon bolting cloth. The samples were preserved in 5-percent Formalin; the zooplankters were later identified and counted at the laboratory.

LIMNOLOGICAL CHARACTERISTICS, 1967-68

Limnological characteristics of the lower Columbia River varied seasonally and between sampling stations.

The greatest differences between any two adjoining stations were between stations 1 and 2 (tables 1-7). Station 2 was usually higher in

Table 1.--Highest, lowest, and mean values of limnological data at station 1, July 1967 through December 1968

Type of data	Highest	Lowest	Mean
Water temperature (° C.).....	22.6	4.8	14.2
Turbidity (JTU)..............	30+	2.3	7.0
Conductivity (μmhos/cm.).....	480	0	280
Salinity (‰)...............	0.33	0.00	0.18
pH...........................	8.6	7.3	7.9
Dissolved O_2 (p.p.m.)........	12.6	8.3	10.5
Phosphate (p.p.m.)...........	0.35	0.05	0.15
Silicate (p.p.m.)............	17.1	3.2	7.8
Calcium (p.p.m.).............	22	15	18
Magnesium (p.p.m.)...........	7	3.6	5.2
Sodium (p.p.m.)..............	12.1	2.9	6.2
Chlorophyll a (mg./m.^{3})......	32.3	1.9	9.9

Table 2.--Highest, lowest, and mean values of limnological data at station 2, July 1967 through December 1968

Type of data	Highest	Lowest	Mean
Water temperature (° C.).....	23.2	5.5	14.3
Turbidity (JTU)..............	30+	1.4	8.3
Conductivity (μmhos/cm.).....	450	100	250
Salinity (‰)...............	0.32	0.04	0.15
pH...........................	8.6	7.3	7.8
Dissolved O_2 (p.p.m.)........	12.2	8.3	10.4
Phosphate (p.p.m.)...........	0.43	0.03	0.15
Silicate (p.p.m.)............	16.6	3.1	8.0
Calcium (p.p.m.).............	21	11	17
Magnesium (p.p.m.)...........	6	3	4.7
Sodium (p.p.m.)..............	9.5	2.8	5.6
Chlorophyll a (mg./m.^{3})......	28.0	1.7	9.6

Table 3.--Highest, lowest, and mean values of limnological data at station 3, July 1967 through December 1968

Type of data	Highest	Lowest	Mean
Water temperature (° C.)....	22.6	5.1	14.0
Turbidity (JTU).............	30+	1.6	7.9
Conductivity (μmhos/cm.)....	790	150	290
Salinity (‰)..............	0.76	0.06	0.20
pH..........................	8.6	7.3	7.8
Dissolved O_2 (p.p.m.).......	12.1	6.5	10.2
Phosphate (p.p.m.)..........	0.32	0.06	0.15
Silicate (p.p.m.)...........	16.7	3.3	8.2
Calcium (p.p.m.)............	21	13	17
Magnesium (p.p.m.)..........	6.3	3.6	4.8
Sodium (p.p.m.).............	11	2.8	5.8
Chlorophyll a (mg./m.^{3}).....	27.5	1.9	10.1

Table 4.--Highest, lowest, and mean values of limnological data at station 4, July 1967 through December 1968

Type of data	Highest	Lowest	Mean
Water temperature (° C.).....	22.9	5.0	14.2
Turbidity (JTU)..............	30+	1.9	8.0
Conductivity (μmhos/cm.).....	580	120	260
Salinity (‰)...............	0.41	0.07	0.17
pH...........................	8.6	7.3	7.7
Dissolved O_2 (p.p.m.)........	12.1	7.7	10.0
Phosphate (p.p.m.)...........	0.35	0.03	0.15
Silicate (p.p.m.)............	16.1	3.3	8.2
Calcium (p.p.m.).............	19	10	16
Magnesium (p.p.m.)...........	6	3.5	4.7
Sodium (p.p.m.)..............	9.4	2.8	5.6
Chlorophyll a (mg./m.^{3})	24.9	1.4	10.3

Table 5.--Highest, lowest, and mean values of limnological data at station 5, July 1967 through December 1968

Type of data	Highest	Lowest	Mean
Water temperature (° C.).....	22.5	4.8	13.9
Turbidity (JTU)..............	30+	2.3	8.9
Conductivity (μmhos/cm.).....	1070	170	450
Salinity (‰)...............	0.96	0.08	0.31
pH...........................	8.5	7.0	7.7
Dissolved O_2 (p.p.m.)........	12.2	7.2	10.0
Phosphate (p.p.m.)...........	0.33	0.06	0.15
Silicate (p.p.m.)............	15.5	3.4	8.4
Calcium (p.p.m.).............	20	11	16
Magnesium (p.p.m.)...........	6.0	3.4	4.4
Sodium (p.p.m.)..............	8.9	2.8	5.6
Chlorophyll a (mg./m.^{3})......	23.9	1.7	10.1

Table 6.--Highest, lowest, and mean values of limnological data at station 6, July 1967 through December 1968

Type of data	Highest	Lowest	Mean
Water temperature (° C.).....	22.4	5.2	14.2
Turbidity (JTU)..............	30+	1.4	8.3
Conductivity (μmhos/cm.).....	660	120	330
Salinity (‰)...............	0.52	0.04	0.22
pH...........................	8.5	7.1	7.6
Dissolved O_2 (p.p.m.)........	12.1	6.9	9.8
Phosphate (p.p.m.)...........	0.35	0.06	0.15
Silicate (p.p.m.)............	14.8	3.4	8.5
Calcium (p.p.m.).............	20	11	16
Magnesium (p.p.m.)...........	6.0	3.0	4.3
Sodium (p.p.m.)..............	8.2	3.1	5.7
Chlorophyll a (mg./m.^{3})......	29.0	1.7	9.7

Table 7.--Highest, lowest, and mean values of limnological data at station 7, July 1967 through December 1968

Type of data	Highest	Lowest	Mean
Water temperature (° C.).....	22.9	5.1	14.7
Turbidity (JTU)..............	30+	1.1	8.2
Conductivity (μmhos/cm.).....	620	110	270
Salinity (‰)...............	0.50	0.04	0.17
pH...........................	8.7	7.1	7.6
Dissolved O_2 (p.p.m.)........	12.1	6.9	9.6
Phosphate (p.p.m.)...........	0.30	0.06	0.14
Silicate (p.p.m.)............	14.2	3.0	8.3
Calcium (p.p.m.).............	19	8	16
Magnesium (p.p.m.)...........	6.0	3.4	4.5
Sodium (p.p.m.)..............	9.2	3.1	5.7
Chlorophyll a (mg./m.^{3})......	25.7	1.6	10.5

silicate (fig. 2) than station 1 and lower in pH (fig. 3), sodium (fig. 4), calcium (fig. 5), and magnesium (fig. 5). Records of the U.S. Geological Survey (1964) show the same difference between these variables in waters of the Columbia at The Dalles Dam and the Willamette River at Salem, Oreg. Because the Willamette enters the Columbia between stations 1 and 2, this tributary is most likely responsible for the higher silicate and lower pH, sodium, calcium, and magnesium at station 2.

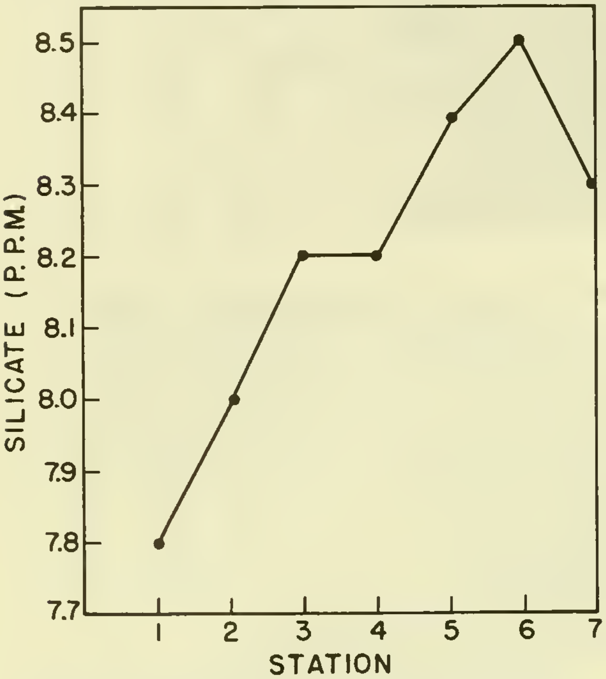

Figure 2.--Average concentration of silicate at each sampling station, July 1967 through December 1968.

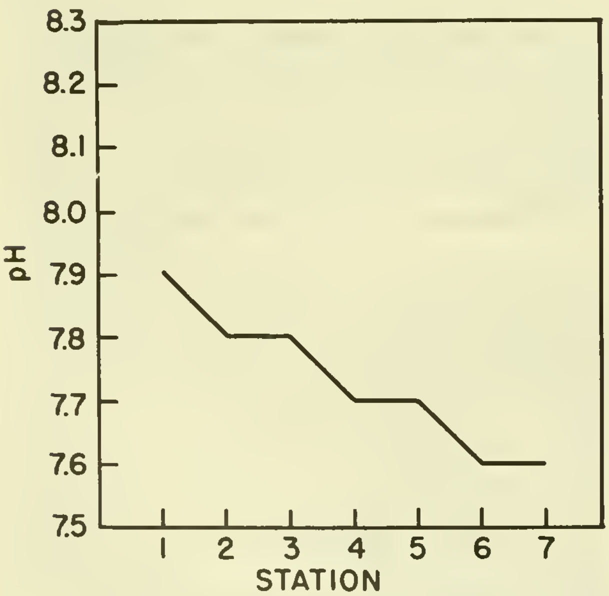

Figure 3.--Average pH value at each sampling station, July 1967 through December 1968.

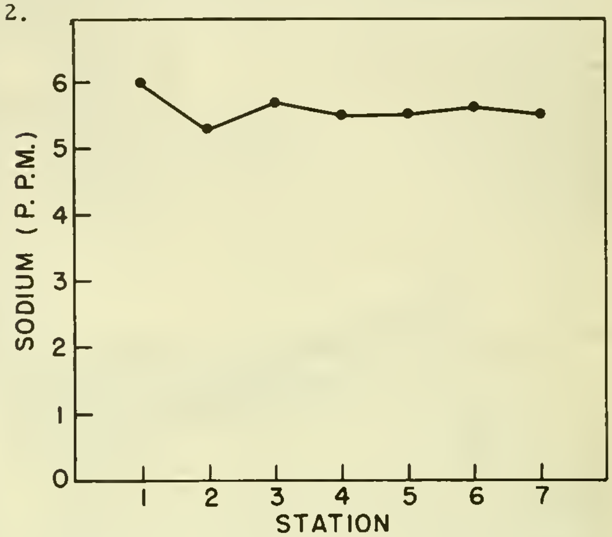

Figure 4.--Average concentration of sodium at each sampling station, July 1967 through December 1968.

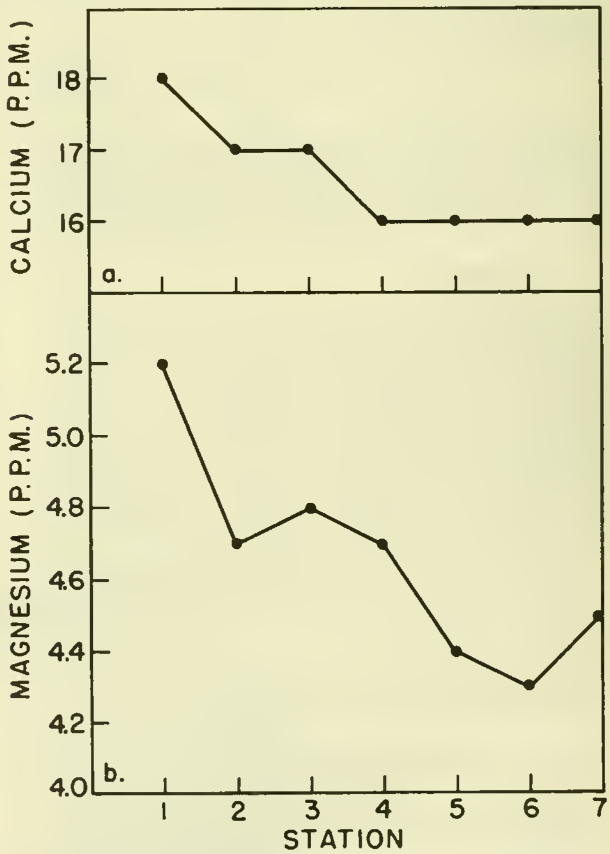

Figure 5.--Average concentrations of calcium (a) and magnesium (b) at each sampling station, July 1967 through December 1968.

Seasonal variation was apparent in most types of data. Figures 6 to 10 show the average values in the lower river for each type of data (by sampling date) and disclose the following information on seasonal variation.

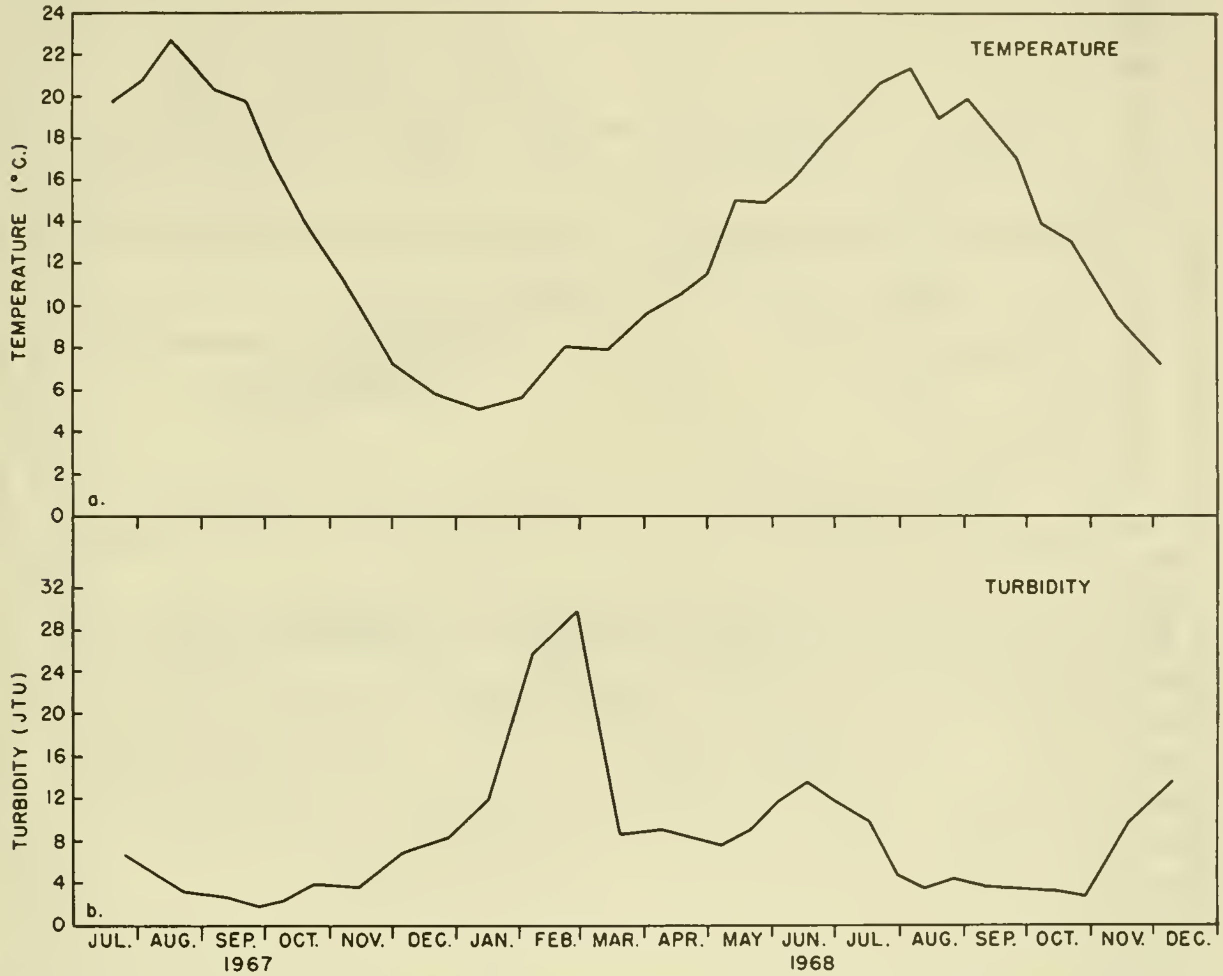

Figure 6.--Average water temperature (a) and turbidity (b) in the lower Columbia River, July 1967 through December 1968.

Figure 7.--Average pH (a), dissolved oxygen (b), conductivity (c), and salinity (d), in the lower Columbia River, July 1967 through December 1968.

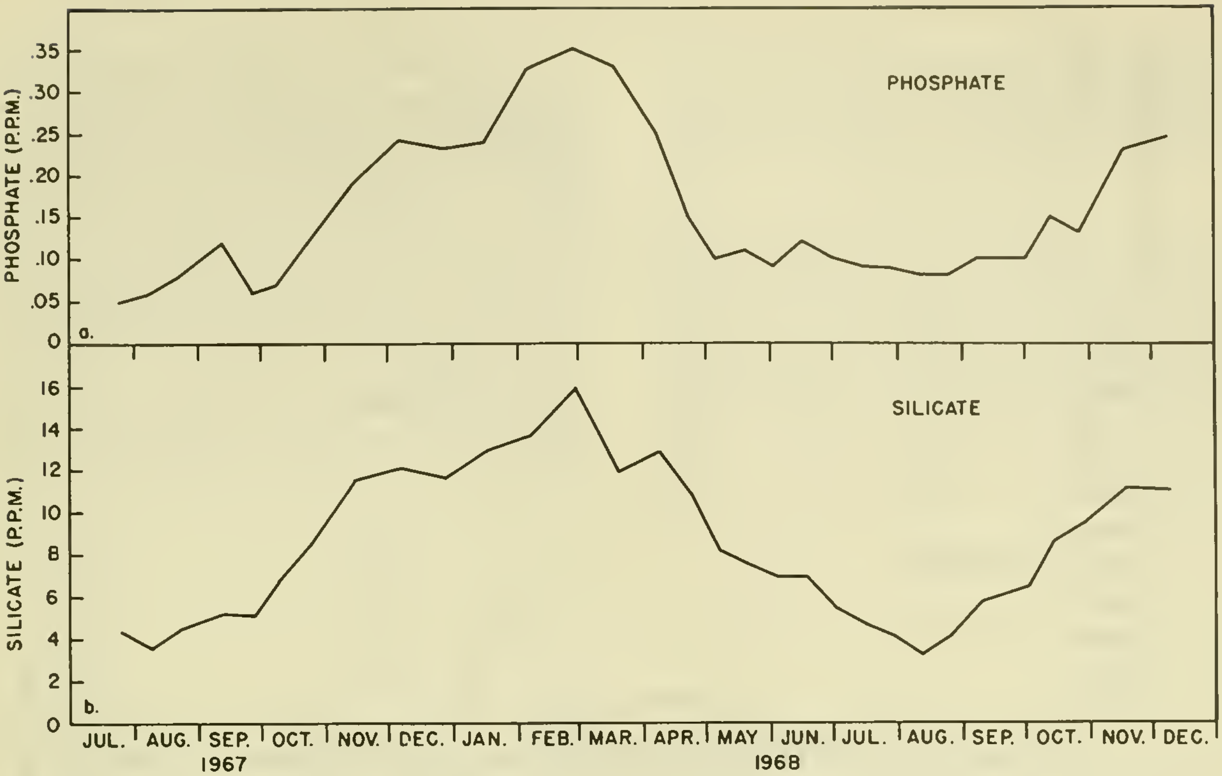

Figure 8.--Average phosphate (a) and silicate (b) in the lower Columbia River, July 1967 through December 1968.

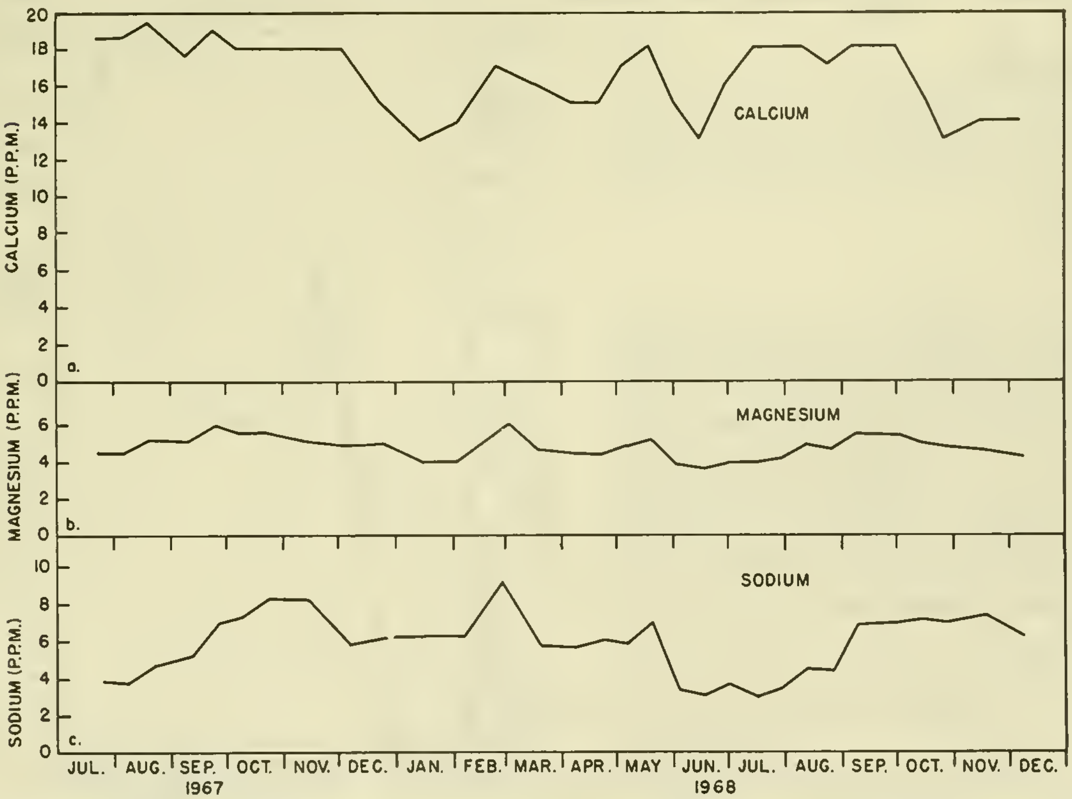

Figure 9.--Average calcium (a), magnesium (b), and sodium (c) in the lower Columbia River, July 1967 through December 1968.

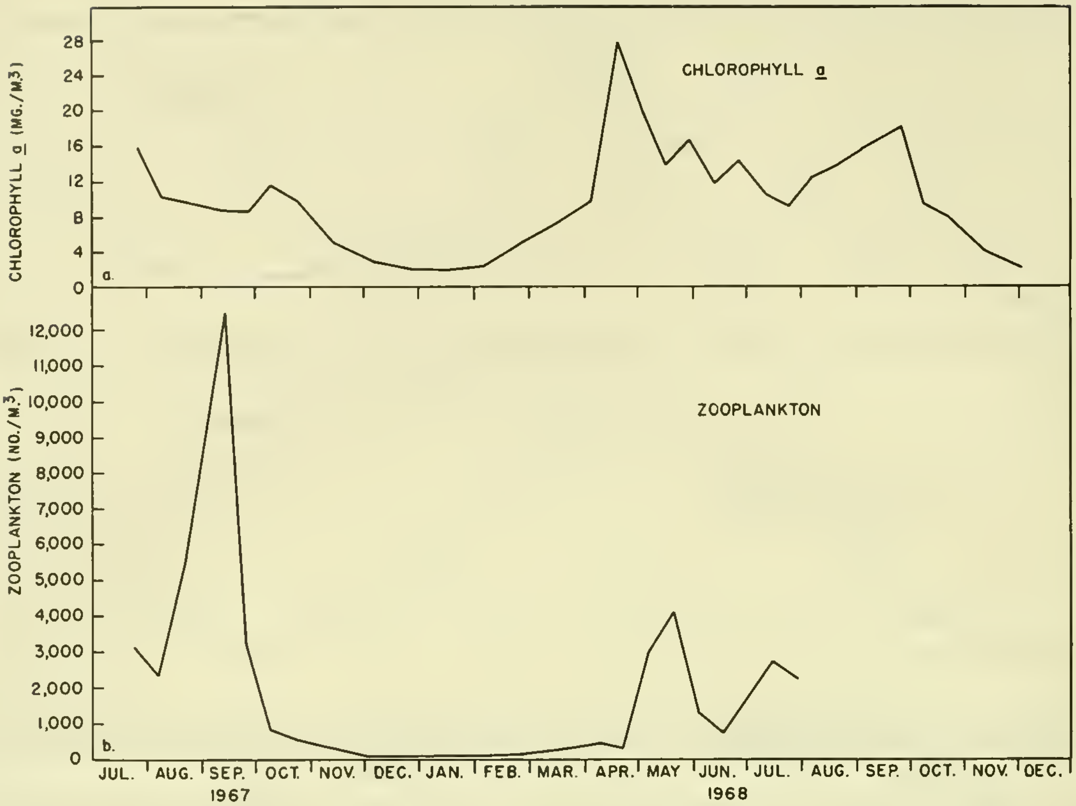

Figure 10.--Average chlorophyll a (a) and zooplankton (b) in the lower Columbia River, 1967-68.

Water Temperature

The highest average temperatures in 1967 and 1968 were 22.7° C. in late August 1967 and 21.3° C. in mid-August 1968 (fig. 6). The lowest average temperature was 5.1° C. in January 1968.

Turbidity

Turbidity is directly correlated with river flow. Griffin, Watkins, and Swenson (1956) attributed the late February rise in turbidity to the increased flow of tributaries into the lower Columbia River during the winter rainy season and the increase in mid-June to the increased flow from tributaries into the upper Columbia when the spring snow melted. The higher turbidity at stations 2 and 5 than at neighboring stations (fig. 11) in this study was attributed to inflow of the Willamette and Cowlitz Rivers, respectively.

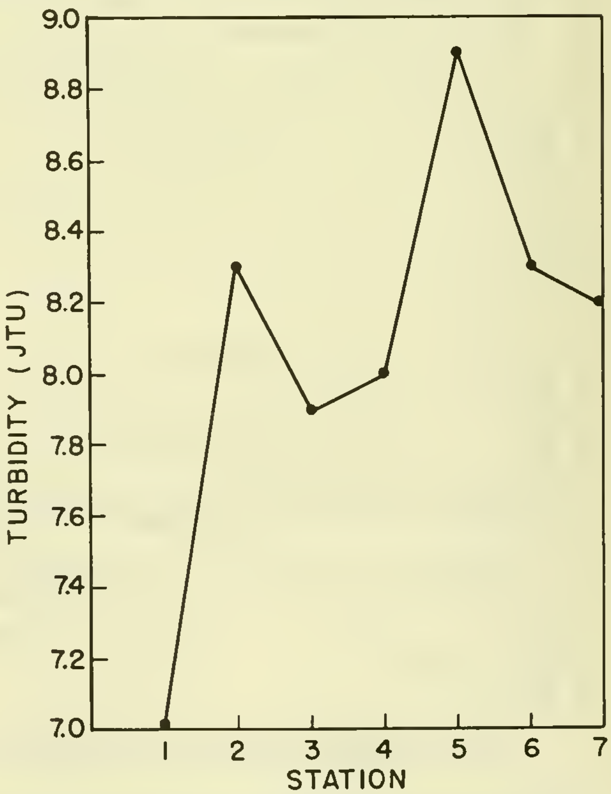

Figure 11.--Average turbidity at each sampling station, July 1967 through December 1968.

Conductivity and Salinity

Conductivity and salinity were usually higher at station 5 than at any other station (fig. 12). This difference was attributed to the Cowlitz River, which flows into the Columbia just above station 5 and receives saline water from underground caverns. Conductivity and salinity at station 5 tended to be higher in winter than in summer. The same tendency, though less pronounced, was also present at the other stations. The range in surface conductivity for station 5 was 220 to 1,100 µmhos/cm.; the average for the other six stations was 160 to 350 µmhos/cm. Surface salinity at station 5 was 0.08 to 0.96 ‰ (parts per thousand); the average for the other six stations ranged from 0.1 to 0.3 ‰. Though conductivity and salinity were measured at 3-m. intervals, only surface values are given here because the water mass was usually vertically homogeneous at all stations at all times of year.

pH

Values of pH decreased from station 1 downriver to station 7 and varied seasonally (figs. 3 and 7). The highest pH recorded in the summer of 1967 was 8.5 in late July and August. After the spring bloom of phytoplankton in late April 1968, the pH reached 7.9 but remained low the rest of the summer, never exceeding 7.7. The lowest pH recorded was 7.3 in June 1968.

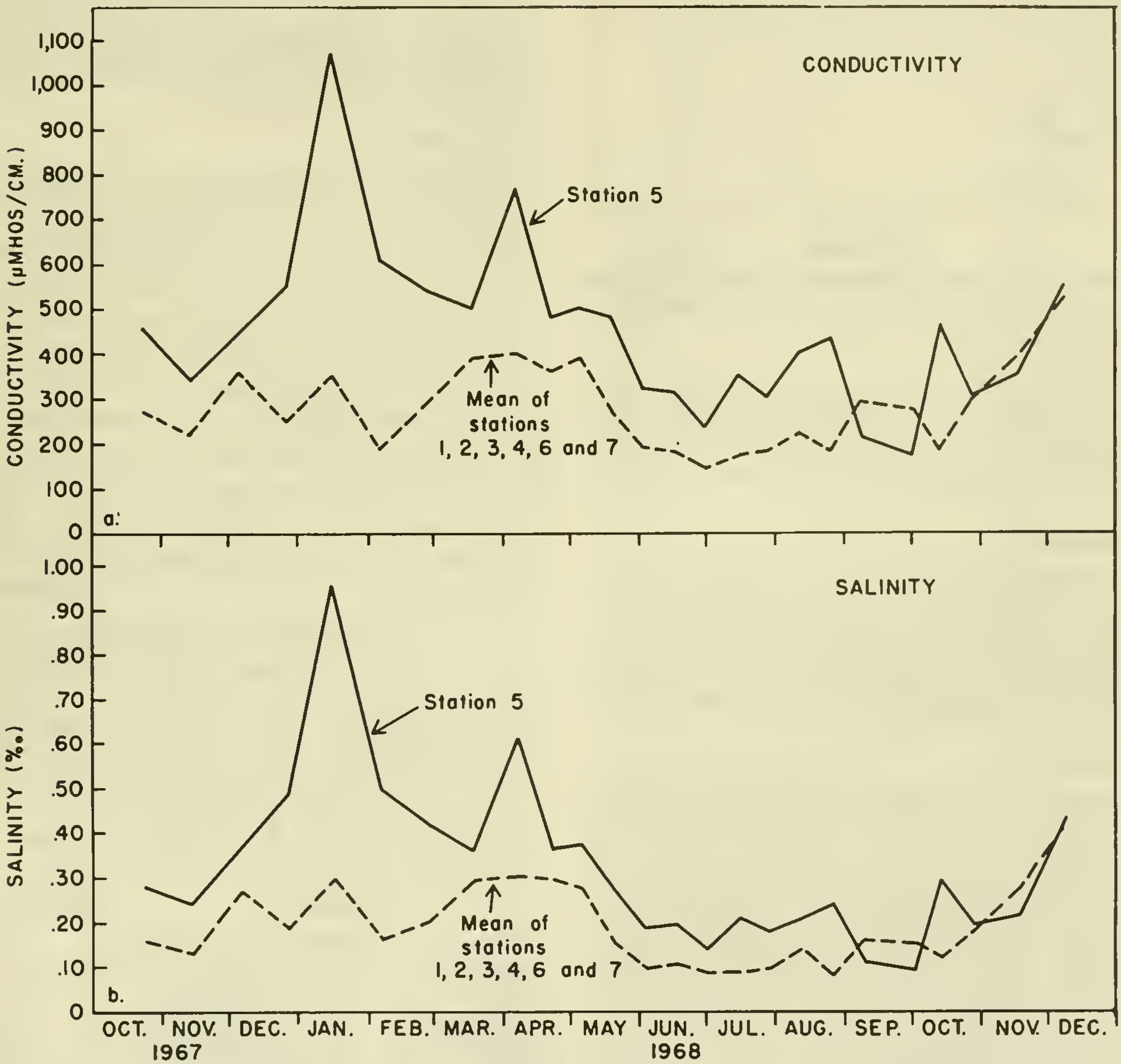

Figure 12.--Average conductivity (a) and salinity (b) at sampling station 5 and stations 1, 2, 3, 4, 6, and 7, October 1967 through December 1968.

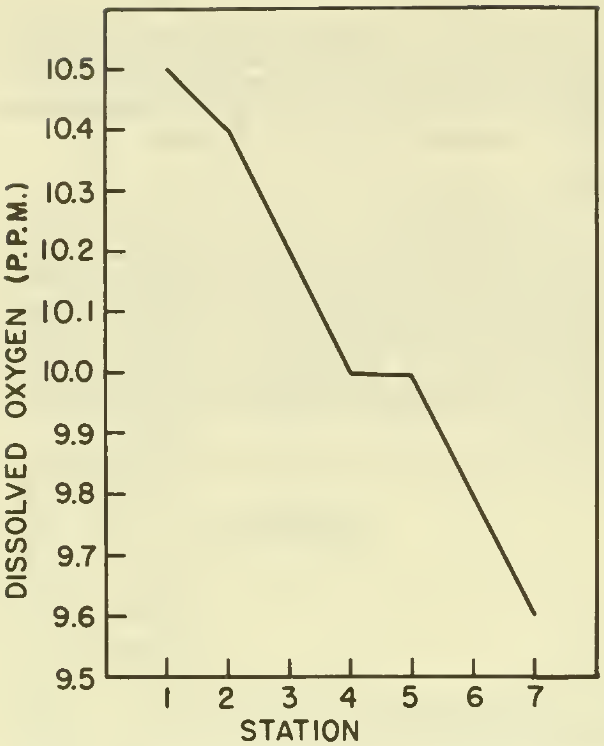

Figure 13.--Average concentration of dissolved oxygen at each sampling station in the lower Columbia River, July 1967 through December 1968.

Dissolved Oxygen

Dissolved oxygen ranged from 7.7 to 11.9 p.p.m. (fig. 7); percentage saturation was 78 to 116 percent. Dissolved oxygen concentration decreased slightly but steadily from station 1 downriver to station 7 (fig. 13).

Phosphate

Phosphate showed seasonal variation typical of a lake--high in winter and low in summer (fig. 8). The highest average concentration was 0.35 p.p.m. in late February; the lowest was 0.05 p.p.m. in late July 1967. The fall increase began in late September; the spring decline began in late March.

Silicate

Silicate was generally high in winter and low in summer (fig. 8). The highest average concentration in the lower river was 15.9 p.p.m., in late February; the lowest was 3.6 p.p.m., in early August. Silicate concentrations tended to increase progressively from station 1 downriver to station 7 (fig. 2). This downriver increase was attributed to higher silicate concentration in tributaries than in the Columbia River (U.S. Geological Survey, 1964).

Calcium and Magnesium

Neither calcium nor magnesium varied seasonally (fig. 9). Calcium ranged from 13 to 19 p.p.m.; magnesium was 3.5 to 6 p.p.m. Concentrations of calcium (fig. 5a) and magnesium (fig. 5b) decreased downriver, which was attributed to the low concentrations of those ions in tributaries of the lower Columbia (U.S. Geological Survey, 1964).

Sodium

In general, sodium concentrations were lower in summer than in winter (fig. 9). Average concentrations for all stations varied from 2.9 p.p.m. in mid-July to 9.2 p.p.m. in late February.

Chlorophyll a

Chlorophyll a content was high in summer and low in winter (fig. 10). The spring bloom was in late April when the average chlorophyll a content for all stations was 27.5 mg./m^3. The smaller fall bloom was in early October, and the winter low was 1.8 mg./m^3.

Zooplankton

Scarola (1968) listed the species of zooplankton collected in McNary Reservoir, which is 470 km. above the mouth of the Columbia River; the same species were collected in the lower river. Many observations by Scarola on seasonal occurrence and abundance of specific species in McNary are similar to observations in the present study on the same species in the lower river.

The largest number of zooplankton organisms collected was on September 10 (fig. 10). Numbers then decreased, remained low through the winter, and began to increase slowly in early spring with small peaks in May and July. This same general variation in relative abundance was seen in the occurrence of the two most abundant zooplankters, Cyclopoids and _Bosmina_ (table 8). Cyclopoids began their spring increase in late February and _Bosmina_ in late March.

Calanoids, _Daphnia_, and _Ceriodaphnia_ were third, fourth, and fifth in abundance, respectively, without large differences in total numbers (table 8). The numerical peak of calanoids and _Ceriodaphnia_ occurred on September 10, whereas _Daphnia_ peaked in late July. The

Table 8.--Abundance of zooplankton at stations 1 to 7, July 1967 through July 1968

Type of zooplankton	Mean per m.^{3}	Type of zooplankton	Mean per m.^{3}
	Number		Number
Cyclopoids..	887.10	_Ilyocryptus_...	4.14
Bosmina.....	826.91	Harpacticoids.	2.58
Calanoids...	73.19	_Pleuroxus_.....	1.95
Daphnia.....	64.74	_Leydigia_......	1.46
Ceriodaphnia	46.34	_Monospilus_....	1.06
Sida........	19.02	_Macrothrix_....	0.77
Alona.......	14.12	_Leptodora_.....	0.56
Chydorus....	10.68	_Diaphanosoma_..	0.25

occurrence of Daphnia was extremely patchy--temporally and spatially--but some were present in every sampling week. Ceriodaphnia, though common in late July, August, and September, was scarce or absent the rest of the year.

The next most abundant species were Sida, Alona, and Chydorus. Sida was present from July through November and scarce or absent the rest of the year. Alona was most abundant in late August, September, and October. Chydorus peaked in mid-June and mid-July.

The other zooplankton species, with the exception of Monospilus, occurred in summer and fall but were never numerous. Monospilus was present from October through early April and absent during the summer. A complete list of zooplankton collected and the average number per cubic meter for the survey year are given in table 8.

The numbers of zooplankton tended to increase progressively downriver from stations 1 to 7 (fig. 14).

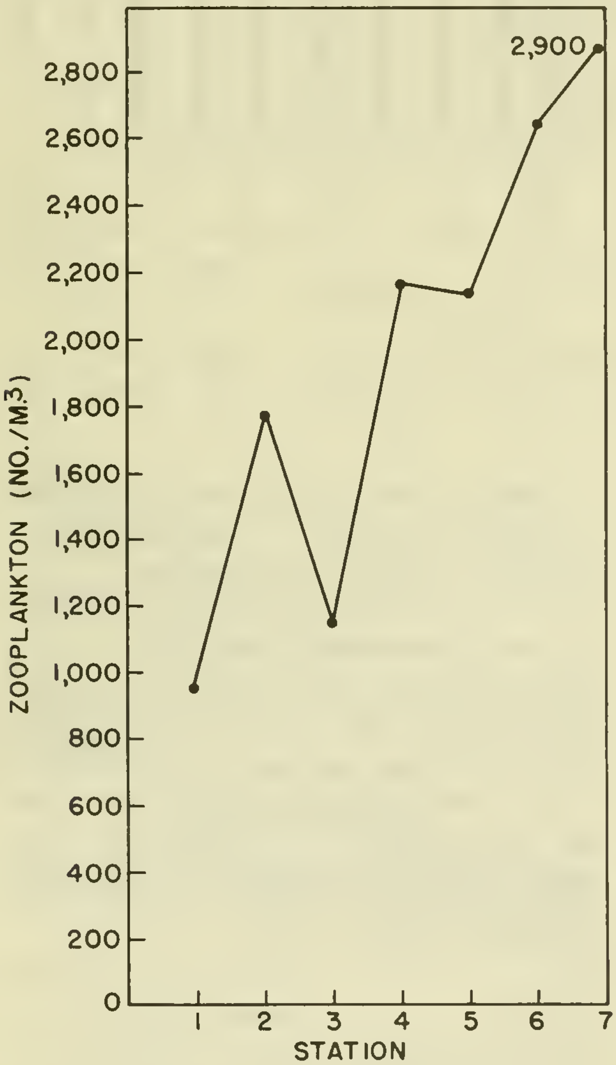

Figure 14.--Relative abundance of zooplankton at each sampling station, July 1967 through July 1968.

Cyclopoids and Bosmina made up more than 75 percent of the population in all months except November through February; their contribution reached a low of 35.6 percent in early February (table 9). Zooplankton, low in the summer, constituted a larger percentage of the population in winter. Daphnia reached 24 percent of the population in early February, whereas in early September it constituted only 1 percent; calanoids went from 2 to 15 percent, Alona from 0.6 to 10 percent, and Ilyocryptus from 0.1 to 9 percent in the same September to February time interval. Thus, the diversity of the zooplankton community is greater in winter than in spring, summer, or fall.

Table 9.--Percentage of cyclopoids and Bosmina in samples of zooplankton at stations 1 to 7, July 1967 through July 1968

Sampling date	Cyclopoids and Bosmina
	Percent
1967:	
July 25-26	83.5
Aug. 8-9	83.5
Aug. 22-23	91.5
Sept. 12-13	89.7
Sept. 27-28	86.5
Oct. 9-10	76.8
Oct. 24-25	76.7
Nov. 14-15	71.9
Dec. 6-7	61.4
Dec. 27-28	56.9
1968:	
Jan. 16-17	47.9
Feb. 6-7	35.6
Feb. 28-29	71.7
Mar. 19-20	78.5
Apr. 8-9	89.5
Apr. 23-24	86.2
May 6-7	90.6
May 20-21	95.6
June 3-4	77.4
June 17-18	78.7
July 1-2	78.8
July 16-17	80.8
July 29-30	81.0

COMPARISON OF DATA BETWEEN YEARS

Limnological data collected in 1967-68 are compared with data of 1954-55 from Sylvester (1958) in table 10. In the 1967-68 data, the concentration of dissolved oxygen is lower than in the 1954-55 data (0.7 p.p.m. in December to 2.0 p.p.m. in June). That this is not just a factor of temperature is shown by the data on percentage of oxygen saturation. The river water

Table 10.--Comparison of mean monthly values of limnological data collected in 1954-55 (Sylvester, 1958) with data collected in 1967-68

Type of data and year	Month								Mean value
	Mar.	May	June	July	Aug.	Sept.	Nov.	Dec.	
Water temperature (° C.):									
1954-55	5.2	12.8	14.5	16.9	18.9	18.1	10.6	5.4	12.8
1967-68	7.8	13.5	15.6	19.3	20.8	19.9	9.3	6.7	14.1
Dissolved oxygen (p.p.m.):									
1954-55	12.5	10.2	11.4	11.3	9.6	9.3	10.5	11.7	10.8
1967-68	11.6	10.5	9.4	9.7	8.6	7.7	10.8	11.0	9.9
Dissolved oxygen (% saturation):									
1954-55	98	96	111	116	102	97	94	92	101
1967-68	97	100	94	104	95	83	88	89	94
pH:									
1954-55	7.5	7.5	7.4	7.9	8.0	7.9	7.9	7.4	7.7
1967-68	7.5	7.6	7.4	7.7	7.9	7.9	7.1	7.4	7.6
Turbidity (JTU):									
1954-55	12	3	20	14	6	13	4	10	10
1967-68	8.5	7.7	13	7.3	4.2	2.4	13.8	9.6	8.3
Calcium (p.p.m.):									
1954-55	17	17	20	17.5	17	18	21	18	18
1967-68	15	17.5	14.5	17.3	18.2	16.2	16	16	16.3
Magnesium (p.p.m.):									
1954-55	0.5	1.0	0.2	2.4	1.1	0.7	0.6	0.6	0.9
1967-68	4.4	4.7	3.5	3.9	4.6	5.3	4.8	4.6	4.5
Sodium (p.p.m.):									
1954-55	7.0	12.0	6.0	1.0	2.7	4.0	16.0	10.0	7.3
1967-68	6.2	6.8	3.3	3.7	4.6	6.5	7.8	6.0	5.6

in 1967-68 was actually less saturated with oxygen at any given temperature than it was in 1954-55. Figure 15 shows graphically the comparison of percentage saturation between 1954-55 and 1967-68.

The concentration of magnesium was higher in 1967-68 than that reported by Sylvester (1958) for 1954-55 (table 10). The U.S. Geological Survey (1959a, 1959b), however, did not report such a low concentration of magnesium during 1954-55 nor were like differences apparent in calcium concentration, which usually parallels that of magnesium. Therefore, differences in concentration of magnesium between the data of Sylvester (1958) and those collected in the present study are probably not meaningful.

Comparison of limnological data for 1954-55 with those for 1967-68 does not suggest any significant differences in pH, turbidity, or calcium and sodium concentrations.

In table 11, 1967 and 1968 data are compared with 1960 data of Sylvester and Carlson (1961). It must be remembered that data for 1967 reflect conditions only from late July through December. Thus, the maximum chlorophyll *a* value for 1967 does not indicate a lower spring bloom than in 1960 or 1968. Concentration of dissolved oxygen was less in 1967-68 than in 1960 as can be seen by comparing percentage saturation of oxygen data for the 3 years. Thus, the concentration of dissolved oxygen in the lower Columbia River appears to be decreasing with time since it was lower in 1967-68 than in either 1954-55 or 1960.

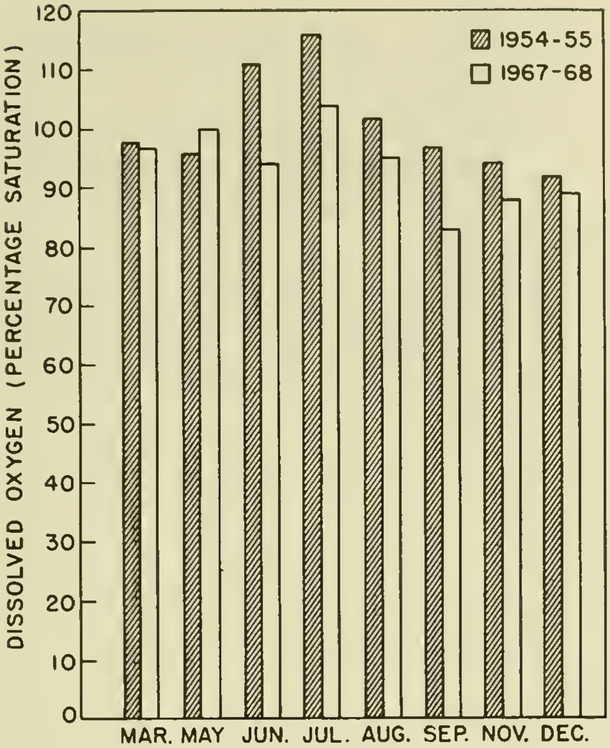

Figure 15.--Average concentration of dissolved oxygen in the lower Columbia River during 1967-68 compared with levels given by Sylvester (1958) for 1954-55.

Table 11.--Comparison of limnological data collected in 1960 (Sylvester and Carlson, 1961), 1967, and 1968

Type of data	Maximum			Minimum			Mean		
	1960	1967	1968	1960	1967	1968	1960	1967	1968
pH	8.5	8.7	8.1	6.6	7.0	7.0	7.8	8.1	7.5
Temperature (^{0} C.)	23.0	22.9	21.6	2.0	5.7	4.8	12.1	15.9	13.4
Chlorophyll *a* (mg./m.^{3})	20.4	17.0	32.3	1.0	1.7	1.4	8.3	8.6	10.8
Dissolved oxygen:									
P.p.m.	14.4	12.0	12.6	8.4	6.7	7.7	11.0	8.9	10.5
Percentage saturation	150	138	142	61	53	59	102	89	99

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