LIMNOLOGICAL STUDIES OF SODUS BAY AND ITS TRIBUTARIES

by

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EXECUTIVE SUMMARY

1. Six sites on the major tributaries entering Sodus Bay (First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East) were monitored weekly for 13 weeks (5 April - 28 June 1988) for 19 chemical and physical parameters including stream discharge.

2. Eleven stations on Sodus Bay were sampled at a depth of 1 m. One station near the deepest point in Sodus Bay was sampled at meter intervals (depth = 12 m) for 18 chemical and physical parameters on 15 August 1988. Sediments were also sampled at five stations on the Bay and analyzed for sediment size, total kjeldahl nitrogen, total phosphorus and sodium. Macrophytes were taken from East Bay, Port Bay and from five stations on Sodus Bay. They were analyzed for total kjeldahl nitrogen, total phosphorus and seven metals. The macrophytes from East and Port Bays were also analyzed for selected chlorinated hydrocarbons.

3. Statistical analysis of mean daily levels of tributary parameters demonstrated that Clark Creek had the minimum level for eight of the parameters measured (temperature, alkalinity, conductivity, calcium, magnesium, potassium, sodium, and chloride) and the maximum level for one parameter (silica). Sodus Creek East had the maximum daily mean of seven parameters (pH, alkalinity, dissolved oxygen, magnesium, sulfate, soluble reactive phosphorus and nitrate). The differences between the two creeks are probably related to watershed usage and size. Clark Creek, which generally had the lowest concentration of ions, is almost completely forested and has the smallest watershed area. Sodus Creek East, on the other hand, has the largest watershed area and generally had the highest daily mean concentration of ions.

   First Creek shows evidence (low dissolved oxygen, low pH, high turbidity, relatively high total phosphorus) of a source or sources of organic loading. Causes could include agricultural runoff, industrial discharge and/or leaching from septic systems. This problem should be investigated further. First and Second Creeks were also significantly higher in both sodium and chloride concentrations. These differences are probably related to usage of deicing salts on roadways in these watersheds. In general, Second Creek had the highest concentration of metals.

   The seasonal trend of increased levels of nutrients in the streams (especially phosphorus) during the study period is interesting. It may be caused by increased agricultural activity in the spring (either tillage or fertilization). However, the data suggest that fertilization is the most likely cause because tillage would have cause increased turbidity levels which was not the case.

4. By mid-August thermal stratification of Sodus Bay had occurred. At Station 5, the water column consisted of an epilimnion (upper layer of uniform, warm circulating water - ~7 m in thickness) overlying a thermal discontinuity layer (the metalimnion - ~3 m in thickness) and a deeper, cooler hypolimnion. Hypolimnetic oxygen values were close to zero which

caused dramatic increases in soluble reactive phosphorus and total phosphorus in the hypolimnion. Nitrate was non-detectable throughout the water column.

Many chemical parameters in Sodus Bay are influenced by discharge from tributaries. The majority of the maximum and minimum values of various chemical constituents within Sodus Bay occurred at stations adjacent to creek mouths. For example, high levels of sodium and chloride in First Creek were reflected at Station 4 within the Bay. Station 4 had the highest sodium, chloride and conductivity levels within the Bay. Similarly, Station 4 and First Creek (which enters the Bay at Station 4) showed similar symptoms of organic loading. First Creek had the lowest dissolved oxygen and pH levels, the highest total phosphorus concentration and the second highest turbidity. Station 4 (near the mouth of First Creek) had the lowest dissolved oxygen and pH levels in the Bay coupled with high total phosphorus, high turbidity and low secchi disk readings. Possible causes of these conditions include agricultural runoff, sewage leaching or an industrial source. Only further investigation can pinpoint these sources. In addition, total coliforms should be sampled at Station 4.

A positive correlation between chlorophyll concentration and soluble reactive phosphorus levels occurred at tributary mouth stations (r^2=0.731), but not at the non-tributary stations (r^2 = 0.013). This suggests that phosphorus loading from tributaries is having local effects on plants in Sodus Bay.

The highest epilimnetic concentrations of soluble reactive and total phosphorus were found at Station 2. Station 2 is exposed to winds from the west and is located in a sub-basin of Sodus Bay. High winds and waves, experienced only at this site during sampling, may have eroded the hypolimnion and affected water chemistry. Mixing of epilimnion and hypolimnion water would result in lower temperatures, higher soluble reactive and total phosphorus levels, lower chlorophyll concentrations, higher pheophytin levels, lower dissolved oxygen concentrations and lower secchi disk readings in the epilimnion.

Nitrate was non-detectable at all Sodus Bay sites.

Although coliform bacteria were found at Station 6, their level is well below the EPA guidelines for primary contact recreational usage. Station 6 is located near a marina, restaurant and summer homes.

Based on The EPA guidelines for the evaluation of Great Lakes harbor sediment, sediments at the mouths of tributary streams of Sodus Bay would be considered moderately to heavily polluted.

Detectable levels of chlorinated hydrocarbons were not observed in macrophytes from Port and East Bays. The levels of sodium, potassium, magnesium, calcium, phosphorus and copper in macrophytes from Sodus, Port and East Bays were similar to those reported for a mixture of Myriophyllum sp., Vallisneria sp., Elodea sp., Ceratophyllum sp. and

Najas sp. from Chemung Lake, Canada. Chemical analysis of macrophytes suggest that macrophytes from Sodus, East and Port Bays could be safely used as animal fodder.

Of the six creeks monitored during the spring, Sodus East was the major contributor of nutrients to Sodus Bay. Sodus Creek (East and West) accounted for 61.6% and 58% of the total phosphorus and nitrate, respectively, entering Sodus Bay. Thus, it is not suprising that an extensive macrophyte community, which extends well into the Bay, exists at the mouth of Sodus Creek. Similarly, Second Creek, which had the second highest loading of total phosphorus (20.2%), has a large macrophyte community at its mouth.

Based on the limited phosphorus loading and chlorophyll data that we have collected for Sodus Bay and its tributaries, Sodus Bay falls into the eutrophic category of bodies of water. That is to say, Sodus Bay is a productive body of water. The low hypolimnetic oxygen levels during the summer also support this conclusion.

INTRODUCTION

In response to public concern created by an abundance of nuisance weeds (i.e. macrophytes) within the three embayments of Wayne County (Sodus, East and Port Bays), the Aquatic Vegetation Control Program was created in 1987 to develop long-term management strategies for the Bays. The program is administered jointly by the Wayne County Planning Board and the Wayne County Soil and Water Conservation District. The Soil and Water Conservation District recognized early that management of the bay ecosystem would require the development of a data base presently not available. Toward this end, the Wayne County Soil and Water Conservation District contracted with SUNY Brockport to collect and analyze limnological data from Sodus Bay and its tributaries. In a separate study, the Community College of the Finger Lakes investigated macrophyte distribution and composition within the Bay. The general objectives of this study were:

1. To characterize the environmental status and water quality of Sodus Bay during summer conditions;

2. To determine the nutrient and pollutant content of macrophytes in Sodus Bay, Port Bay and East Bay;

3. To conduct selected sediment analyses on Sodus Bay at the mouth of each tributary;

4. To monitor weekly the five streams entering Sodus Bay for selected chemical parameters from April to June; and

5. To develop nutrient loads for each stream for April to June.

Study Site:

Sodus Bay is located along the south shore of Lake Ontario midway between Rochester and Oswego, N.Y. Sample sites on Sodus Bay were chosen to encompass a variety of habitats on the Bay (e.g. marinas, open water, recreational areas, tributary mouths) (Fig. 1). First Creek originates in the Town of Sodus and empties into the northwestern corner of Sodus Bay. Samples were taken adjacent to the intersection of Sargeant and Morley Roads. Second Creek, which originates in the Town of Lyons, was sampled on the south side of Glover Road. Third Creek originates in the Town of Rose and empties into Sawmill Cove on Sodus Bay. Third Creek was sampled on the south side of the bridge on Ridge Road. Sodus Creek is the major tributary to Sodus Bay; its watershed extends to the Barge Canal in the Town of Galen. Sodus Creek was sampled at two locations (Sodus Creek East, Sodus Creek West) in the Town of Huron. Both sites on Sodus Creek were north of Route 104, where the creek crossed under this major highway. Clark Creek originates in the Town of Huron and empties into the east side of the Bay. Clark Creek was sampled on the east side of Lake Bluff Road.

METHODS

General

Stream water samples were collected and stream height was measured weekly at all stream sites from 5 April to 28 June 1988. Sites were chosen, above the influence of Sodus Bay, for ease of access (i.e. closeness to a bridge or culvert for gaging purposes)(Fig. 1). Bay water samples were taken at twelve stations on Sodus Bay on 15 August 1988 (Fig 1). Station 5 was sampled at meter intervals (0-11 m). All other water samples were taken at a depth of 1 meter. Sediment, macrophyte and fecal coliform samples were also taken at selected sites from the Bay only.

All sampling bottles were pre-coded so as to ensure exact identification of the particular sample. All filtration units and other processing apparatus were cleaned routinely with phosphate-free RBS. Containers were rinsed prior to sample collection with the water being collected. In general, all procedures followed EPA standard methods (EPA 1979) or Standard Methods for the Analysis of Water and Wastewater (APHA 1985). Sample water for dissolved nutrient analyses (SRP, nitrate + nitrite, silica) was filtered immediately with 0.45 um MCI Magma Nylon 66 membrane filters and held at $4^{o}C$ until analysis. Analyses of pH, alkalinity, specific conductance, turbidity and dissolved oxygen were completed within two hours of collection. Subsequent analyses were always completed within 24 hours of collection.

Statistics were performed on a PRIME 9955 mini-computer using MINITAB and SPSSx software packages. Significant differences were determined by oneway analysis of variance and Tukey's honestly significant difference test.

Water Chemistry

Turbidity: Turbidity was measured with a Turner nephelometric turbidimeter as soon as possible after sample collection. When analyzing cold water samples, care was taken to avoid condensation on the outside of the sample tube or gas bubble formation within the tube.

Specific Conductance: A Thomas Model 275 Conductivity Meter was used to measure conductivity. Results were corrected to $25^{o}C$.

pH: Analyses were made by electrode using the Beckman SS-2 meter standardized daily using two buffers (4 and 9). pH was measured as soon as possible following sample collection.

Dissolved Oxygen: Dissolved oxygen analyses were made using the modified Winkler method (APHA 1985). Samples were fixed in the field and transported to the laboratory for final titration.

Total Alkalinity: Alkalinity was estimated within two hours of collection by titrating with standard H_2SO_4 to a pH end point of 4.5.

Nitrate + Nitrite: Dissolved nitrate + nitrite nitrogen analyses were performed by the automated (Technicon Autoanalyser) cadmium reduction method (EPA 1979).

Total Phosphorus: The persulfate digestion procedure was used prior to analysis by the automated (Technicon Autoanalyser) colorimetric ascorbic acid method (APHA 1985).

Soluble Reactive Phosphorus: Analysis was performed using the automated (Technicon) colorimetric ascorbic acid method (APHA 1985).

Chloride: Analyses were performed using the mercuric nitrate method (APHA 1985).

Dissolved Reactive Silica: Dissolved reactive silica was measured using the automated (Technicon Autoanalyser) colorimetric molybdosilicate method (APHA 1985).

Metals: Calcium, magnesium, sodium and potassium were determined by atomic absorption spectrophotometry (Perkin-Elmer 3030) (APHA 1985).

Physical Measurements

Temperature: Stream and Bay temperatures were measured with a calibrated mercury thermometer and a Whitney thermistor, respectively.

Stream Height: Stream height was determined weekly by measurements of the distance from the surface of the stream to a standard location on the overlying bridge. Stream area for various stream heights was calculated by planimetry. A line was fit to the values for stream area by polynomial interpolation using Curve Fitter (Interactive Microware 1980), which allowed stream cross-sectional area to be estimated for all sampling dates based on stream heights.

Stream Velocity: Stream velocity was measured either in the culvert or within the cement channel of a bridge (Chow 1964). Measurements were at equally spaced locations (Table 1) at each station on 12 dates with a Gurley Pygmy Meter. On 12 April 1988 only First Creek was measured before the meter became inoperative. For the remaining creeks on 12 April 1988, velocity was estimated from regressions of stream height and velocity from all sampling dates.

Table 1. The number of velocity measurements at each tributary site.

Creek	Measurements
First	3
Second	3
Third	3
Clark	1
Sodus - west	2
Sodus - east	3

Watershed Area: Areas used in the loading calculations were obtained by planimetry from USGS topography maps. Watershed areas were not the whole area of the watershed but were the area of the watershed upstream from the sampling point.

Sediment

General: Sediment samples were taken in Sodus Bay at the mouths of the major tributaries (Stations 4,7,8,11,12) (Fig. 1) using a Ponar dredge. Samples were iced for transport to the laboratory. In the laboratory, the supernatant water was removed, the pH reduced to 2-3 with H_2SO_4, and the resulting sediment stored at 4°C until analysis. Samples were homogenized before being subsampled for analysis.

Percent Moisture: Percent moisture was determined on each sediment sample by drying a subsample in a tared ceramic dish at 103-105°C to constant weight (USGS 1979). Percent moisture was then used to express results on a dry weight basis.

Total Kjeldahl Nitrogen (TKN): Sediments were digested using the macro-Kjeldahl method with final ammonia measurement by nesslerization (APHA 1985).

Total Phosphorus: An acid persulfate digestion was performed on sediment subsamples before analysis by the automated (Technicon Autoanalyser) colorimetric ascorbic acid method (USGS 1979).

Sodium: Sodium was extracted from sediment by destruction of organic material with 30% H_2O_2, followed by hot acid digestion and filtration (USGS 1979). Analysis was performed by atomic absorption spectrophotometry (APHA 1985).

Sediment size: Air dried sediments were washed through ASTM U.S. standard sieve series. Sediment left in each sieve was air dried and weighed. Sediments were classified by the Wentworth size class distribution (Krumbein and Pettijohn 1938).

Macrophytes

General: Macrophyte samples were taken in Sodus Bay at the mouths of the major tributaries (Stations 4,7,8,11,12) (Fig. 1). Samples were simultaneously being taken at sites on Port Bay and East Bay by Wayne County Soil and Conservation Service personnel. Samples were frozen in sealed plastic bags until analysis.

Percent Moisture: Percent moisture was determined on each macrophyte sample by drying a subsample in a tared ceramic dish at 103-105^{o}C to constant weight (USGS 1979). Percent moisture was then used to express results on a dry weight basis.

Total Kjeldahl Nitrogen (TKN): Macrophytes were digested using the macro-Kjeldahl method with final ammonia measurement by nesslerization (APHA 1985).

Total Phosphorus: An acid persulfate digestion was performed on macrophyte subsamples before analysis by the automated (Technicon Autoanalyser) colorimetric ascorbic acid method (Likens and Bormann 1970, USGS 1979).

Metals: Metals were extracted from macrophytes by destruction of organic material with 30% H_2O_2 followed by hot acid digestion and filtration (Likens and Bormann 1970, USGS 1979). Analyses for sodium, potassium, calcium and magnesium were performed by atomic absorption spectrophotometry (APHA 1985). Analyses for cadmium, copper and lead were performed by electrothermal atomic spectrophotometry using a graphite furnace with background correction (Perkin-Elmer HGA-400/3030) (APHA 1985).

Chlorinated Hydrocarbons: Macrophytes from East Bay and Port Bay were extracted following AOAC (1984) and analyzed following EPA (1982) Method 608 for selected chlorinated hydrocarbons by Delta Laboratories.

Fecal Coliform: Fecal coliform samples were taken at three stations (3,6,12) on Sodus Bay on 15 August 1988. Four volumes of sample water (1,10,50,and 100 ml) were passed through four separate 0.45 um membrane filters and placed on pre-wetted nutrient pads (Nalge Inc.) for each station and incubated at 44.5^{o}C for 24 hours. Filters were allowed to air dry before enumeration of colonies (APHA 1985).

Quality Control

Quality Assurance Internal Quality Control: Multiple sample control charts (APHA 1985) were constructed for each parameter analyzed, except oxygen. A prepared quality control solution was placed in the analysis stream for each sampling date. If the control solution was beyond the set limits of the control chart, corrective action was taken and the samples re-run. Frequency of instrument calibration is indicated in Table 2. Table 3 provides a summary of the quality assurance data.

External Quality Control: Biannually, reference solutions were obtained from The USEPA EMSL Laboratory in Cincinnati, Ohio, and placed into the analysis stream. In all cases, analyses fell within the standard error of the control sample provided.

Table 2. Frequency of Calibration of Reagents or Instruments

Instrument	**Standard / Recalibration**
Turbidity	Polymer standards weekly
YSI Conductivity Bridge	KCL standards weekly
pH meter	Standards weekly
Alkalinity	$NaCO_3$ quarterly
Dissolved Oxygen	Biniodate quarterly
Technicon-Nitrate Nitrite	Stock standards weekly
Technicon-TP	Stock standards weekly
Technicon-SRP	Stock standards weekly
Chloride	Stock standards weekly
Technicon-DRS	Stock standards weekly
Atomic Absorption Spectrophotometer	Stock standards weekly

Table 3. Summary of quality assurance data from water quality laboratory SUNY at Brockport, Brockport, NY. May 1987 - May 1988.

pH			
Number	34	19	
True value	4.02	9.18	
Mean	4.05	9.12	
Standard deviation	0.042	0.050	
Coefficient of variation	0.010	0.005	
95% Confidence interval	3.97 - 4.14	9.02 - 9.22	
Relative error	0.9%	0.7%	
Alkalinity (mg $CaCO_3$/L)			
Number	53		
True value	75.51		
Mean	75.17		
Standard deviation	0.931		
Coefficient of variation	0.012		
95% Confidence interval	73.31 - 77.03		
Relative error	0.5%		
Conductivity (umhos/cm)			
Number	24	16	13
True value	278	354	717
Mean	276	349	717
Standard deviation	6.784	8.414	6.713
Coefficient of variation	0.024	0.024	0.009
95% Confidence interval	262 - 289	332 - 365	704 - 731
Relative error	0.77%	1.56%	0.04%
Turbidity (NTU)			
Number	52		
True value	0.46		
Mean	0.44		
Standard deviation	0.032		
Coefficient of variation	0.070		
95% Confidence interval	0.37 - 0.50		
Relative error	4.8%		
Calcium (mg/L)			
Number	24	24	
True value	18.31	41.86	
Mean	18.93	42.62	
Standard deviation	0.407	0.499	
Coefficient of variation	0.022	0.012	
95% Confidence interval	18.12 - 19.74	41.62 - 43.62	
Relative error	3.3%	1.8%	
Magnesium (mg/L)			
Number	26	22	
True value	8.64	23.62	
Mean	8.69	24.42	
Standard deviation	0.078	0.932	
Coefficient of variation	0.009	0.039	
95% Confidence interval	8.54 - 8.85	22.55 -26.28	
Relative error	0.6%	3.3%	
Potassium (mg/L)			
Number	27	26	
True value	1.01	5.00	
Mean	0.97	5.00	
Standard deviation	0.042	0.064	
Coefficient of variation	0.042	0.013	
95% Confidence interval	0.89 - 1.06	4.88 - 5.13	
Relative error	3.6%	0.1%	
Sodium (mg/L)			
Number	16	26	
True value	5.06	15.10	
Mean	5.01	15.06	
Standard deviation	0.127	0.175	
Coefficient of variation	0.025	0.012	
95% Confidence interval	4.76 - 5.27	14.71 - 15.41	
Relative error	0.9%	0.3%	

Table 3. (cont). Summary of quality assurance data from water quality laboratory SUNY at Brockport, Brockport, NY. May 1987 - May 1988.

Chloride (mg/L)		
Number	40	13
True value	26.49	27.93
Mean	25.40	29.38
Standard deviation	1.451	0.900
Coefficient of variation	0.055	0.032
95% Confidence interval	22.50 - 28.31	27.58 - 31.18
Relative error	4.3%	4.9%
Sulfate (mg/L)		
Number	21	32
True value	18.6	30.1
Mean	19.2	28.5
Standard deviation	1.739	1.563
Coefficient of variation	0.093	0.052
95% Confidence interval	15.7 - 22.6	25.4 - 31.7
Relative error	3.0%	5.5%
Dissolved reactive silica (ug SiO_2/L)		
Number	22	31
True value	400	900
Mean	400.2	899.6
Standard deviation	8.238	9.715
Coefficient of variation	0.021	0.011
95% Confidence interval	383.71 - 416.66	880.15 - 919.01
Relative error	0.05%	0.05%
Total phosphorus (ug P/L)		
Number	28	25
True value	24.8	37.2
Mean	22.4	33.4
Standard deviation	3.122	2.941
Coefficient of variation	0.126	0.079
95% Confidence interval	16.1 - 28.6	27.5 - 39.2
Relative error	10.9%	11.5%
Soluble reactive phosphorus (ug P/L)		
Number	29	23
True value	5.0	24.0
Mean	4.9	24.5
Standard deviation	1.641	2.993
Coefficient of variation	0.328	0.125
95% Confidence interval	1.6 - 8.2	18.5 - 30.5
Relative error	1.8%	1.9%
Nitrate + nitrite (mg N/L)		
Number	29	19
True value	0.40	1.60
Mean	0.39	1.59
Standard deviation	0.037	0.056
Coefficient of variation	0.092	0.035
95% Confidence interval	0.32 - 0.47	1.48 - 1.70
Relative error	1.9%	0.7%

RESULTS and DISCUSSION

SODUS BAY TRIBUTARY DATA (5 April - 28 June 1988):

Stream Height and Discharge (Figure 2-6)

The relationship between stream height and cross-sectional area of the stream at a given stream height is shown in Figures 2-4. The lines fit to the points are by polynomial interpolation rather than regression. Regression essentially smooths out variability in an X/Y coordinate system while interpolation fits points between actual measurements. In a creek with an undulating bottom, such as those worked on here, interpolation would provide a better estimate of area. The range, mean and standard error in stream height are given in Table 4. Weekly stream heights are presented in Figure 5.

Mean daily discharge values (m^3/sec) in descending order were Sodus Creek East (0.30), Second Creek (0.17), Third Creek (0.10), Sodus Creek West (0.10), First Creek (0.04) and Clark Creek (0.01) (Table 4). Weekly discharge is presented in Figure 6. Although calculated, discharge data for First Creek were compromised. Beaver activity below our sampling station reduced the flow through the sampling culvert to below the detectable level of the Gurley Pygmy meter on 11 of the 13 sampling dates.

Temperature (Figure 7)

The general increase in stream temperature reflects the increase in air temperature as the summer season approaches. Range and variability of temperature in all locations were very similar and no significant differences between streams ($p>0.05$) were observed (Table 4).

Table 4. Summary of physical and chemical parameters (5 April 1988 - 28 June 1988, n = 13) for First, Second, Third, Clark, Sodus West, and Sodus East Creeks.

MEAN ± S.E. (RANGE)

	FIRST	SECOND	THIRD	CLARK	SODUS WEST	SODUS EAST
Temperature (Celsius)	14.7 ± 1.6 (6.0-23.2)	15.3 ± 1.4 (7.5 - 23.0)	14.9 ± 1.5 (7.3 - 22.0)	12.7 ± 1.2 (6.0 - 18.0)	13.3 ± 1.2 (5.5 - 19.2)	14.3 ± 1.4 (6.5 - 21.8)
Stream Height (centimeters)	109.01 ± 2.70 (176.53 - 206.38)	207.16 ± 3.05 (179.07 - 221.62)	231.24 ± 2.12 (212.09 - 240.03)	91.15 ± 1.94 (80.01 - 110.49)	277.89 ± 1.40 (265.43 - 287.66	280.33 ± 2.76 (251.46 - 289.56)
pH	7.84 ± 0.058 (7.40 - 8.09)	8.21 ± 0.054 (7.70 - 8.45)	8.00 ± 0.037 (7.79 - 8.21)	7.93 ± 0.029 (7.75 - 8.10)	8.11 ± 0.025 (7.95 - 8.26)	8.25 ± 0.047 (8.06 - 8.58)
Alkalinity (mg $CaCO_3$/L)	152.84 ± 5.93 (107.59 - 189.07)	197.55 ± 6.85 (138.04 - 237.15)	175.68 ± 8.28 (111.65 - 232.30)	119.83 ± 5.88 (71.05 - 152.31)	139.92 ± 5.98 (87.29 - 162.41)	202.08 ± 4.40 (154.28 - 217.35)
Conductivity (umhos/cm)	462 ± 16 (379 - 572)	555 ± 31 (371 - 742)	421 ± 16 (302 - 500)	277 ± 12 (171 - 322)	314 ± 17 (184 - 395)	518 ± 12 (402 - 569)
Turbidity (NTU)	6.14 ± 0.59 (2.41 - 10.30)	3.22 ± 0.68 (1.20 - 11.00)	6.43 ± 0.90 (2.32 - 12.90)	5.19 ± 0.74 (1.88 - 10.90)	3.42 ± 0.70 (1.68 - 10.80)	5.49 ± 1.32 (2.54 - 18.60)
Dissolved oxygen (mg/L)	9.2 ± 0.74 (5.0 - 13.3)	10.6 ± 0.28 (9.2 - 12.6)	9.5 ± 0.58 (6.4 - 12.4)	10.1 ± 0.26 (8.7 - 11.5)	10.3 ± 0.26 (8.4 - 11.7)	11.1 ± 0.39 (9.2 - 13.3)
Calcium (mg/L)	48.20 ± 1.70 (31.90 - 58.18)	62.57 ± 2.47 (37.20 - 71.77)	55.89 ± 1.80 (36.90 - 61.90)	37.62 ± 1.64 (22.30 - 44.45)	43.31 ± 1.91 (24.80 - 50.69)	61.84 ± 1.57 (45.20 - 67.76)
Magnesium (mg/L)	12.55 ± 0.80 (7.08 - 17.78)	15.38 ± 0.81 (8.32 - 18.76)	14.20 ± 0.93 (8.56 - 20.54)	9.78 ± 0.48 (6.14 - 12.75)	11.49 ± 0.78 (6.09 - 16.83)	18.54 ± 0.75 (11.61 - 23.30)
Potassium (mg/L)	1.75 ± 0.055 (1.54 - 2.08)	2.54 ± 0.303 (1.41 - 4.60)	1.40 ± 0.045 (1.20 - 1.73)	1.13 ± 0.033 (0.96 - 1.33)	1.24 ± 0.075 (0.88 - 1.73)	2.03 ± 0.132 (1.59 - 3.17)
Sodium (mg/L)	22.77 ± 1.20 (17.50 - 32.60)	27.26 ± 3.99 (14.60 - 56.39)	9.37 ± 0.80 (6.21 - 18.02)	3.40 ± 0.13 (2.42 - 4.18)	4.08 ± 0.25 (2.80 - 6.17)	13.81 ± 0.73 (8.12 - 17.76)
Chloride (mg/L)	39.03 ± 1.33 (35.34 - 52.41)	39.95 ± 3.82 (25.81 - 69.88)	19.10 ± 1.33 (13.90 - 33.75)	7.18 ± 0.31 (5.66 - 9.13)	9.31 ± 0.63 (5.96 - 13.50)	25.50 ± 0.91 (20.15 - 31.37)
Sulfate (mg/L)	28.8 ± 0.6 (24.8 - 32.2)	29.4 ± 1.1 (23.4 - 35.5)	31.1 ± 0.7 (27.0 - 35.2)	22.4 ± 0.3 (20.9 - 24.3)	21.2 ± 1.0 (18.1 - 27.9)	37.9 ± 1.0 (32.2 - 44.2)
Dissolved reactive silica (mg SiO_2/L)	5.0 ± 0.66 (1.9 - 9.5)	3.2 ± 0.42 (1.2 - 5.7)	5.2 ± 0.67 (2.6 - 11.4)	7.2 ± 0.67 (4.2 - 11.5)	4.7 ± 0.80 (2.0 - 11.2)	5.9 ± 0.82 (2.6 - 13.0)
Total phosphorus (ug P/L)	51.9 ± 8.1 (20.0 - 105.2)	38.2 ± 4.4 (16.7 - 65.0)	41.8 ± 5.4 (17.7 - 77.5)	36.6 ± 4.1 (14.0 - 56.4)	24.9 ± 1.4 (15.2 - 36.6)	48.0 ± 5.5 (25.3 - 79.0)
Soluble reactive phosphorus (ug P/L)	20.1 ± 3.7 (3.9 - 45.2)	24.7 ± 4.4 (2.5 - 47.3)	20.8 ± 3.4 (2.1 - 42.7)	25.5 ± 3.8 (5.3 - 48.4)	17.5 ± 2.4 (2.1 - 28.5)	34.3 ± 4.9 (7.1 - 60.9)
Nitrate + nitrite (mg/L)	0.30 ± 0.080 (0.01 - 1.10)	0.51 ± 0.037 (0.20 - 0.81)	0.44 ± 0.025 (0.25 - 0.60)	0.58 ± 0.061 (0.26 - 1.01)	0.55 ± 0.082 (0.14 - 1.08)	0.66 ± 0.056 (0.29 - 1.07)

pH (Figure 8)

Mean daily values of stream pH in descending order were 8.25 (Sodus East), 8.21 (Second), 8.11 (Sodus West), 8.00 (Third), 7.93 (Clark) and 7.84 (First) (Table 4). Variability within each stream over the sampling period was relatively low.

Turbidity (Figure 9)

Turbidity is caused by suspended matter in the water and is an expression of the optical property that causes light to be scattered. Mean daily turbidity levels in the creeks ranged from 3.22 NTU (Second Creek) to 6.42 NTU (Third Creek) (Table 4) during the study period. Because of the high variability within each creek, there were no significant differences ($p>0.05$) between creeks.

Alkalinity (Figure 10)

Alkalinity is a measure of acid neutralizing capacity of the water. Daily mean alkalinity varied considerably between creeks (Table 4). Mean daily alkalinity values (mg $CaCO_3/L$) in descending order within the streams were 202.08 (Sodus East), 197.55 (Second), 175.68 (Third), 152.84 (First), 139.84 (Sodus West) and 119.83 (Clark). Concentrations of $CaCO_3$ in the streams were directly related to the area of the watershed they drain (Table 5). Watershed area accounted for over 90% ($r^2 = 0.900$) of the variability in alkalinity (Fig. 11). Within each creek, alkalinity remained relatively constant although each showed a slight upward trend during the sample period.

Conductivity (Figure 12)

Conductivity is an expression of the ability of water to conduct an electrical current, which is quantitatively dependent upon the presence of ions and the temperature of the stream water. Daily mean conductivity values were significantly lower ($p<0.05$) in Clark Creek and Sodus West Creek than in the other four creeks studied (Table 4). Conductivity, as alkalinity, is also directly related to watershed area (Fig. 11). Watershed area accounted for over 75% (r^2 = 0.752) of the variability in conductivity. If First Creek is eliminated from the analysis, the correlation coefficient (r^2) improves to 0.901. Relative to the size of its watershed, First Creek has an abnormally high conductivity, which suggests possible anthropogenic sources of materials within the watershed.

Table 5. Relationship between watershed area and alkalinity and conductivity for First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West and Sodus Creek East for the period 5 April to 28 June 1988. Watershed area is the area upstream from the sampling station.

Creek	Watershed Area (ha)	Alkalinity (mg $CaCO_3$/L)	Conductivity (umhos/cm)
First	893	152.84	462
Second	2610	197.55	555
Third	1185	175.68	421
Clark	155	119.83	277
Sodus West	820	139.92	314
Sodus East	3065	202.08	518

Dissolved Oxygen (Figure 13)

Mean daily stream concentrations of dissolved oxygen (mg/L) were in descending order: Sodus East (11.1), Second (10.6), Sodus West (10.3), Clark (10.1), Third (9.5) and First (9.2) (Table 4). Oxygen concentrations were not significantly different ($p>0.05$) between streams. The solubility of oxygen in water decreases with increasing temperature which accounts for the decreasing trend during the study (Fig. 13). The relatively high mean concentration of dissolved oxygen (10.1 mg/L) for all streams suggests that there were no major sources of organic matter being loaded into these streams. An exception is First Creek which shows periodic dips in dissolved oxygen that correlate with total phosphorus concentrations ($r^2 = 0.830$) (Fig. 14). There appears to be sufficient organic material in the stream to raise total phosphorus levels and lower dissolved oxygen concentrations through decomposition.

Calcium (Figure 15)

Mean daily values of calcium (mg/L) in descending order were 62.57 (Second Creek), 61.84 (Sodus Creek East), 55.89 (Third Creek), 48.20 (First Creek), 43.31 (Sodus Creek West) and 37.62 (Clark Creek) (Table 4). Calcium increased in all streams during April before stabilizing for the rest of the Spring.

Magnesium (Figure 16)

Mean daily values of magnesium (mg/L) in descending order were 18.54 (Sodus Creek East), 15.38 (Second Creek), 14.20 (Third Creek), 12.55 (First Creek), 11.49 (Sodus Creek West) and 9.78 (Clark Creek) (Table 4). Magnesium generally increased in all streams during the study period.

Potassium (Figure 17)

Potassium daily means (mg/L) in descending order were 2.54 (Second Creek), 2.03 (Sodus Creek East), 1.75 (First Creek), 1.40 (Third Creek), 1.24 (Sodus Creek West) and 1.13 (Clark Creek) (Table 4). An increase in potassium occurred in Second Creek in June. This appears to correlate with low discharge.

Sodium (Figure 18)

Daily mean values of sodium (mg/L) ranged from 3.40 (Clark Creek) to 27.26 (Second Creek) (Table 4). First (22.77) and Second Creeks were significantly higher ($p<0.05$) than all the other streams sampled (Sodus East [13.81], Third [9.37], Sodus West [4.08] and Clark).

The increase in sodium on 17 May at Third Creek is difficult to explain. The increase in sodium does correlate with an increase in chloride (Fig. 19).

Over 2.54 cm of rain fell in the week preceding the increase in sodium and chloride. However, the high air temperature (~10 to 15°C) suggests that deicing salt was not applied to roads within the watershed. Since a similar peak was not observed in the other creeks (Fig. 18), a source of salt, that was washed into the stream during this meteorological event, may have existed within the watershed.

The increase of sodium in Second Creek at the end of June correlates well with a similar increase in potassium and chloride at this site. These increases are correlated with low discharge during this period. Without more information it is difficult to conclude cause and effect. This may represent base flow conditions whereby flow and chemical composition are possibly affected by springs.

Chloride (Figure 19)

The six creeks paired off into three distinct groups with respect to chloride (Table 4). The three pairs in descending order of daily means (mg/L) were First and Second (39.03, 39.95), Sodus East and Third (25.50, 19.10) and Sodus West and Clark (9.31, 7.18). Each pair was significantly different ($p<0.05$) than the other four creeks.

The increase in chloride on 17 May in Third Creek and the increase in chloride in Second Creek in June are both discussed under sodium.

Sulfate (Figure 20)

Daily mean values (mg/L) for Sodus East (37.9) were significantly higher ($p<0.05$) than for the other five creeks (Third [31.1], Second [29.4], First [28.8], Clark [22.4] and Sodus West [21.2]) (Table 4). No obvious weekly pattern was observed.

Dissolved Reactive Silica (Figure 21)

Mean daily concentrations were significantly different ($p<0.05$) between the creeks with the highest and lowest concentration (Second Creek [3.2 mg

SiO_2/L] and Clark Creek [7.2 mg SiO_2/L]) (Table 4). Concentrations of silica were not significantly different ($p>0.05$) between the other streams monitored. Silica showed a definite upward trend in all creeks during the sample period.

Soluble Reactive Phosphorus and Total Phosphorus (Figure 22 and 23)

Concentrations of total phosphorus (48.0 ug P/L) and soluble reactive phosphorus (34.3 ug P/L) in Sodus East and concentrations of total phosphorus (51.9 ug P/L) in First Creek were significantly higher ($p<0.05$) than in the other creeks monitored (Table 4). Both parameters showed an upward trend during the study.

Nitrate + Nitrite (Figure 24)

Concentrations of nitrate (mg N/L) in streams were in descending order: 0.66 (Sodus Creek East), 0.58 (Clark Creek), 0.55 (Sodus Creek West), 0.51 (Second Creek), 0.44 (Third Creek) and 0.30 (First Creek) (Table 4). During the study period, Sodus Creek West, Sodus Creek East and Clark Creek had an increase in nitrate levels. Nitrate in First Creek, Second Creek and Third Creek fluctuated during the study period but had no obvious pattern.

SUMMARY OF SODUS BAY TRIBUTARY DATA

Statistical analysis of mean daily levels of tributary parameters demonstrated that Clark Creek had the minimum level for eight of the parameters measured (temperature, alkalinity, conductivity, calcium, magnesium, potassium, sodium and chloride) and the maximum level for one parameter (silica). Sodus Creek East had the maximum daily mean of seven parameters (pH, alkalinity, dissolved oxygen, magnesium, sulfate, soluble reactive phosphorus and nitrate). The differences between the two creeks are probably related to watershed usage and size. Clark Creek, which generally has the lowest concentration of ions, is almost completely forested and has the smallest watershed area. Sodus Creek East, on the other hand, has the largest watershed area and generally has the highest daily mean concentration of ions.

First Creek shows evidence (low dissolved oxygen, low pH, high turbidity, relatively high total phosphorus) of a source or sources of organic loading. Causes could include agricultural runoff, industrial discharge and/or leaching from septic systems. This problem should be investigated further. First and Second Creeks are also significantly higher in both sodium and chloride concentrations. These differences are probably related to usage of deicing salts on roadways in these watersheds. In general, Second Creek had the highest concentration of metals.

The trend of increased levels of nutrients in the streams (especially phosphorus) during the study period is interesting. It may be caused by increased agricultural activity in the spring (either tillage or fertilization). However, the data suggest that fertilization is the most likely cause because tillage would have cause increased turbidity levels which was not the case.

SODUS BAY (15 AUGUST 1988):

Bathymetric Data:

The hypsographic area curve for Sodus Bay is presented in Figure 25. Sodus Bay is generally shallow (38% of the surface area is above 1 meter of depth) with a surface area of approximately 13.79 km^2 (Table 6). The mean depth (volume / surface area) is 5.2 m.

Table 6. Bathymetric data for Sodus Bay.

Depth Range (ft)	Mean Depth (ft)	Mean Depth (m)	Surface area (km^2)	Volume (m^3X10^6)
0	0	0.00	13.79	0.0
0 - 6	3	.91	3.44	3.2
6 - 12	9	2.74	1.96	5.4
12 - 18	15	4.57	2.29	10.5
18 - 24	21	6.40	1.47	9.4
24 - 30	27	8.23	2.33	19.2
30 - 36	33	10.06	1.91	19.2
36 - 40	39	11.89	0.27	3.2
40 - 46	43	13.11	0.11	1.4
46 - 48	47	14.33	0.01	0.08
			Total	71.5

Vertical Profile: (Figures 26, 27 and 28)

Thermal stratification was evident by 15 August 1988. However, because of the high temperature of the hypolimnion (18.4 ^oC), it is obvious that the Bay can and has mixed during the summer. By 15 August 1988, hypolimnetic oxygen values were close to zero (0.7 mg/L). As expected with low oxygen concentrations in the hypolimnion, total phosphorus and soluble reactive phosphorus increased dramatically. Similarly, pheophytin increased in the deeper waters while chlorophyll peaked in the epilimnion (3 m). Nitrate was non-detectable throughout the water column. Vertical profiles of other parameters are presented in Figures 26, 27 and 28.

GEOGRAPHICAL COMPARISONS WITHIN SODUS BAY

Temperature:

Temperature deviated less than two degrees Celsius for all stations on Sodus Bay (Table 7). The minimum (25.85^{o}C) was observed at Station 2. This may be a result of mixing of hypolimnetic water with surface water due to strong west winds (25-35 mph) on the sampling day. The shallowest station, not influenced by a tributary (Station 3), had the maximum temperature 27.62^{o}C.

pH:

pH ranged from 7.57 (Station 4) to 8.64 (Station 10) (Table 7). The low pH at Station 4 is probably due to the discharge from First Creek. This creek had the lowest mean daily pH value (7.84) of all the tributaries during the April through June tributary monitoring.

Turbidity:

The mean turbidity level of Sodus Bay water was 4.24 NTU (Table 7). Station 6, which is located 50 meters west of a marina, had the highest turbidity reading (8.85 NTU) on the Bay.

Alkalinity:

Alkalinity (mg $CaCO_3$/L) ranged from 84.70 (Station 6) to 109.73 (Station 12) (Table 7). The high values at Station 12 in the Bay may be attributed to the discharge from Sodus Creek which had the highest alkalinity value of all the tributaries.

Conductivity:

Conductivity (umhos/cm) ranged from 249 (Station 9) to 309 (Station 4) (Table 7). The high conductivity at Station 4 is due to high sodium and chloride concentrations which are related to sodium and chloride discharge from the watershed (Table 4).

Dissolved Oxygen:

Station 4 had the lowest mean dissolved oxygen concentration (4.7 mg/L) (Table 7). Station 4 receives water from First Creek which had fluctuating oxygen values during the spring monitoring of the streams. All other stations had at least 6.0 mg/L of dissolved oxygen with a maximum of 8.0 mg/L at Stations 8 and 10. The low concentration of dissolved oxygen at Station 4 suggests that a source of organic matter exists within the watershed of First Creek.

Calcium:

Levels of calcium ranged from 24.88 mg/L (Station 11) to 33.56 mg/L (Station 4) (Table 7).

Magnesium:

Magnesium ranged from 7.55 (Station 5) to 9.90 mg/L (Station 12) (Table 7). Geographically, magnesium varies within Sodus Bay. Four of the five highest concentrations of sodium recorded were in a south to north gradient beginning at the mouth of Sodus Creek. Sodus Creek East appears to be the source of the magnesium as magnesium levels were high (18.54 mg/L) in this stream during the April through June monitoring.

Potassium:

Potassium varied only 0.53 mg/L throughout Sodus Bay. Levels ranged from 1.29 mg/L (Station 11 - mouth of Clark Creek) to 1.82 mg/L (Station 12 - mouth of Sodus Creek) (Table 7).

Sodium and Chloride:

Sodium and chloride ranged from 10.51 to 13.34 mg Na/L and 22.19 to 27.02 mg Cl/L at Stations 11 and 4, respectively (Table 7). Once again, tributary waters seem to influence Bay stations. Clark Creek, which during April through June had the lowest mean daily level of sodium (3.40 mg/L) and chloride (7.18 mg/L) of all Sodus Bay tributaries, empties into the Bay at Station 11. Station 4 receives water from First Creek which had the second highest sodium and chloride tributary levels.

Sulfate:

Sulfate varied only 3.4 mg/L throughout Sodus Bay (range: 22.4 to 25.8 mg/L) (Table 7).

Dissolved Reactive Silica:

Silica (mg SiO_2/L) ranged from 0.6 (Station 6) to 4.2 (Station 4) (Table 7).

Soluble Reactive Phosphorus and Total Phosphorus:

Total phosphorus within the open waters of Sodus Bay averaged ~50 ug/L, except for Stations 2,4 and 12. Stations 4 and 12 receive water directly from First Creek and Sodus Creek, respectively. Both these creeks had high total phosphorus values during the spring monitoring (Table 4). The highest epilimnetic concentrations of soluble reactive and total phosphorus were found at Station 2. Station 2 is exposed to winds from the west and is located in a sub-basin of Sodus Bay. High winds and waves, experienced only at this site during the August sampling, may have eroded the hypolimnion and affected water chemistry. Mixing of epilimnion and hypolimnion water would result in lower temperatures, high soluble reactive and total phosphorus levels, low chlorophyll concentrations, high pheophytin levels, low dissolved oxygen concentration and low secchi disk readings in the epilimnion.

Nitrate + Nitrite:

No detectable levels (detection limit 0.02 mg N/L) of nitrate were found at any of the stations on Sodus Bay (Table 7).

Fecal Coliforms:

Fecal coliforms are indicators of the probable presence of human sewage in the water. Fecal coliform samples were taken at Stations 3, 6, 12 and results are given in Table 8. Station 6 was the only sample that contained colonies of fecal coliforms (41 colonies/100 ml). Although coliforms were present, this level is well below the cutoff for primary contact recreational water (200 colonies/100 ml) and a public water supply (2000 colonies/100ml) with treatment (EPA 1978).

Sediments:

Sediment size was classified following the Wentworth scale. All sediments collected from Sodus Bay would be considered silt (Table 9). Sodium, within the sediments, ranged from 40 mg Na/kg (Station 8) to 165 mg Na/kg (Station 12).

Total kjeldahl nitrogen (TKN) (mg N/kg) ranged from 1210 (Station 8) to 14,090 at Station 11 in Sodus Bay (Table 10). TKN values at Stations 4,8 and 12 fall within the range of values observed in Sodus Bay in 1968 and in Irondequoit Bay, NY. (Table 11). The exceptionally high values at Station 7 (10,640 mg N/L) and Station 11 (14,090 mg N/L) are comparable to those observed in Chemung Lake, Canada (Table 12). Both Stations 7 and 11 had heavy infestations of aquatic macrophytes. Nitrogen and phosphorus levels have been shown to be substantially higher in sediment with macrophytes (Muztar *et al.* 1978)

Table 7. Physical and chemical parameters from 1 meter depths on Sodus Bay sampled on 15 August 1988. TP= total phosphorus, SRP= Soluble reactive phosphorus, CHL= chlorophyll a, PHEO= pheophytin, TEMP= temperature, DO= dissolved oxygen, COND= conductivity, S.Disk= secchi disk depth.

STATION	Chloride (mg/L)	Sulfate (mg/L)	Silica (mg SiO_2/L)	TP (ug P/L)	Nitrate (mg N/L)	SRP (ug P/L)
1	23.50	25.2	1.61	31.7	N.D.	8.1
2	22.68	24.9	2.85	130.3	N.D.	93.0
3	23.09	23.0	3.96	68.9	N.D.	5.8
4	27.02	22.4	4.20	109.3	N.D.	34.1
5	23.01	25.6	1.42	36.6	N.D.	10.7
6	23.75	25.2	0.61	59.1	N.D.	7.7
7	23.26	25.7	1.38	42.4	N.D.	18.9
8	22.60	23.6	1.31	46.6	N.D.	10.3
9	23.01	25.8	1.56	49.9	N.D.	14.4
10	23.26	25.2	1.42	48.7	N.D.	9.2
11	22.19	23.0	3.69	68.1	N.D.	25.6
12	24.48	24.2	1.15	94.1	N.D.	46.1

STATION	CHL (ug/L)	PHEO (ug/L)	TEMP (^oC)	DO (mg/L)	pH	Alkalinity (mg/L)
1	15.9	0.0	27.00	7.4	8.35	89.51
2	11.6	21.8	25.85	6.0	8.17	98.18
3	41.3	9.8	27.62	7.0	8.34	92.40
4	26.8	8.9	26.48	4.7	7.57	108.76
5	13.8	0.0	26.12	7.3	8.15	88.94
6	21.9	13.4	26.75	7.2	8.44	84.70
7	14.3	2.5	26.69	6.4	7.99	90.48
8	15.3	10.5	26.10	8.0	8.62	92.40
9	22.2	1.8	26.95	7.1	8.47	96.25
10	20.1	8.6	27.25	8.0	8.64	92.40
11	15.9	7.6	26.90	7.6	8.61	92.40
12	77.6	32.6	26.95	7.5	8.38	109.73

STATION	COND (umhos/cm)	S. Disk (meter)	Turbidity (NTU)	Potassium (mg/L)	Sodium (mg/L)	Magnesium (mg/L)	Calcium (mg/L)
1	253	1.15	4.47	1.77	11.60	7.61	27.15
2	268	1.00	3.96	1.78	11.47	8.07	30.02
3	260	0.95	4.71	1.65	11.15	8.02	27.18
4	309	0.62	4.73	1.77	13.34	9.34	33.56
5	260	1.82	3.00	1.71	12.27	7.55	28.45
6	249	0.98	8.85	1.42	11.52	7.78	26.57
7	272	1.31	1.98	1.38	10.75	7.90	28.68
8	268	Bottom	3.86	1.60	11.10	7.76	28.45
9	248	1.30	3.49	1.70	10.78	8.11	27.40
10	265	1.18	4.51	1.44	10.63	8.51	29.10
11	255	Bottom	2.86	1.29	10.51	8.25	24.88
12	295	0.74	4.52	1.82	13.06	9.90	32.66

Table 8. Results of fecal coliform sampling in Sodus Bay on 15 August 1988.

	Colonies/100ml
Station 3	< 1
Station 6	41
Station 12	< 1

Unlike TKN, total phosphorus in the sediments was highest at Station 4 near the mouth of First Creek, which suggests a source of phosphorus within the watershed of First Creek. Within the Bay, total phosphorus in the sediments ranged from 400 to 1,060 mg P/kg which falls in the range observed in Irondequoit Bay (Table 11) and in previous work at Sodus Bay (Table 12).

The EPA guidelines for the evaluation of Great Lakes harbor sediment are presented in Table 10. Based on this classification system, sediments at the mouths of tributary streams of Sodus Bay would be considered moderately to heavily polluted.

Table 9. Sediment size classification from samples collected at the mouths of Sodus Bay tributaries. Size class structure follows the Wentworth scale.

Station	Percent coarse sand	Percent medium sand	Percent fine sand	Percent very fine sand	Percent silt
4	0.0	7.4	8.3	14.9	69.4
7	0.0	0.8	6.0	4.2	89.1
8	0.0	1.7	8.6	25.7	63.9
11	0.0	0.5	21.2	4.8	73.5
12	0.4	11.2	14.3	1.3	72.9

Table 10. A. EPA guidelines for the evaluation of Great Lakes harbor sediments (Great Lakes Water Quality Board 1982). B. Sodium, TKN and TP results for sediments from selected stations on Sodus Bay. TKN = Total kjeldahl nitrogen, TP = Total phosphorus. All concentrations are expressed as dry weight.

A.

	Total Kjeldahl Nitrogen (mg/kg)	Total Phosphorus (mg/kg)
Nonpolluted	<1000	< 420
Moderately polluted	1000 - 2000	420 - 655
Heavily polluted	>2000	> 650

B.

Station	Sodium (mg Na/gm)	TKN (mg N/kg)	TP (mg P/kg)
4	165	6,840	1,060
7	250	10,640	630
8	40	1,210	910
11	159	14,090	480
12	165	2,740	400
Mean	155.8	7,140	696

Macrophytes:

Detectable levels of chlorinated hydrocarbons were not observed in macrophytes from Port and East Bays (Table 13). The mineral content of aquatic plants harvested in Sodus, Port and East Bays is presented in Table 14. In general, the levels of sodium, potassium, magnesium, calcium, phosphorus and copper in macrophytes from Sodus, Port and East Bays were similar to those reported for a mixture of Myriophyllum sp., Vallisneria sp., Elodea sp., Ceratophyllum sp. and Najas sp. from Chemung Lake, Canada (Table 15). The levels of copper, cadmium, lead, magnesium, sodium and total phosphorus were, in general, relatively low and fluctuated between sites but did not show any trend (Table 14). Calcium levels were substantially higher in macrophytes from Stations 8 and 11 in Sodus Bay, while total nitrogen (TKN) was substantially higher in macrophytes from East Bay compared to Port Bay. We have no explanation for these differences except to note that in rooted macrophytes the principal source of several minerals and nutrients, particularly nitrogen and phosphorus, appears to be the sediment (Filbin and Barko 1985). The higher calcium and nitrogen levels in macrophytes at some Stations within Sodus Bay suggest a high content of this ion in the sediment. Similarly, sodium concentrations in macrophytes correlate (r=0.986) with sodium loadings from tributaries adjacent to the Sodus Bay sampling stations. Macrophytes are known to take up sodium from the water column (Muztar *et al.* 1978).

Table 11. Total kjeldahl nitrogen and total phosphorus concentrations in sediments of Irondequoit Bay, N.Y. Data from USEPA 1976.

Total Kjeldahl Nitrogen (mg/kg)	Total Phosphorus (mg/kg)
7000	1300
950	170
1100	170
430	350
370	300
680	340
350	170
1000	170
580	160
300	100
820	140
670	110

Alfalfa is a terrestrial legume and because of its widespread use for feeding cattle, it is a logical reference material with which to compare the aquatic macrophytes. Compared with alfalfa, aquatic macrophytes contained much higher levels of calcium and sodium but slightly lower levels of potassium (Table 15). Phosphorus, magnesium and copper content were generally lower in the aquatic plants than in alfalfa. These data suggest that macrophytes from Sodus, East and Port Bays could be safely used as animal fodder.

Table 12. Total kjeldahl nitrogen and total phosphorus concentrations in Chemung Lake and Sodus Bay.

	Total Phosphorus (mg/kg)	Total Kjeldahl Nitrogen (mg/kg)
Chemung Lake [1]	1,000 - 1,900	13,000 - 27,000
Sodus Bay [2]	1,970	2,270

1 (Muztar *et al.* 1978)

2 (GLWQB 1982)

Table 13. Analysis of selected chlorinated hydrocarbons on macrophytes from East Bay and Port Bay collected on 15 August 1988. Results are on a wet weight basis (ug/kg).

Parameter	East Bay (ug/kg)	Port Bay (ug/kg)
Alpha - BHC	<0.02	<0.02
Lindane	<0.02	<0.02
Beta - BHC	<0.02	<0.02
Heptachlor	<0.02	<0.02
Aldrin	<0.02	<0.02
Heptachlor Epoxide	<0.02	<0.02
p,p' - DDE	<0.02	<0.02
Endo Sulfan I	<0.04	<0.04
Endrin	<0.02	<0.02
p,p' - DDD	<0.02	<0.02
p,p' - DDT	<0.02	<0.02
Endrin Aldehyde	<0.02	<0.02

Table 14. Results of macrophyte analyses on samples taken from selected stations on Sodus Bay and from East and Port Bays. All concentrations are expressed as dry weight. TKN = total kjeldahl nitrogen, TP = total phosphorus, Na = sodium, K = potassium, Ca = calcium, Mg = magnesium, Pb = lead, Cd = cadmium, Cu = copper.

	STATION 4	7	8	11	12	SODUS MEAN	EAST BAY	PORT BAY
TKN (mg N/gm)	10.2	10.6	6.7	4.1	3.9	7.1	47.2	14.9
TP (mg P/gm)	1.7	1.5	0.5	1.5	0.5	1.1	0.7	2.7
Na (mg/gm)	2.4	5.4	2.9	2.0	6.2	3.8	5.2	3.2
K (mg/gm)	3.6	8.2	5.4	1.8	8.0	5.4	9.8	11.2
Ca (mg/gm)	18.7	16.7	135.4	100.1	25.5	59.3	41.5	27.7
Mg (mg/gm)	2.4	2.5	3.8	3.7	2.6	3.0	3.7	5.3
Pb (ug/gm)	1.8	2.7	1.9	2.6	1.3	2.1	1.6	1.0
Cd (ug/gm)	3.3	2.0	2.2	1.7	2.0	2.2	6.4	2.1
Cu (ug/gm)	10.8	5.3	5.0	9.7	0.5	6.3	0.7	7.5

Table 15. Comparison of mineral composition of aquatic macrophytes in Sodus Bay, Port Bay, East Bay and Chemung Lake to alfalfa (*Medicago sativa*). Adapted from Muztar *et al.* (1978). Ca = calcium, P = phosphorus, Na = sodium, K = potassium, Mg = magnesium, Cu = copper.

	Alfalfa	Chemung Lake mixture [1]	Sodus Bay	Port Bay	East Bay
Ca (%)	1.63	8.89	5.93	4.15	2.77
P (%)	0.29	0.19	0.11	0.07	0.27
Na (%)	0.10	1.16	0.38	0.52	0.32
K (%)	2.71	1.39	0.54	0.98	1.12
Mg (%)	0.38	0.53	0.30	0.37	0.53
Cu (ppm)	11.4	4.43	6.3	0.7	7.5

[1] *Myriophyllum* sp., *Vallisneria* sp., *Elodea* sp., *Ceratophyllum* sp. and *Najas* sp. were mixed in the ratio of 40:30:10:10:10 by wet weight respectively

STREAM LOADING TO SODUS BAY:

Table 16 presents loadings of total phosphorus, soluble reactive phosphorus, nitrate and sodium. Because the data represent grab samples, they need to be viewed with some caution. The loading data would be improved considerably when seasonal chemistry and daily discharge from regressions based on continuous stage height recordings become available. Crude estimates of annual loadings can be derived by multiplying values from Table 16 by 365.

Sodium:

Major losses of sodium from the watershed occurred during the study period (Table 16). Sodium is the major constituent of deicing salt. Clark Creek had the lowest loading of sodium probably because it is the only watershed studied that does not cross Route 104. Route 104 is the major highway in the area and would be expected to contribute high levels of sodium and chloride (due to deicing salt) to watersheds that intersect it.

Nutrients:

Of the six creeks monitored during the spring, Sodus East was the major contributor of nutrients to Sodus Bay (Table 16). Sodus Creek (East and West) accounted for 61.6% and 58% of the total phosphorus and nitrate, respectively, entering Sodus Bay. Thus, it is not surprising that an extensive macrophyte community exists at the mouth of Sodus Creek which extends well into the Bay. Similarly, Second Creek, which had the second highest loading of total phosphorus (20.2%), has a large macrophyte community at its mouth.

The various creeks of the Irondequoit Bay watershed (Monroe County, NY.) have been identified as grossly polluted prior to remedial action (O'Brien and Gere 1983). Similarly, Northrup Creek (central Monroe County), which receives effluent from a sewage treatment plant, is known to be polluted and to posses a higher loading of phosphorus than creeks in the Irondequoit Bay watershed (Makarewicz 1988). A comparison of Sodus Bay tributaries to Monroe County creeks is instructive in identifying the relative condition of creeks entering Sodus Bay (Table 17). Compared to the suburban and urban watersheds of Monroe County, the tributaries of Sodus Bay contribute relatively small amounts of phosphorus. However, when Sodus East and West are combined, the impact of this creek on Sodus Bay is comparable to phosphorus loadings from the central basin of Irondequoit Creek prior to remedial action.

Table 16. Average daily loadings for sampling days (n=13) of selected parameters from First, Second, Third, Clark, Sodus East and Sodus West Creeks. A crude estimate of annual loading may be derived by multiplying by 365. TP = total phosphorus, SRP = soluble reactive phosphorus, NO_3 = nitrate, Na = sodium.

A.

	TP g P/d	SRP g P/d	NO_3 kg N/d	Na kg Na/d
FIRST	120	30	2.14	85
SECOND	492	193	7.47	260
THIRD	293	140	3.72	78
CLARK	30	17	0.47	4
SODUS WEST	235	134	3.11	31
SODUS EAST	1,264	808	16.03	333

B.

	TP g P/ha/d	SRP g P/ha/d	NO_3 g N/ha/d	Na g Na/ha/d
FIRST	0.13	0.03	2.40	95
SECOND	0.19	0.07	2.86	100
THIRD	0.25	0.12	3.14	66
CLARK	0.19	0.11	3.05	23
SODUS WEST	0.29	0.16	3.80	38
SODUS EAST	0.41	0.26	5.23	108

Table 17. Comparison of phosphorus loading in subbasins of the Irondequoit Bay watershed, other Monroe County creeks and of tributaries of Sodus Bay. Irondequoit basin data are from 1980-81 (O'Brien and Gere 1983). Data from other Monroe County creeks are from 1987-88 (Makarewicz 1988).

Subbasin or Creek	Total Phosphorus Loading (kg P/d)	Total Phosphorus Loading (kg P/ha/d)
Irondequoit Watershed		
Irondequoit Creek at Thornell Road	13.9	1.20
Thomas Creek	3.7	0.49
Allen Creek	14.9	1.92
Central Basin of Irondequoit Creek	6.7	0.65
Monroe County Creeks		
Larkin	2.2	0.70
Buttonwood	3.6	1.58
Lower Northrup	12.4	6.64
Upper Northrup	3.4	3.23
Wayne County Creeks		
First	0.1	0.13
Second	0.5	0.19
Third	0.3	0.25
Clark	< 0.1	0.19
Sodus West	0.2	0.29
Sodus East	1.3	0.41

TROPHIC STATUS OF SODUS BAY

It is now well accepted that eutrophication of lakes depends on excessive discharge of phosphorus and nitrogen to inland waters. This concept, sometimes called the nutrient loading concept, implies that a quantifiable relationship exists between the amount of nutrients reaching a lake and its trophic status, which can be measured by chlorophyll a levels. Figure 29 presents the relationship of chlorophyll level to potential available phosphorus for some common upstate New York lakes and bays. Based on the limited phosphorus loading and chlorophyll data that we have collected for Sodus Bay and its tributaries, Sodus Bay falls into the eutrophic category of bodies of water. That is to say, Sodus Bay is a productive body of water. The low hypolimnetic oxygen levels during the summer also support this conclusion.

Figure 29 is also instructive in demonstrating the results of remedial action (i.e. decrease in phosphorus loading) in Irondequoit Bay. Since 1971, as various phosphorus control strategies have been implemented within the watershed, chlorophyll levels have dropped dramatically with decreasing phosphorus levels. A similar program of phosphorus control, especially within the branches of Sodus Creek, should create an improvement in Sodus Bay water quality. In addition, the large beds of macrophytes, located at the mouths of some of the tributaries extending into the Bay, may decrease in size with phosphorus control within the Sodus Bay watershed.

SUMMARY OF SODUS BAY WATER QUALITY

By mid-August thermal stratification of Sodus Bay had occurred. At Station 5, the water column consisted of an epilimnion (upper layer of uniform, warm circulating water - ~7 m in thickness) overlying a thermal discontinuity layer (the metalimnion - ~3 m in thickness) and a deeper, cooler hypolimnion. Hypolimnetic oxygen values were close to zero which caused dramatic increases in soluble reactive and total phosphorus in the layer. Nitrate was non-detectable throughout the water column.

Many chemical parameters in Sodus Bay are influenced by discharge from tributaries. The majority of maximum and minimum values of various chemical constituents within the Bay occur at stations adjacent to creek mouths. For example, high levels of sodium and chloride in First Creek were reflected at Station 4 within the Bay. Station 4 had the highest sodium, chloride and conductivity levels within the Bay. Similarly, Station 4 and First Creek (which enters the Bay at Station 4) showed similar symptoms of organic loading. First Creek had the lowest dissolved oxygen and pH levels, the highest total phosphorus concentration and the second highest turbidity. Station 4 (near the mouth of First Creek) had the lowest dissolved oxygen and pH levels in the Bay coupled with high total phosphorus, high turbidity and low secchi disk readings. Possible causes of these conditions include agricultural runoff, sewage leaching or an industrial source. Only further investigation can pinpoint these sources. In addition, total coliforms should be sampled at Station 4.

A positive correlation between chlorophyll concentration and soluble reactive phosphorus levels occurred at tributary mouth stations (r^2=0.731) (Fig. 30), but not at the non-tributary stations (r^2 = 0.013). This suggests that phosphorus loading from tributaries is having local effects on plants in Sodus Bay.

The highest epilimnetic concentrations of soluble reactive and total phosphorus were found at Station 2. Station 2 is exposed to winds from the west and is located in a sub-basin of Sodus Bay. High winds and waves, experienced only at this site during sampling, may have eroded the hypolimnion and affected water chemistry. Mixing of epilimnion and hypolimnion water would result in lower temperatures, high soluble reactive and total phosphorus levels, low chlorophyll concentrations, high pheophytin levels, low dissolved oxygen concentration and low secchi disk readings in the epilimnion.

Nitrate was non-detectable at all Sodus Bay sites.

Although coliform bacteria were only found at Station 6, their level is well below the EPA guideline for primary contact recreational usage. Station 6 is located near a marina and a restaurant and summer homes.

Based on the EPA guidelines for the evaluation of Great Lakes harbor sediment, sediments at the mouths of tributary streams of Sodus Bay would be considered moderately to heavily polluted.

Detectable levels of chlorinated hydrocarbons were not observed in macrophytes from Port and East Bays. The levels of sodium, potassium, magnesium, calcium, phosphorus and copper in macrophytes from Sodus, Port and East Bays were similar to those reported for a mixture of *Myriophyllum* sp., *Vallisneria* sp., *Elodea* sp., *Ceratophyllum* sp. and *Najas* sp. from Chemung Lake, Canada. Results of chemical analysis of macrophytes suggest that macrophytes form Sodus, East and Port Bays could be safely used as animal fodder.

Of the six creeks monitored during the spring, Sodus East was the major contributor of nutrients to Sodus Bay. Sodus Creek (East and West) accounted for 61.6% and 58% of the total phosphorus and nitrate, respectively, entering Sodus Bay. Thus, it is not surprising that an extensive macrophyte community exists at the mouth of Sodus Creek which extends well into the Bay. Similarly, Second Creek, which had the second highest loading of total phosphorus (20.2%), has a large macrophyte community at its mouth.

Based on the limited phosphorus loading and chlorophyll data that we have collected for Sodus Bay and its tributaries, Sodus Bay falls into the eutrophic category of bodies of water. That is to say, Sodus Bay is a productive body of water. The low hypolimnetic oxygen levels during the summer also support this conclusion.

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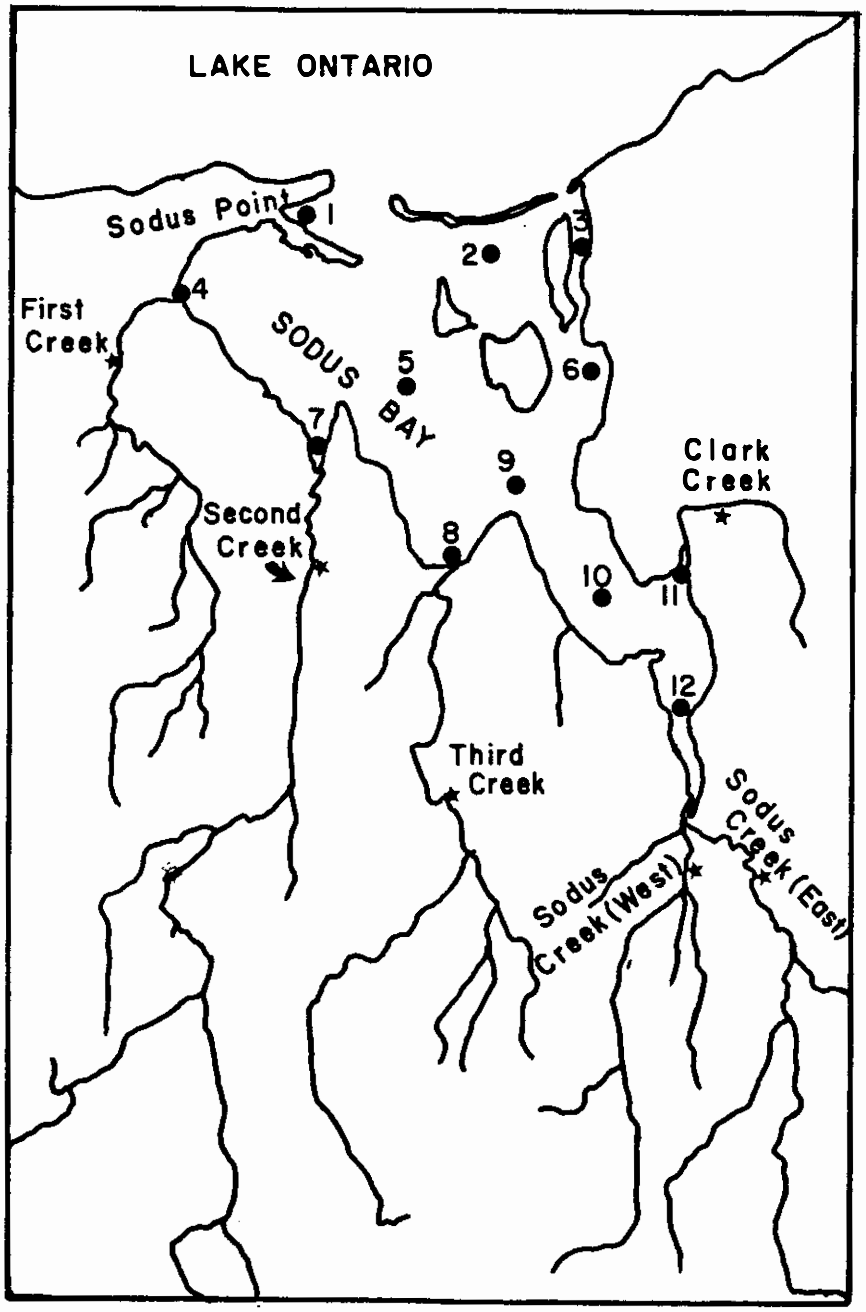

Figure 1 . Sodus Bay and its tributaries showing Bay sampling stations and tributary sampling sites, Wayne County, N.Y.

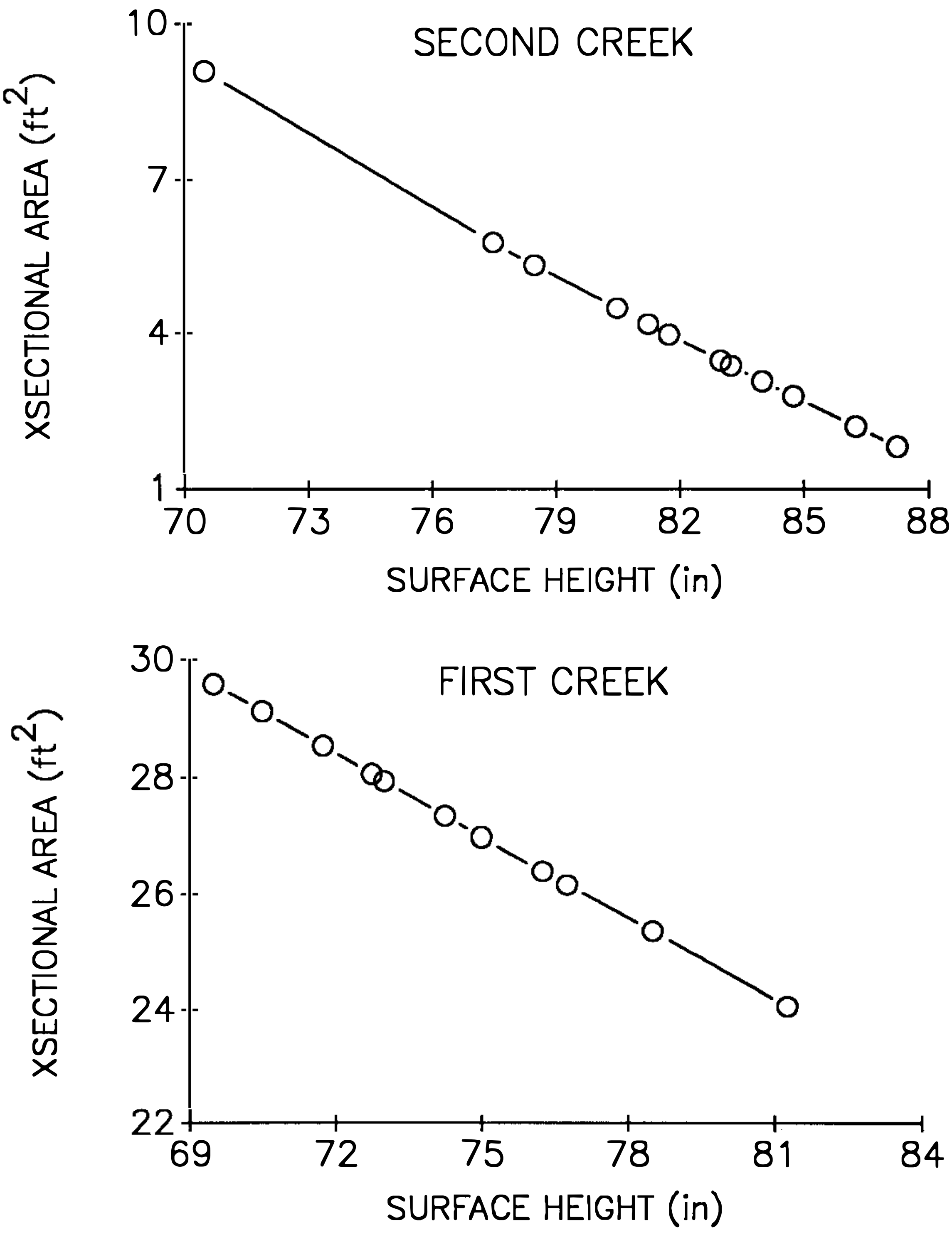

Figure **2**. Cross-sectional area of First Creek and Second Creek versus surface stream height. Stream height is the distance from the surface of the stream to a fixed stable point on the bridge over the stream. Thus, the higher the stream gets the lower the stream height is on the graph.

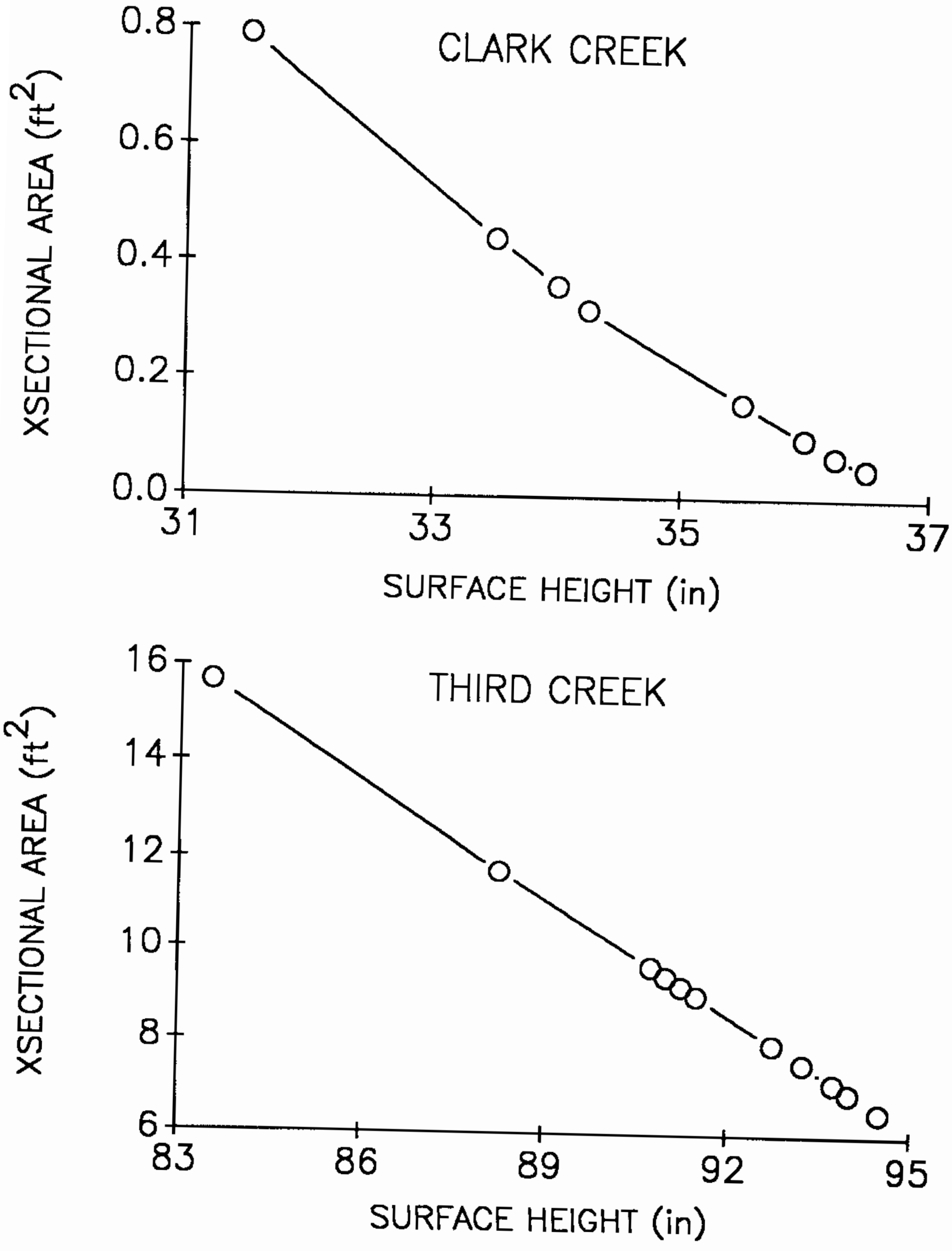

Figure **3**. Cross-sectional area of Third Creek and Clark Creek versus surface stream height. Stream height is the distance from the surface of the stream to a fixed stable point on the bridge over the stream. Thus, the higher the stream gets the lower the stream height is on the graph.

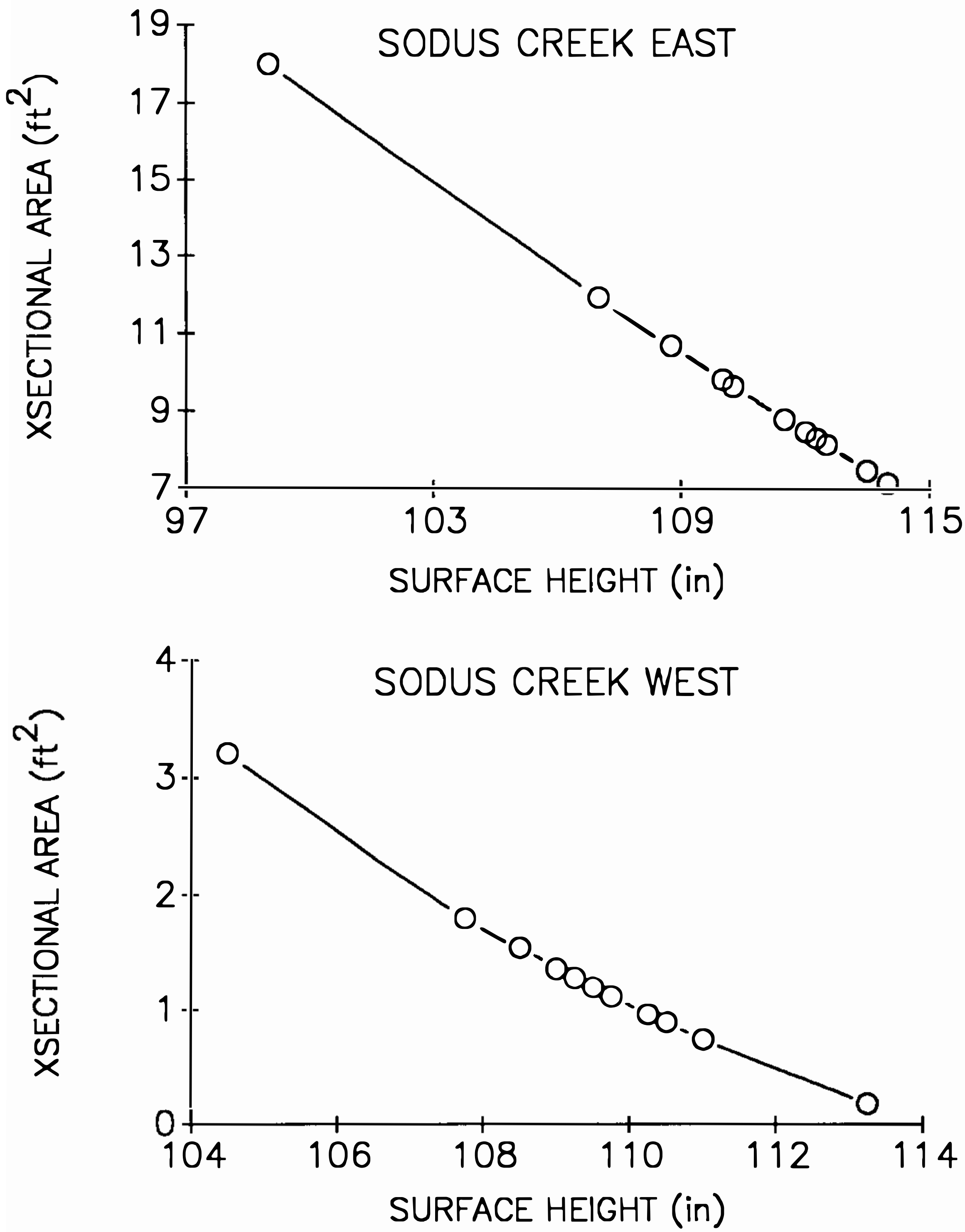

Figure 4. Cross-sectional area of Sodus Creek West and Sodus Creek East versus surface stream height. Stream height is the distance from the surface of the stream to a fixed stable point on the bridge over the stream. Thus, the higher the stream gets the lower the stream height is on the graph.

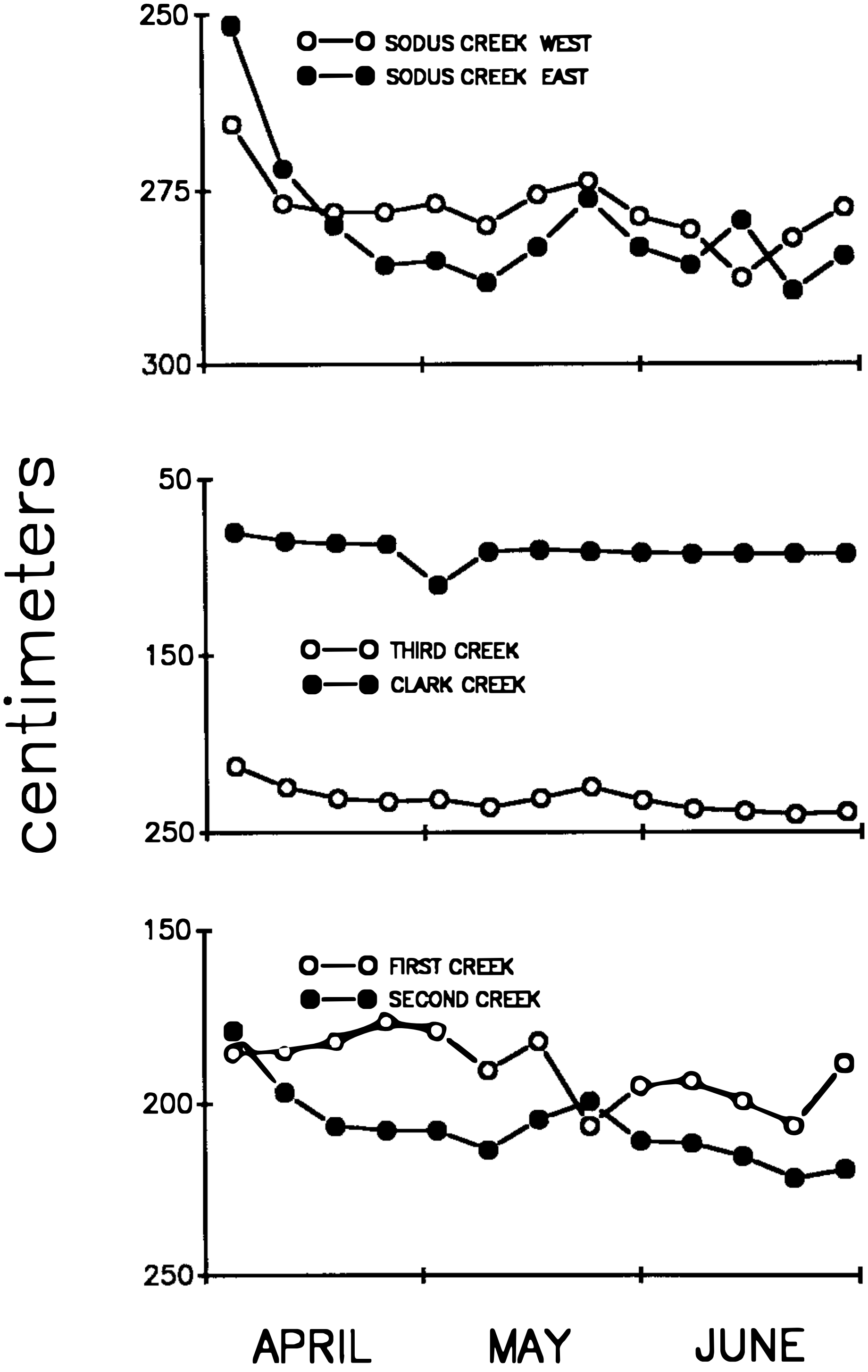

Figure 5. Weekly stream heights in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

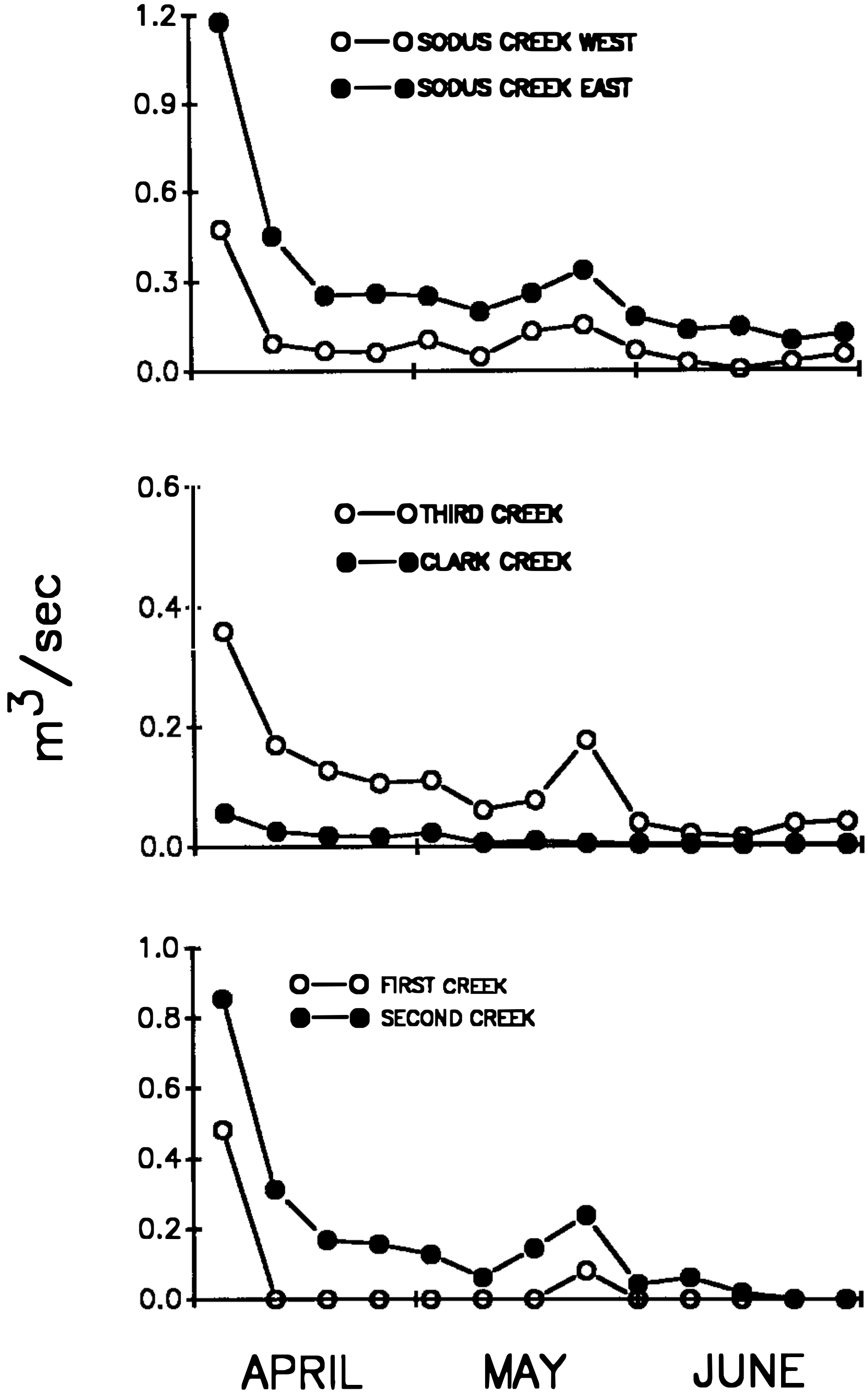

Figure 6. Weekly discharge levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

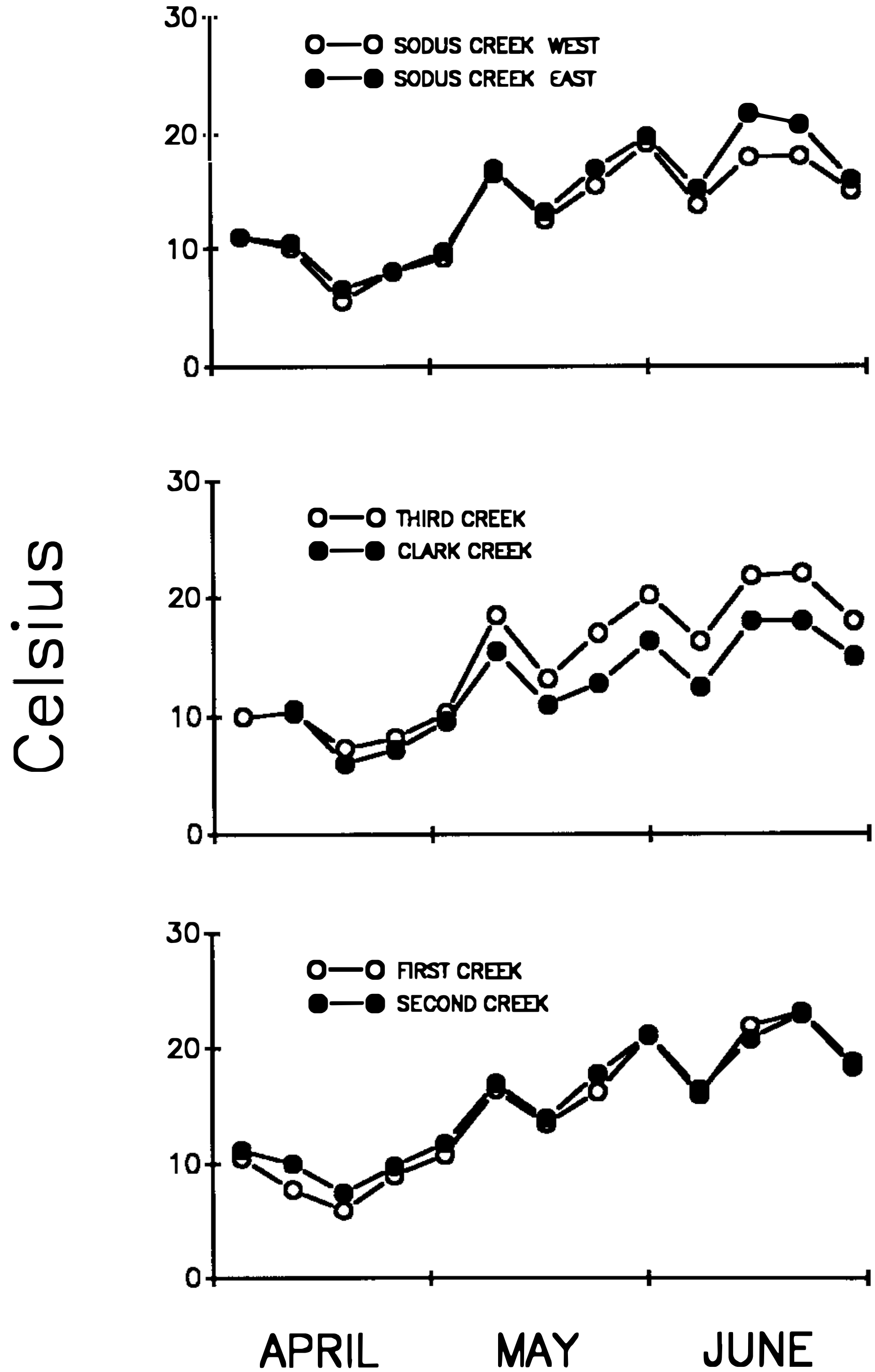

Figure 7. Weekly temperatures in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

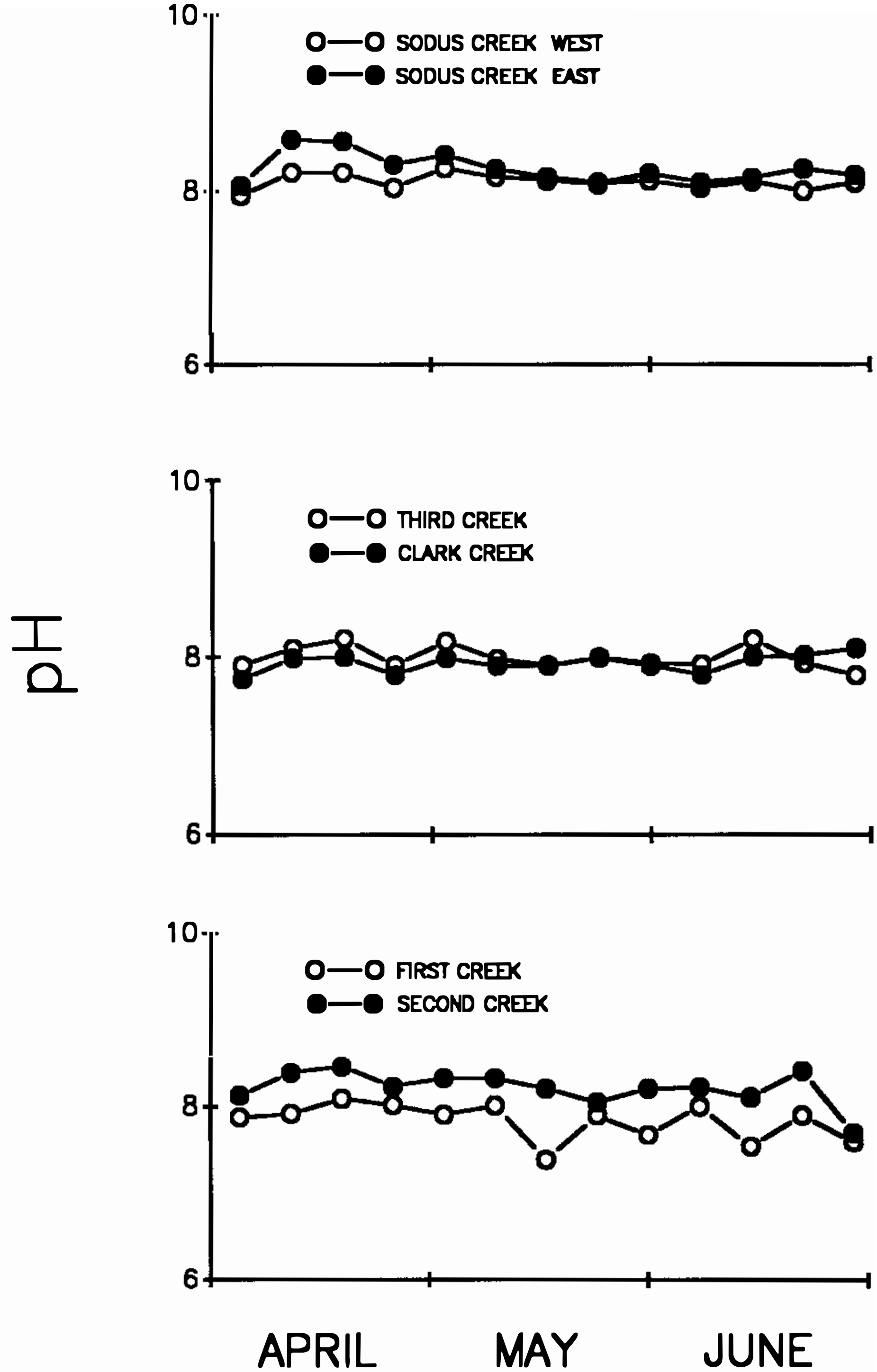

Figure 8. Weekly pH levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

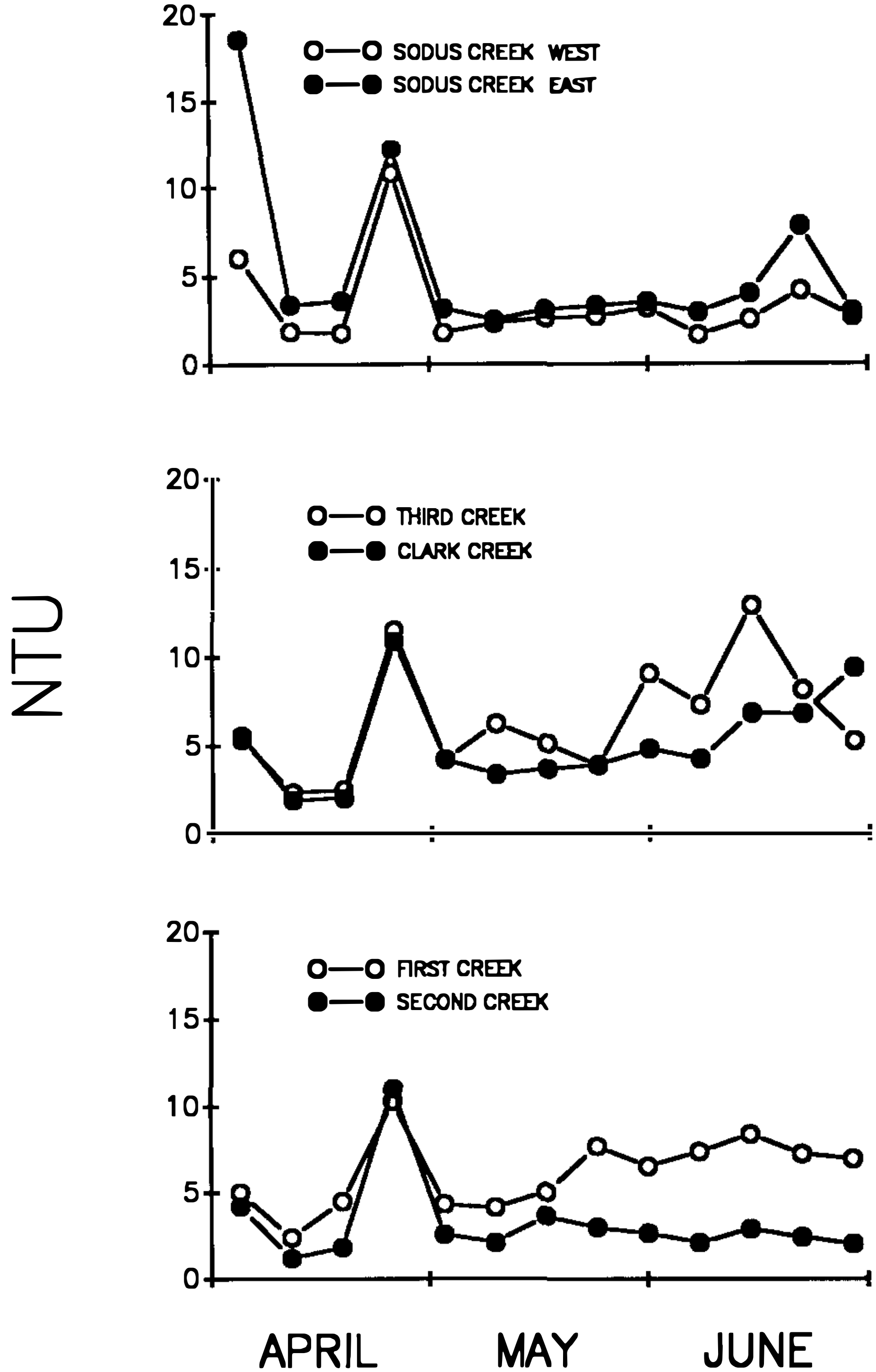

Figure 9. Weekly turbidity levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

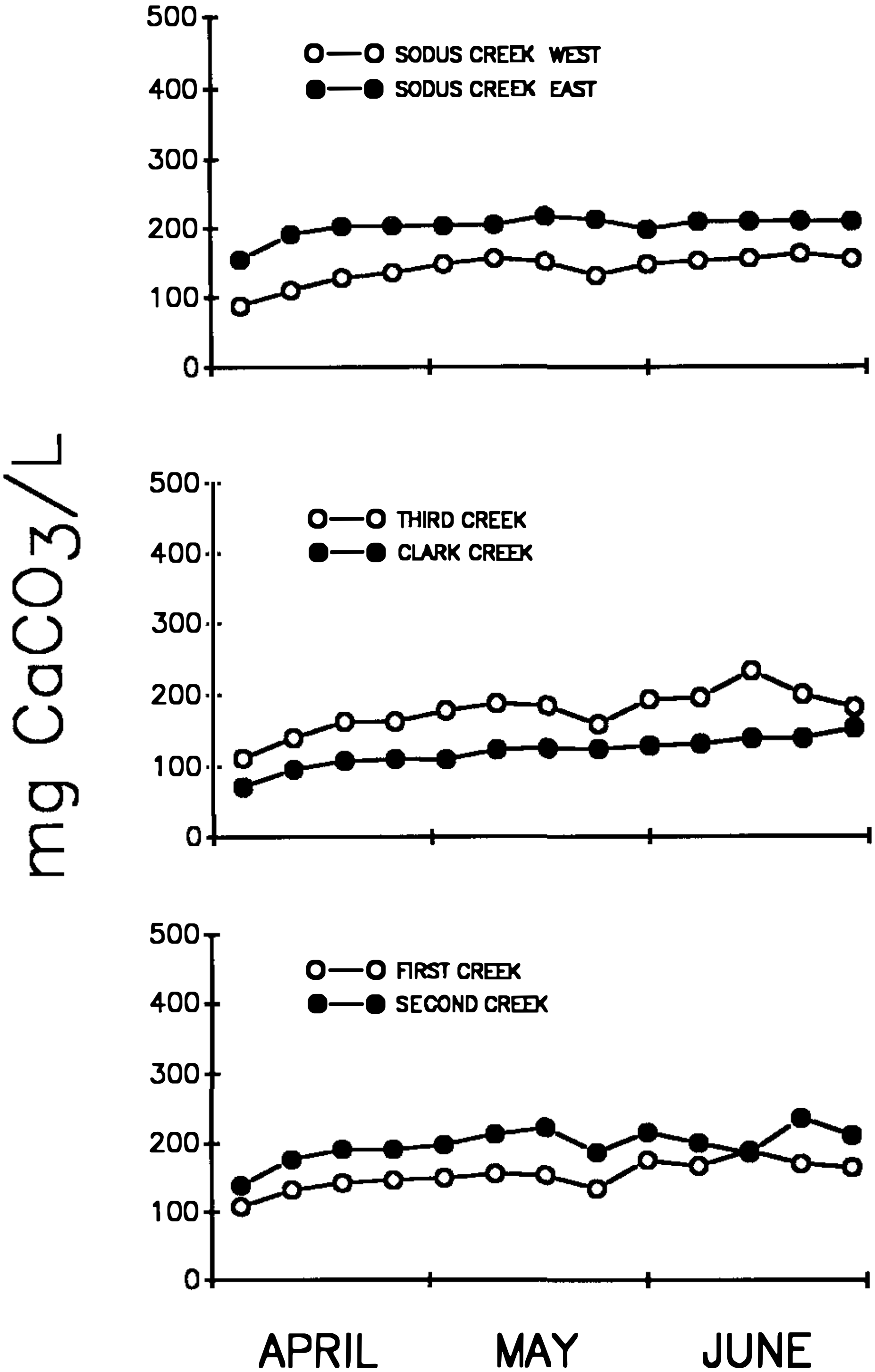

Figure 10. Weekly alkalinity levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

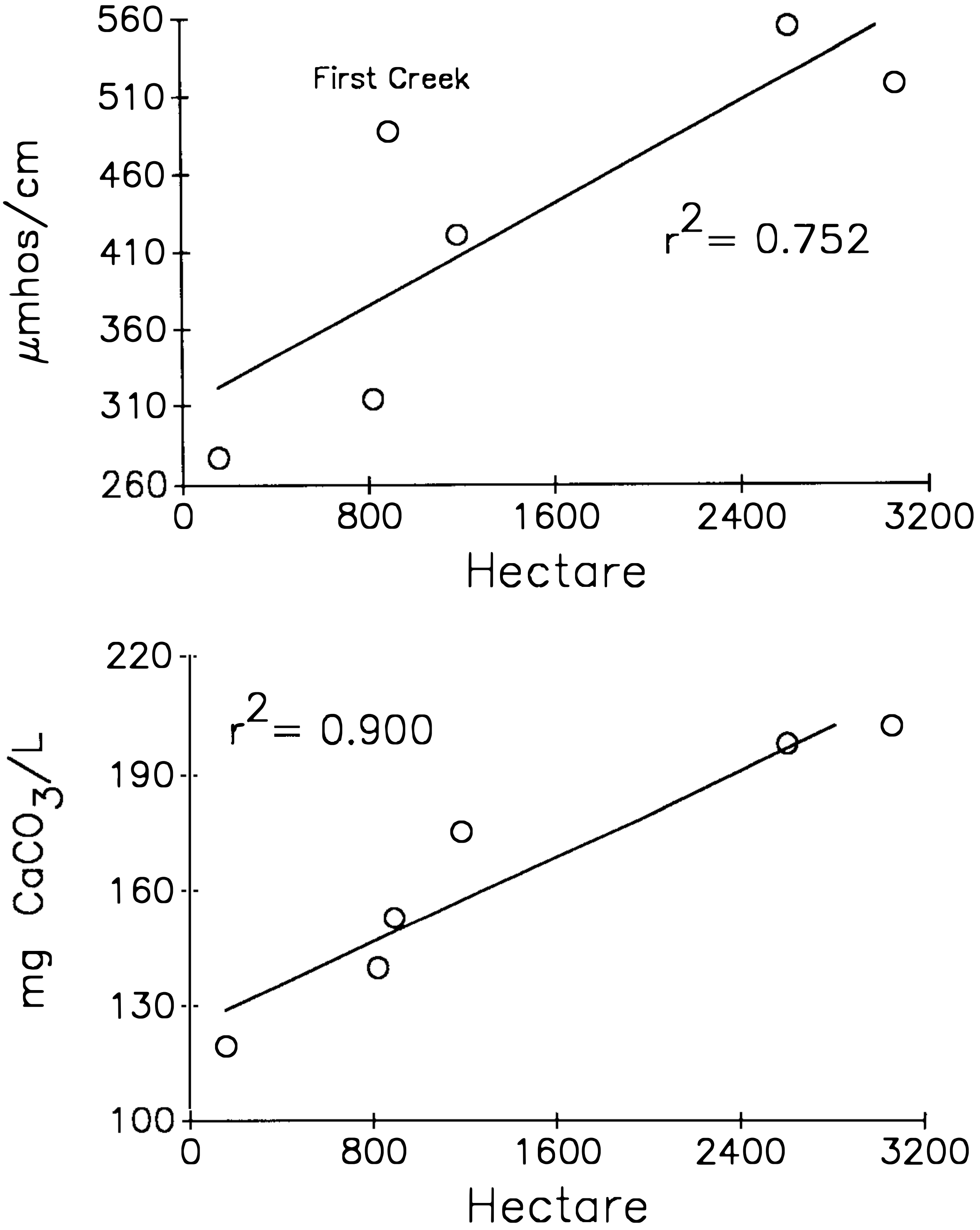

Figure **11**. Mean daily alkalinity and conductivity (n=13) versus watershed area for First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

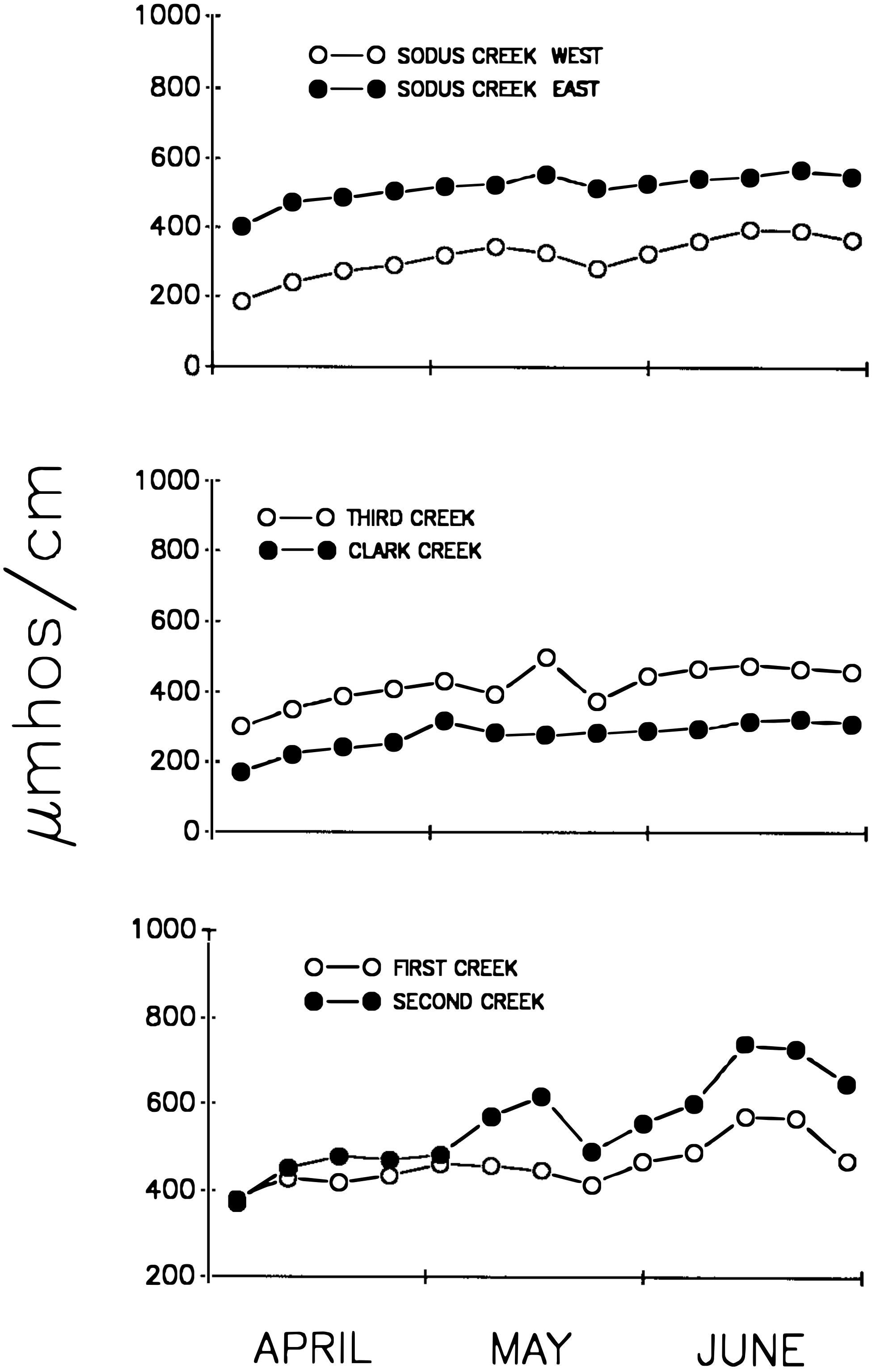

Figure **12**. Weekly conductivity levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

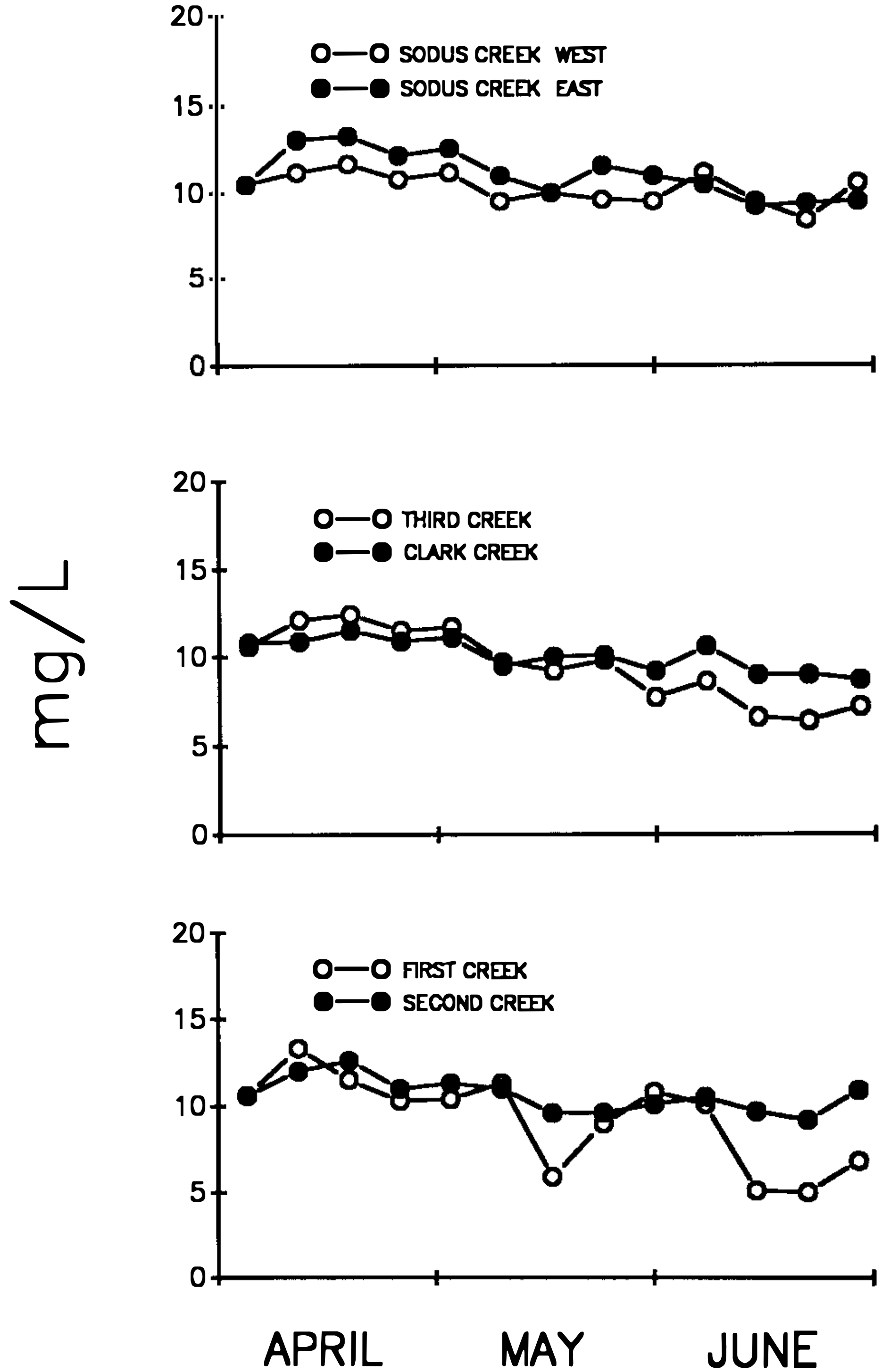

Figure 13. Weekly dissolved oxygen levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

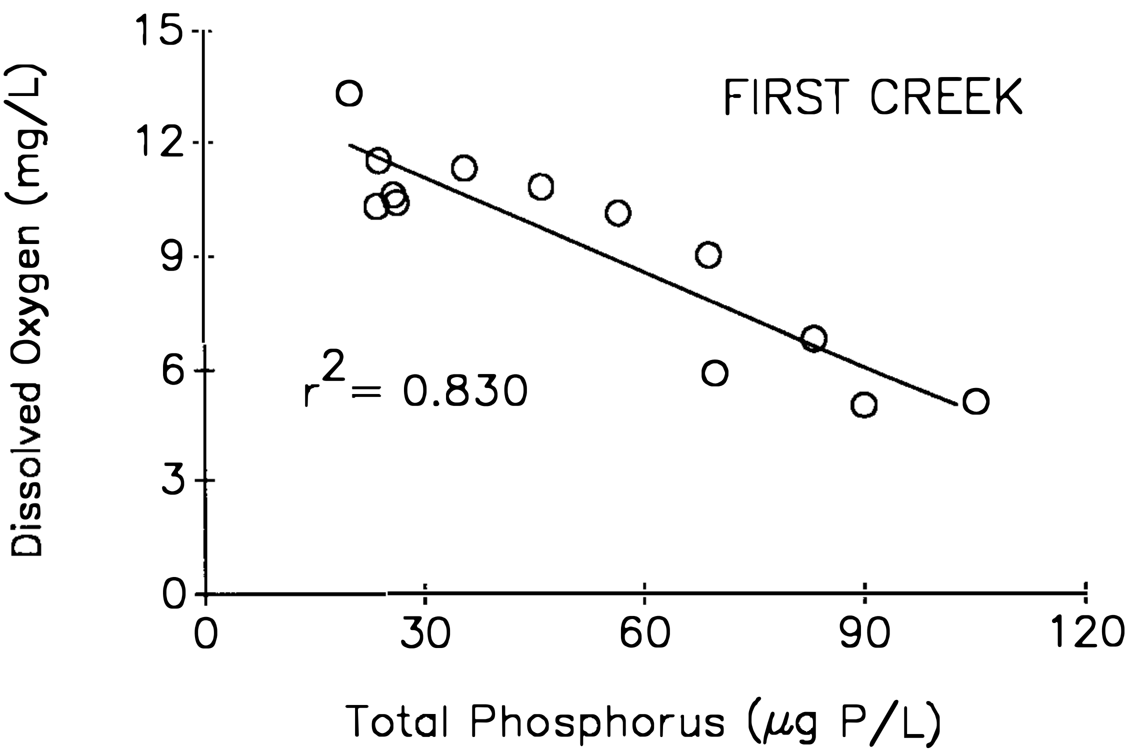

Figure **14**. Total phosphorus versus dissolved oxygen for First Creek from 5 April to 28 June 1988.

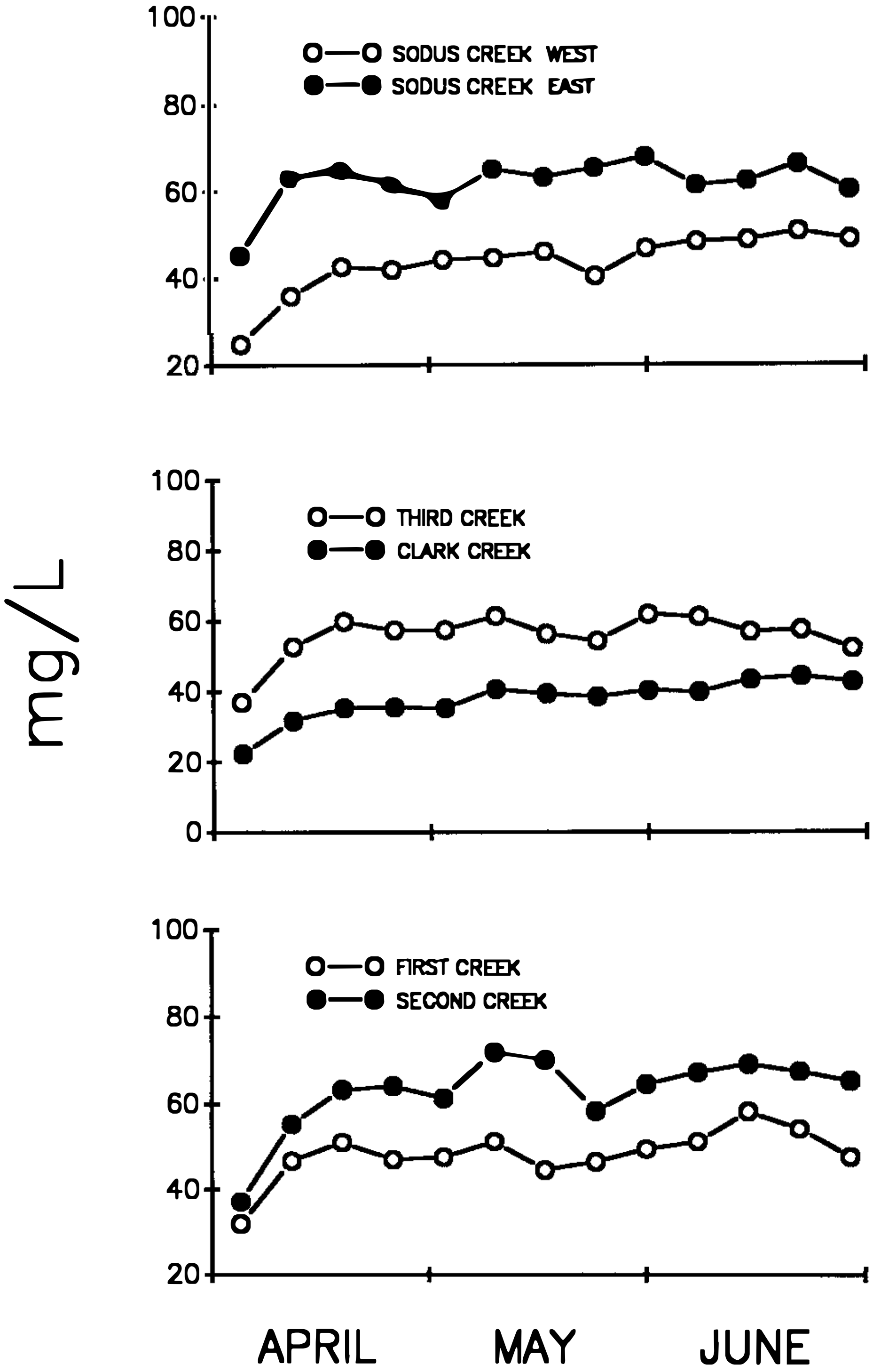

Figure **15**. Weekly calcium levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

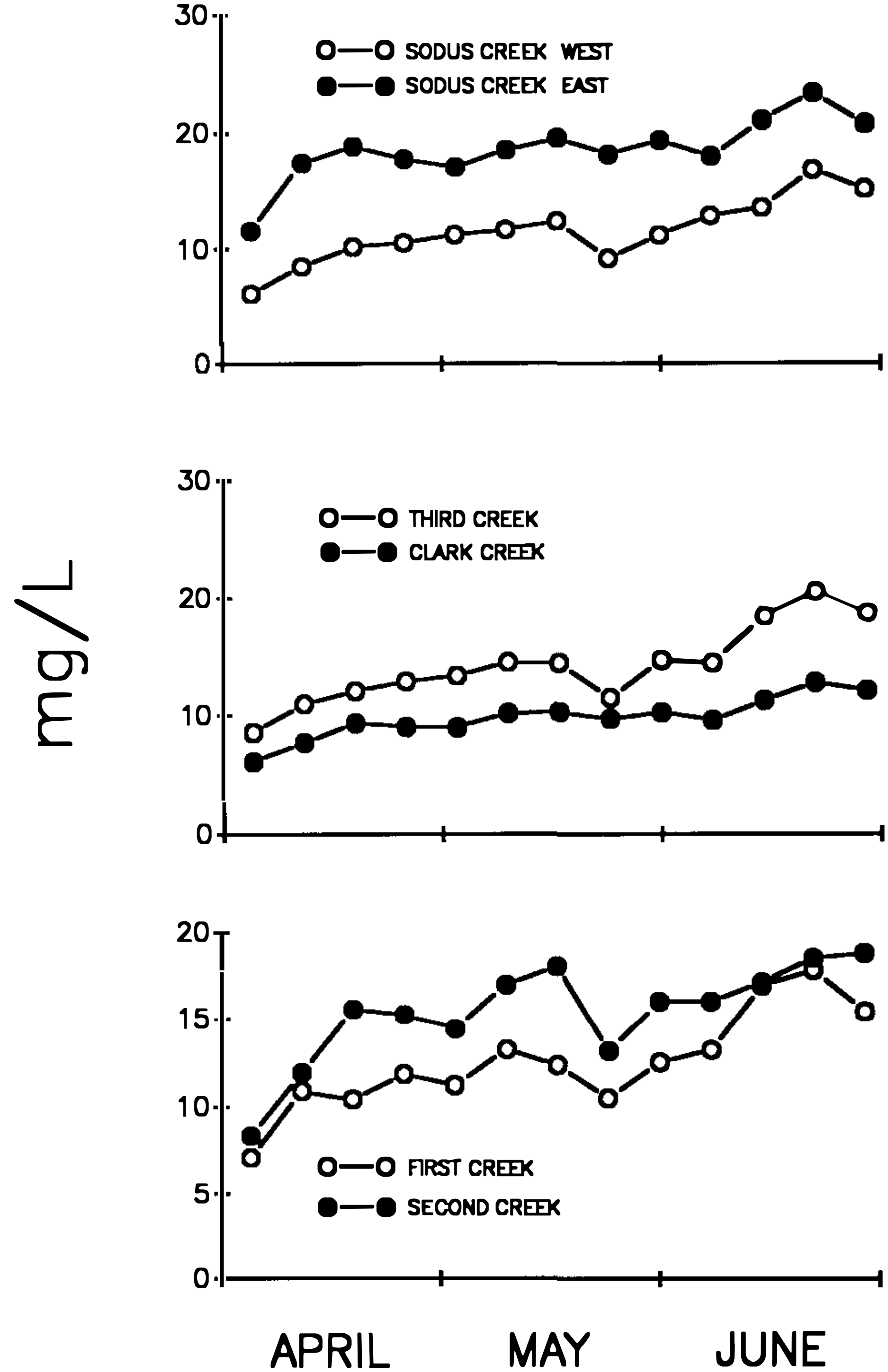

Figure **16**. Weekly magnesium levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

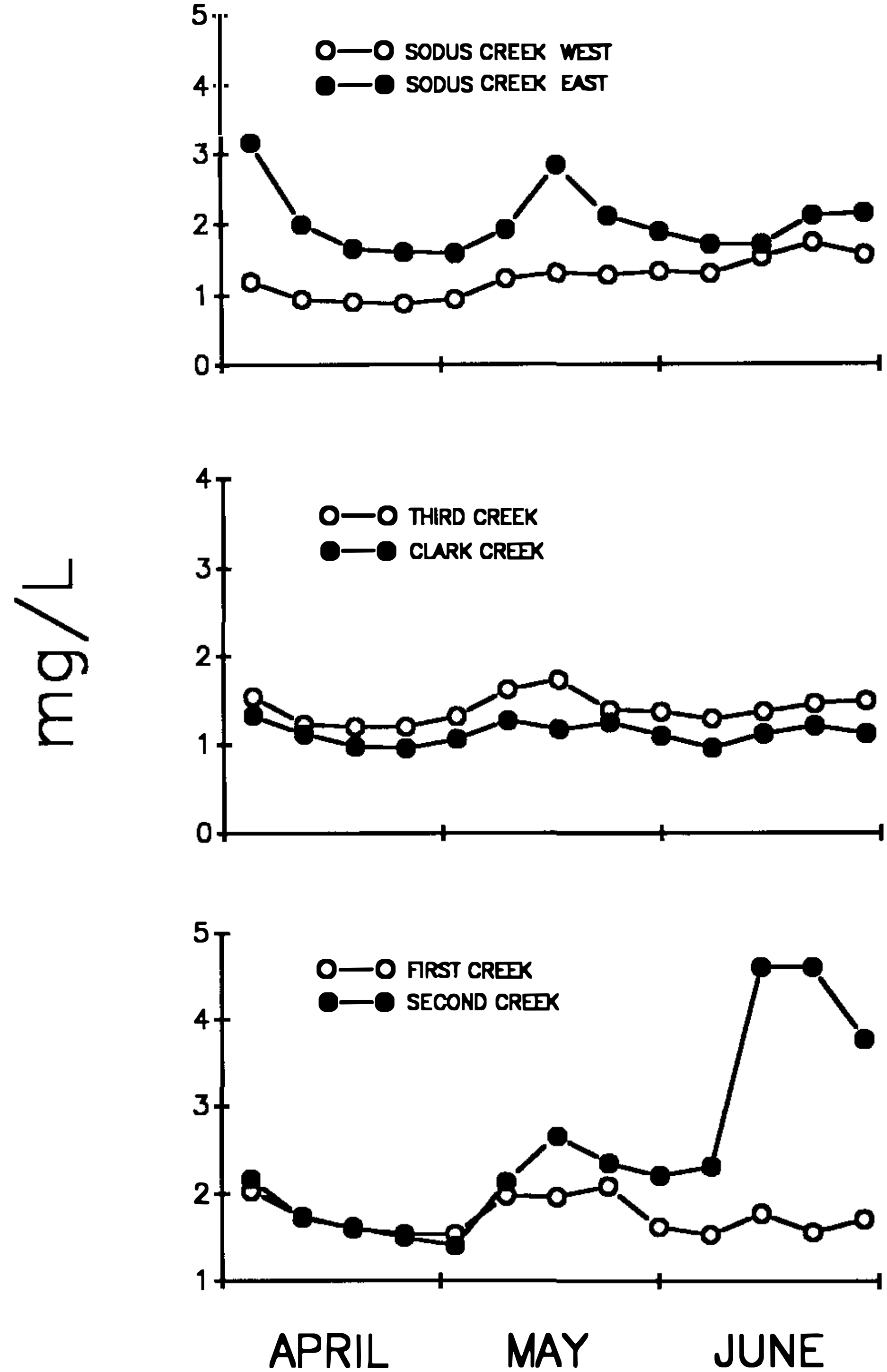

Figure **17**. Weekly potassium levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

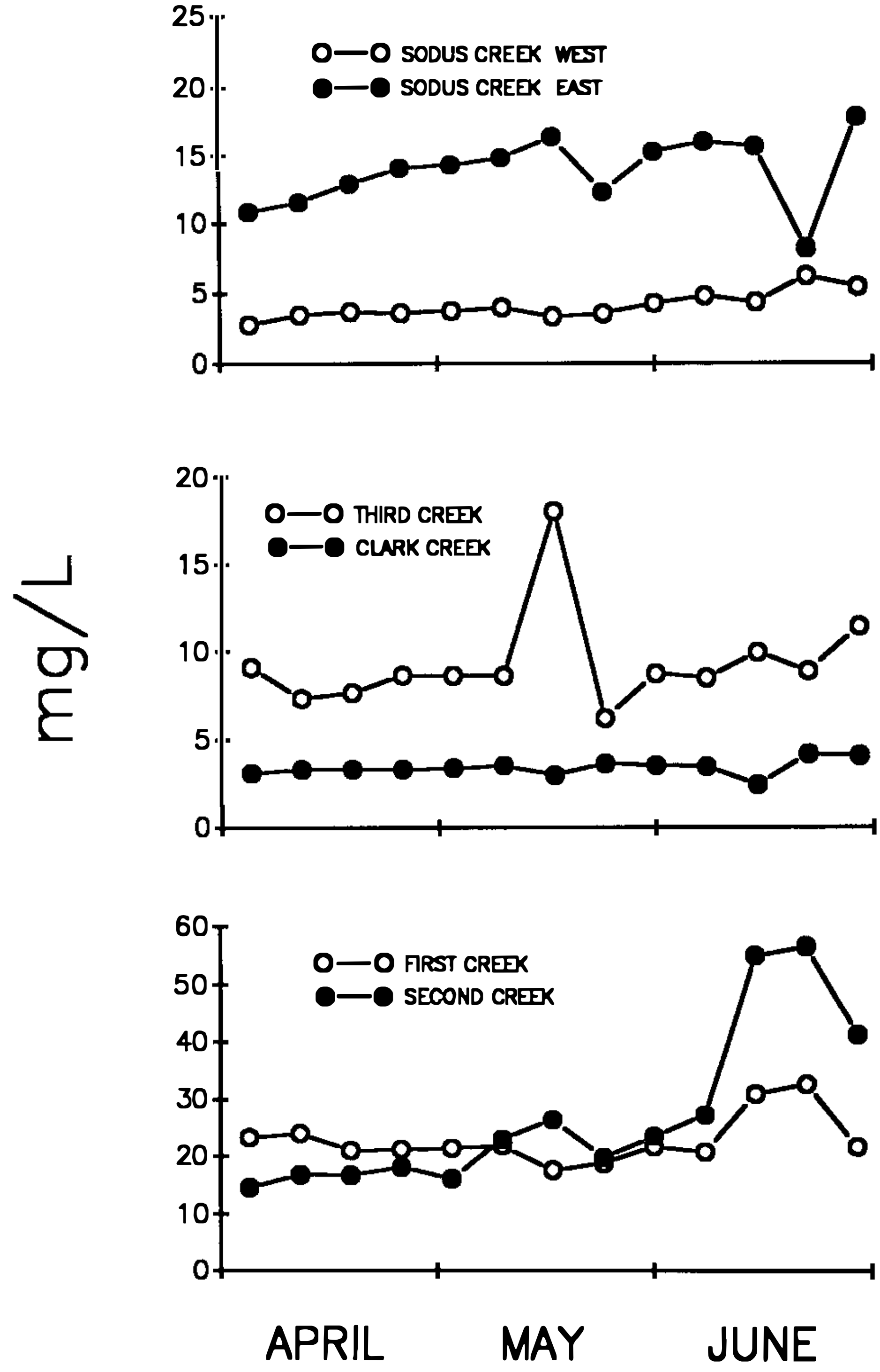

Figure 18. Weekly sodium levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

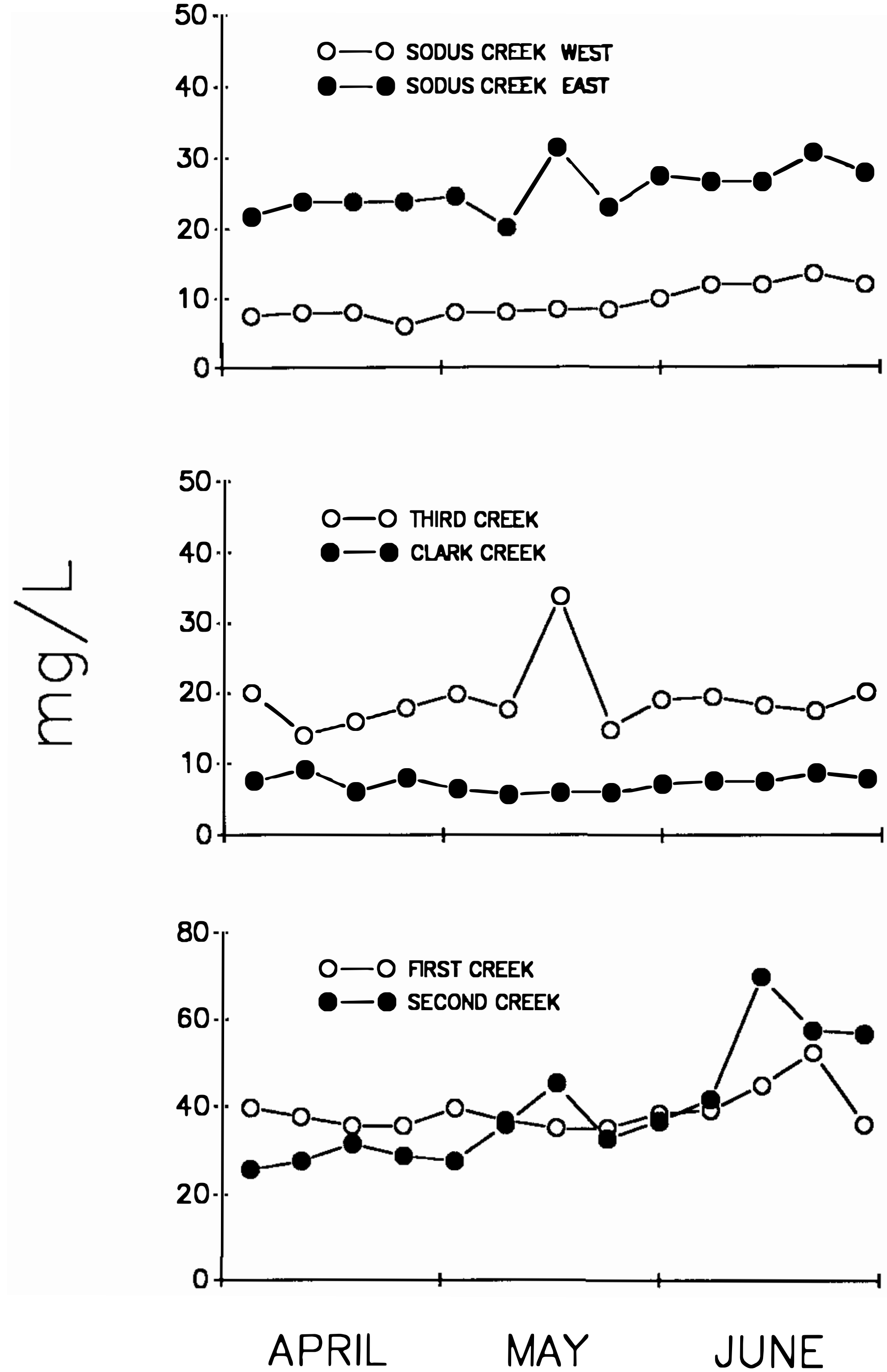

Figure **19**. Weekly chloride levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

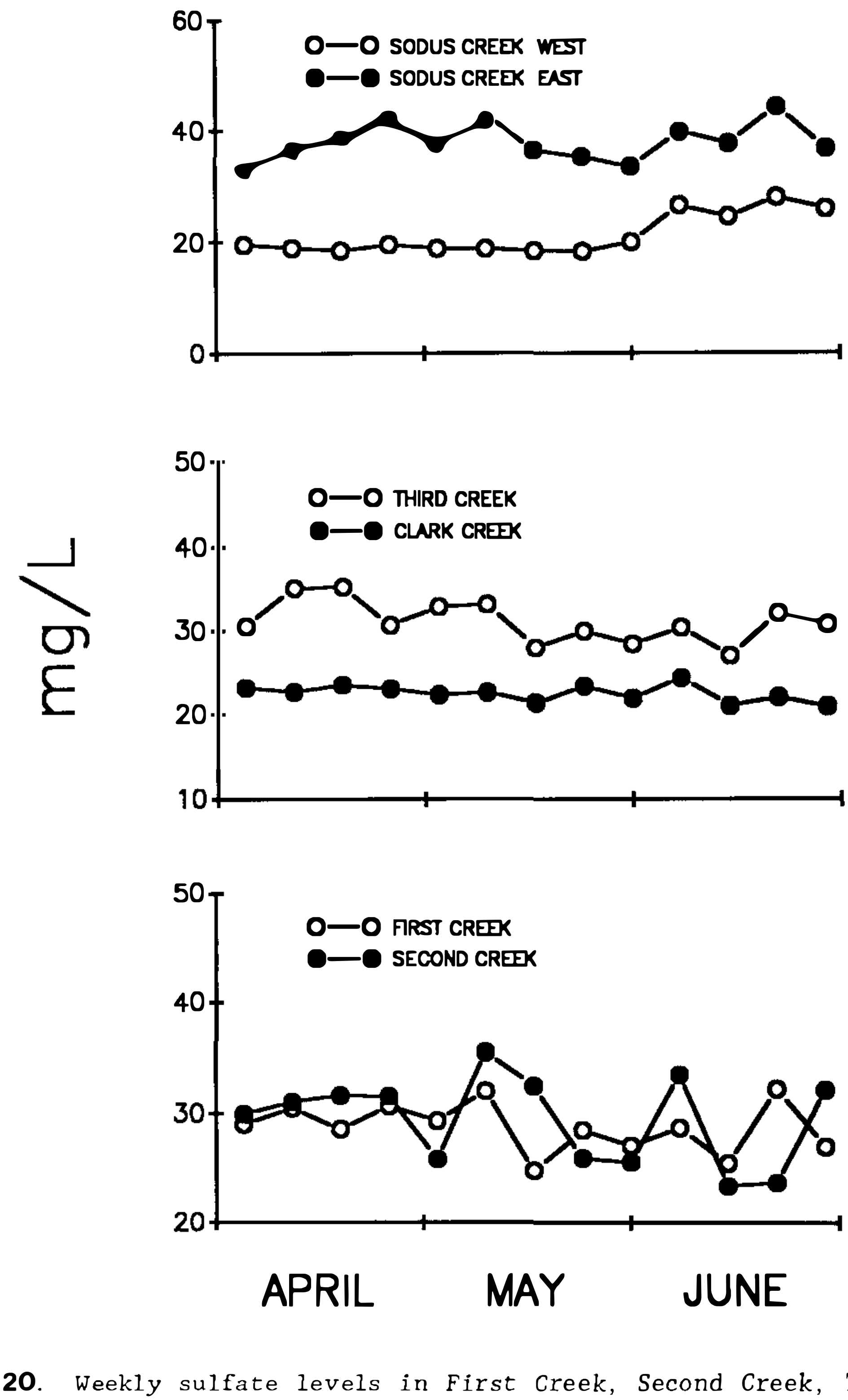

Figure **20**. *Weekly sulfate levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.*

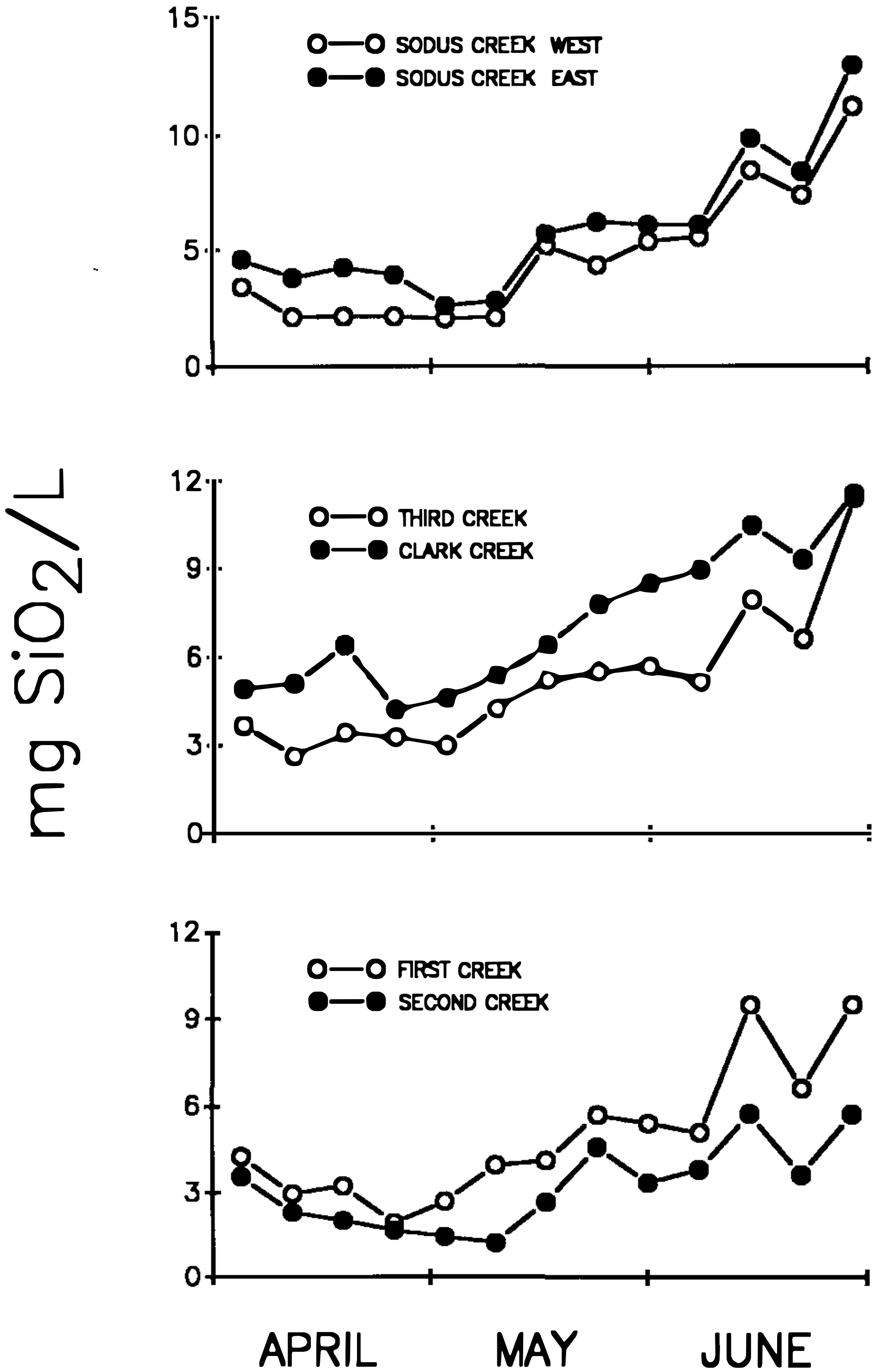

Figure 21. Weekly dissolved reactive silica levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

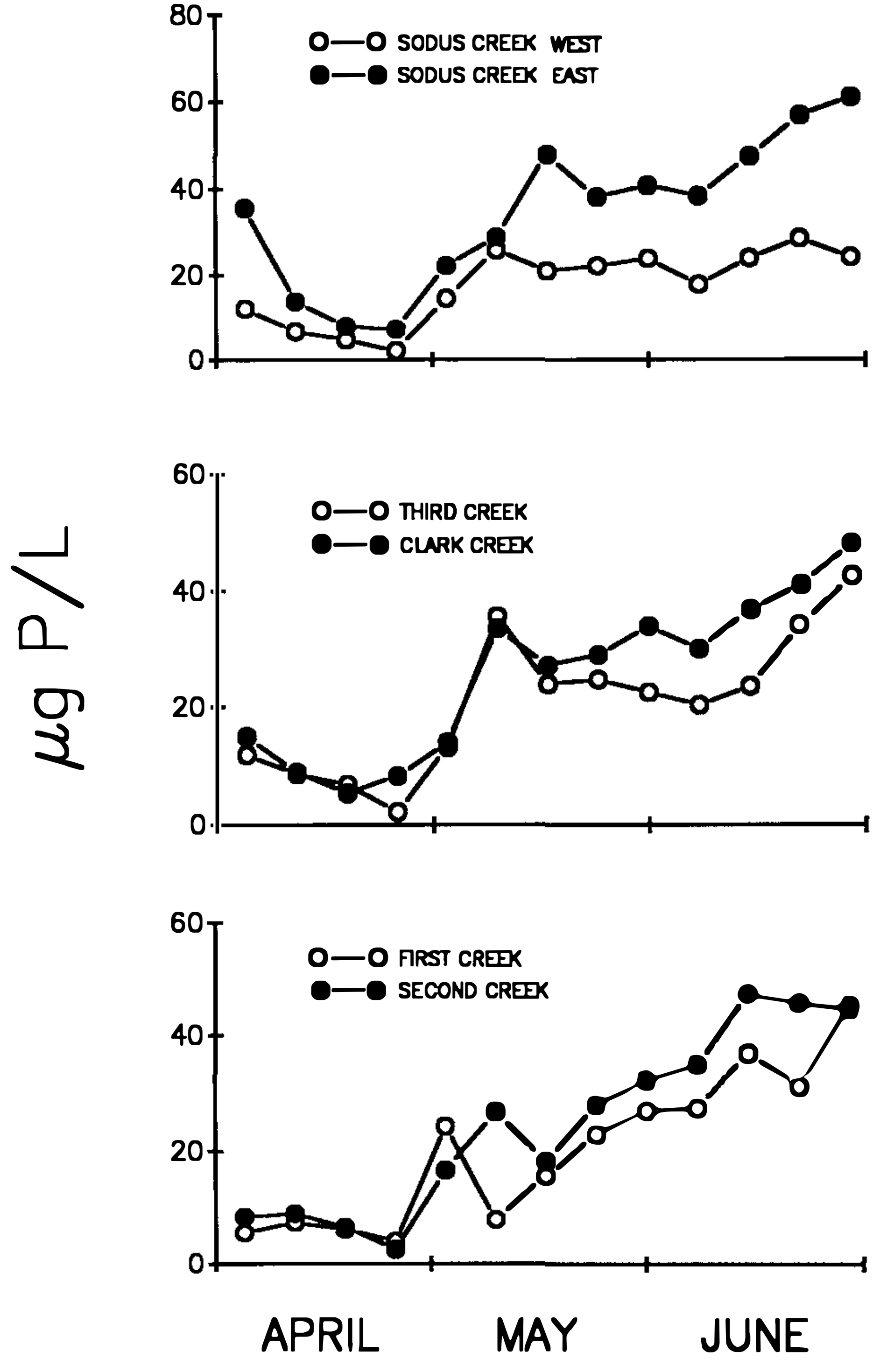

Figure **22**. Weekly soluble reactive phosphorus levels in First Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

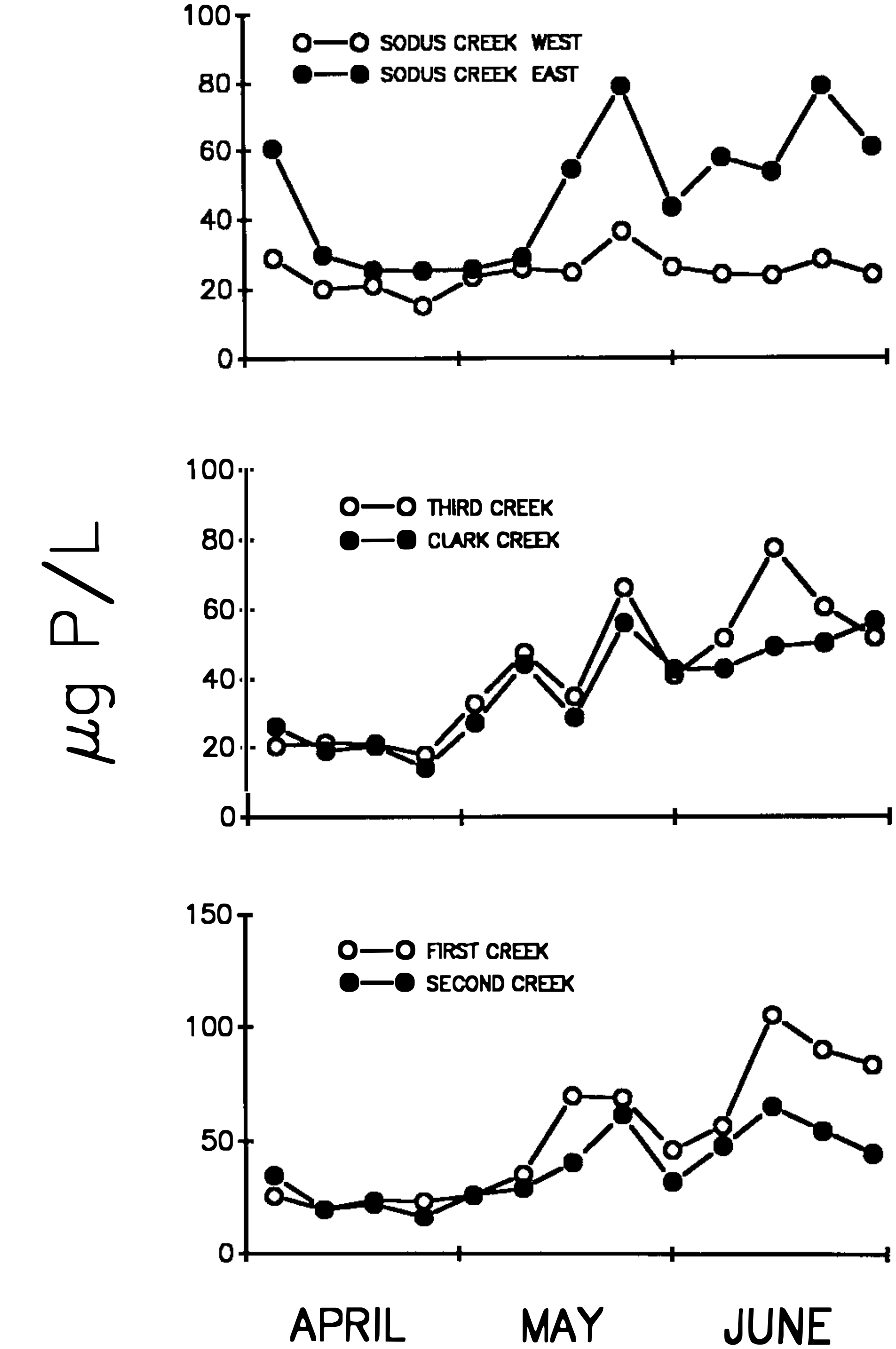

Figure **23**. Weekly total phosphorus *levels in First* Creek, Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus Creek East from 5 April to 28 June 1988.

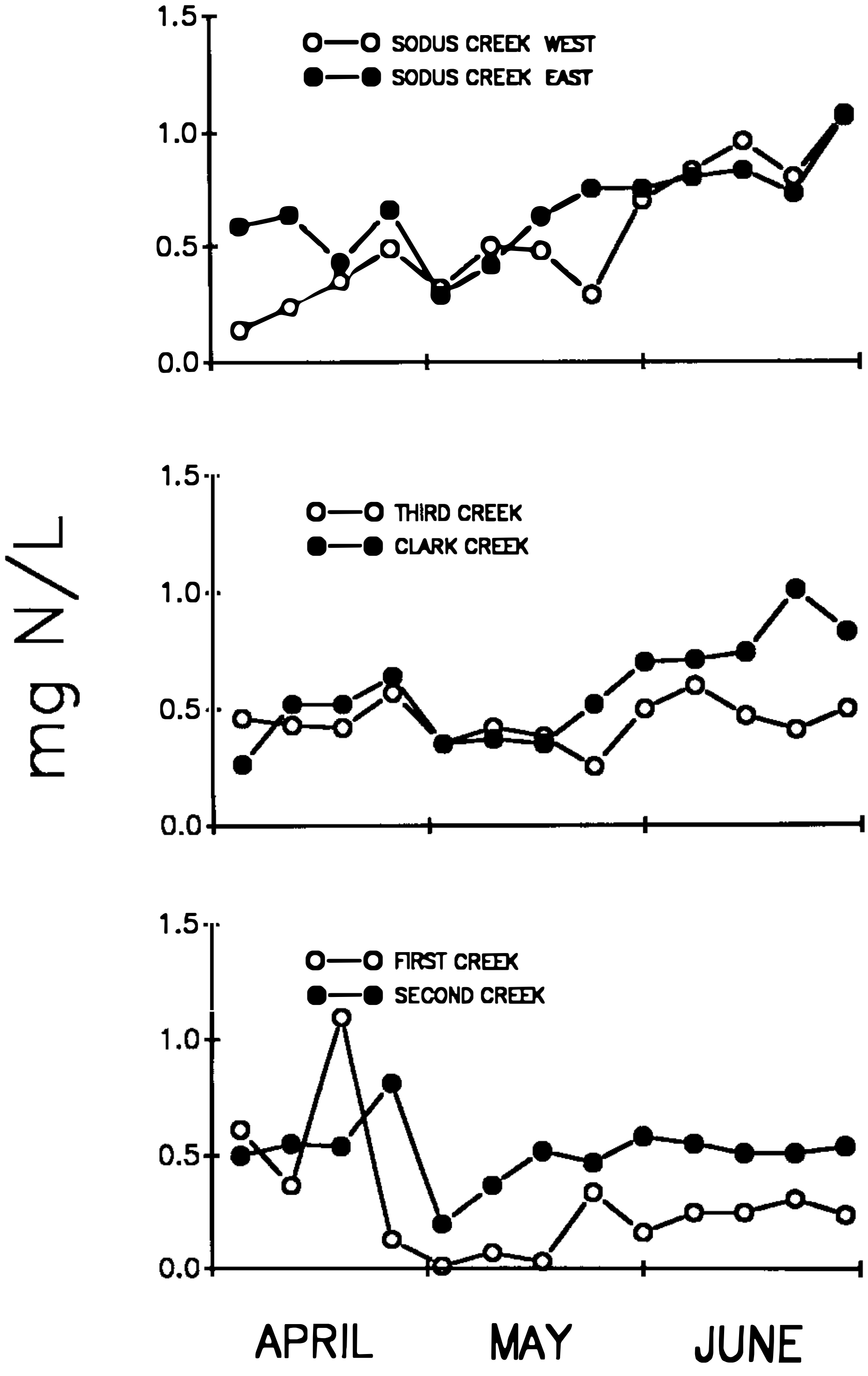

Figure **24**. *Weekly nitrate and nitrite levels in First Creek,* Second Creek, Third Creek, Clark Creek, Sodus Creek West, and Sodus *Creek East from* 5 April to 28 June 1988.

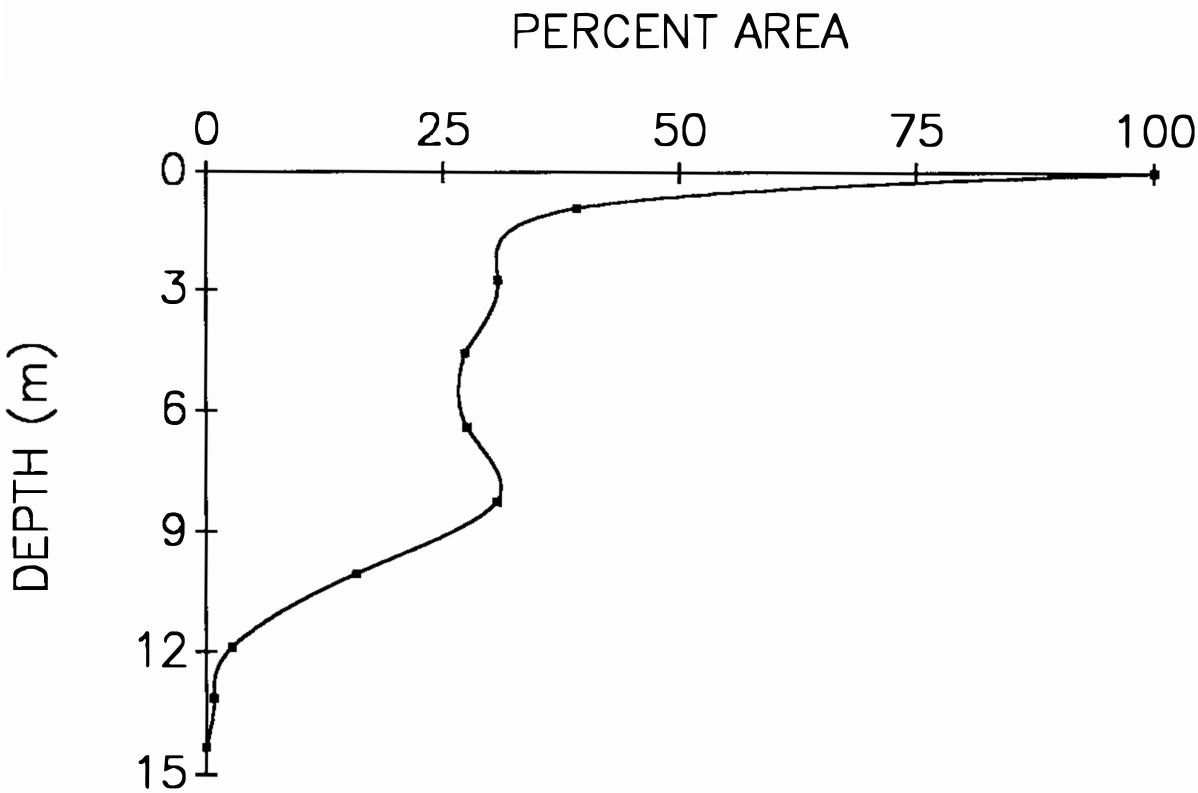

Figure **25**. Sodus Bay hypsographic curve. Plane of reference was 242.8 feet (low water datum) taken from NOAA chart 14814.

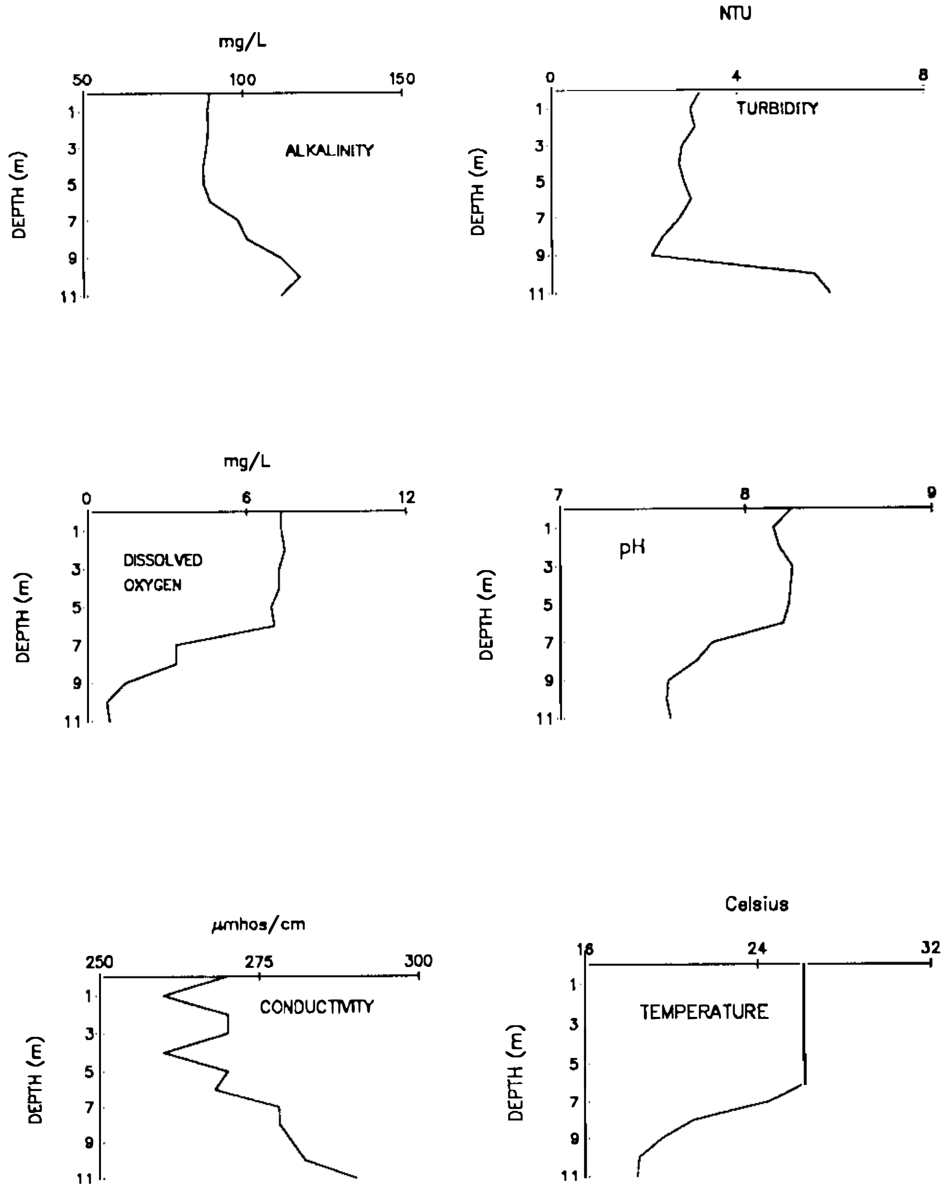

Figure **26**. Depth profiles of chemical and physical parameters at Station 5 in Sodus Bay on 15 August 1988.

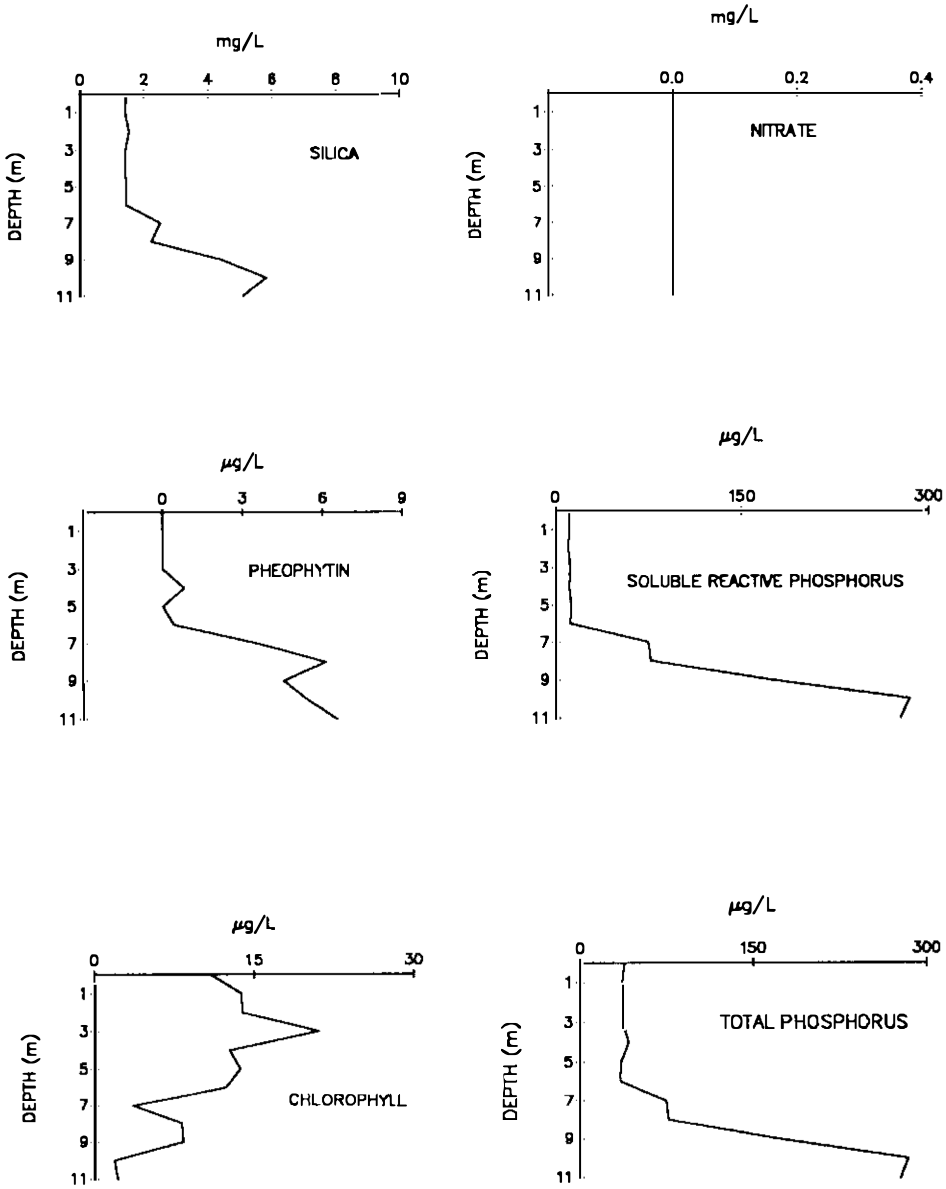

Figure **27**. Depth profiles of chemical and physical parameters at Station 5 in Sodus Bay on 15 August 1988.

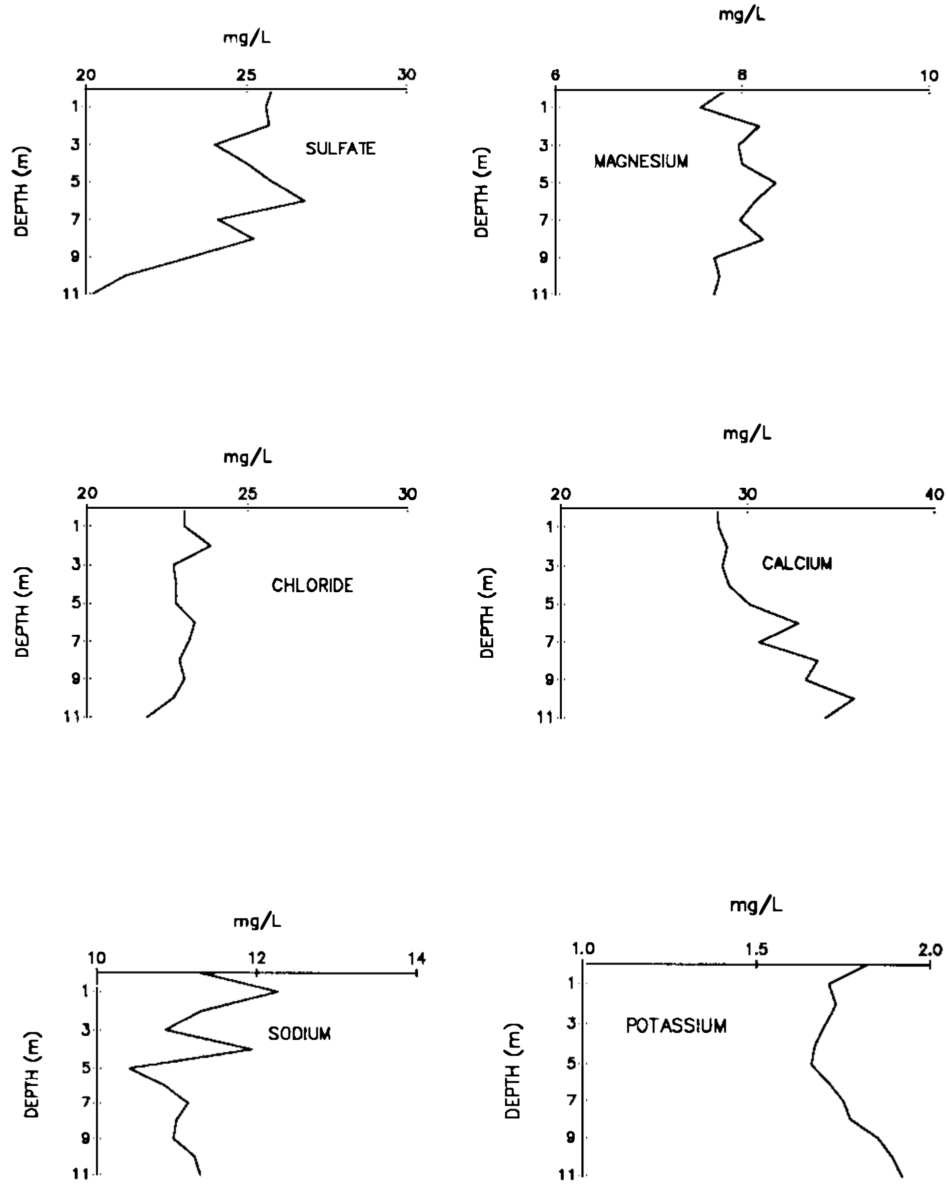

Figure **28**. Depth profiles of chemical and physical parameters at Station 5 in Sodus Bay on 15 August 1988.

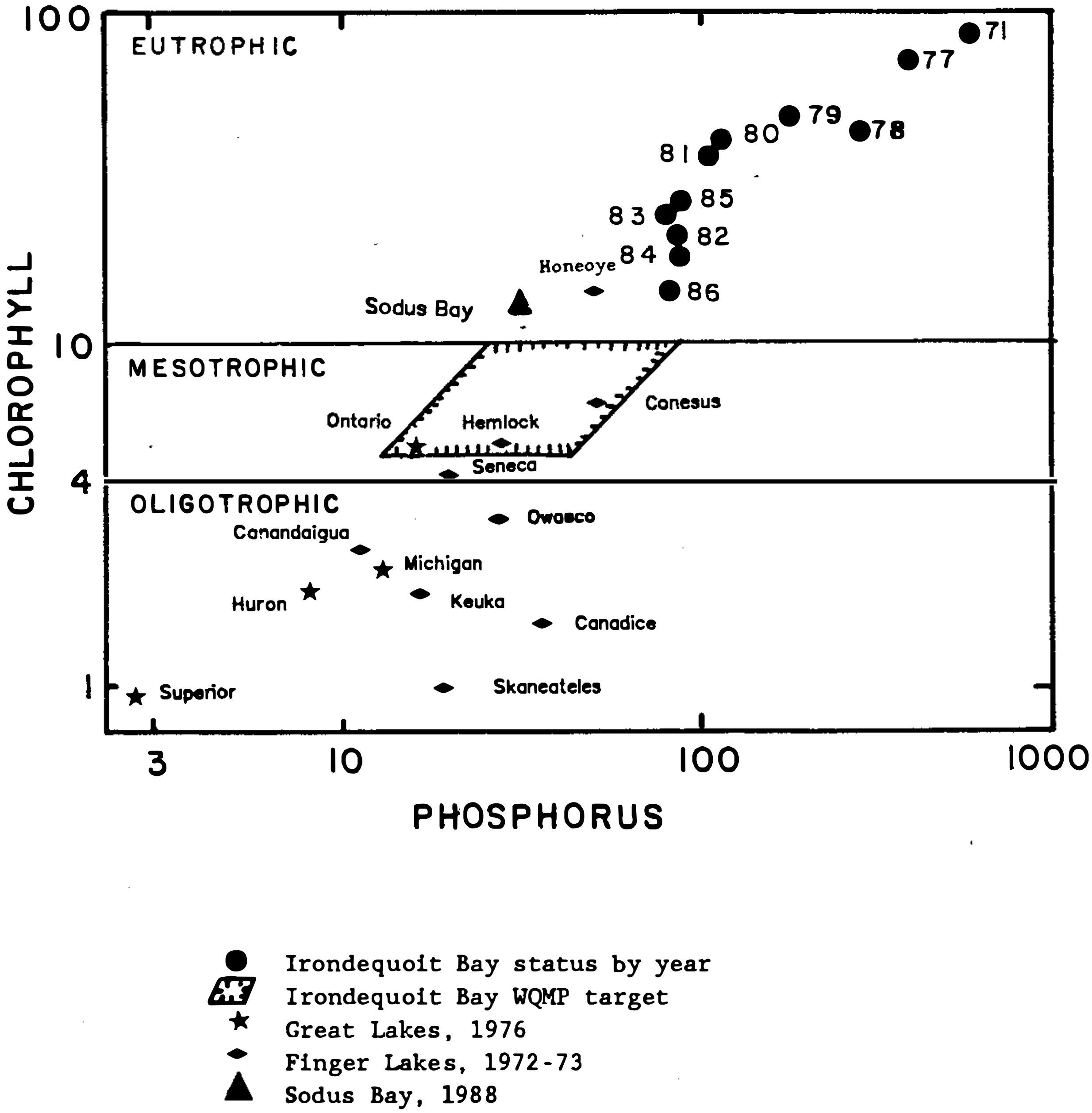

Figure **29**. Relationship between mean summer chlorophyll concentration (mg Chl a/m^3) and potential phosphorus (mg TPO_4/m^3), a function of retention time and total phosphorus loading. Modified from Burton (1988) and Vollenweider (1976).

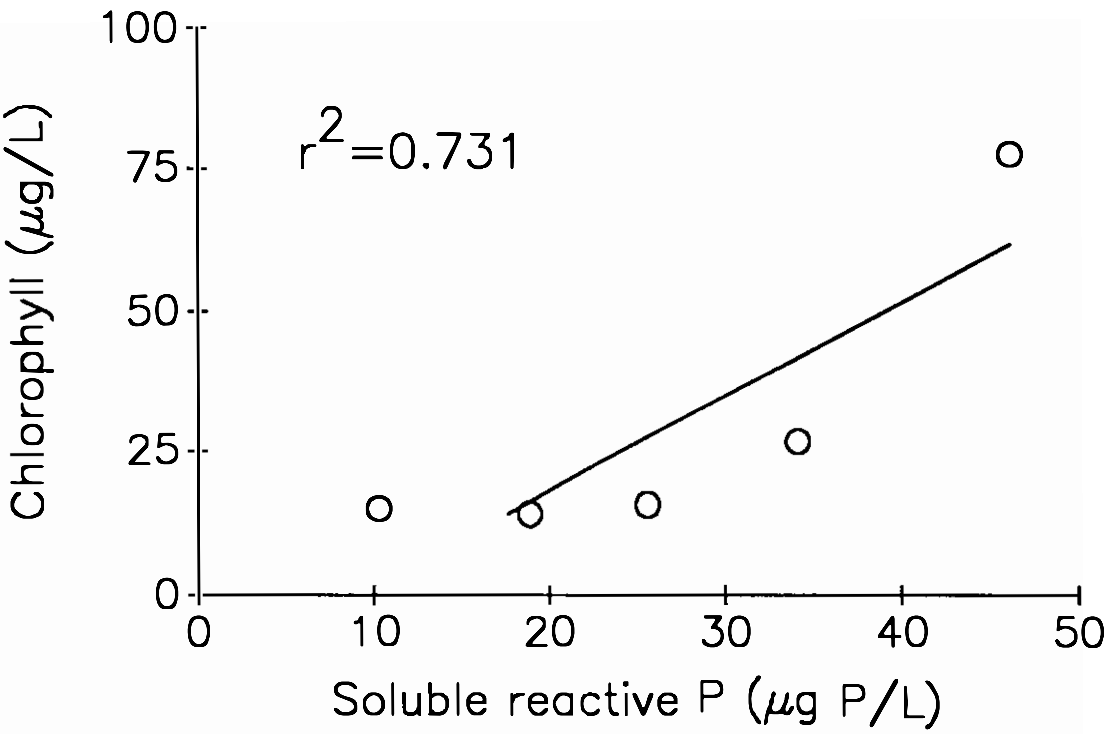

Figure **30**. Relationship between chlorophyll a and soluble reactive phosphorus at Sodus Bay tributary mouths on 15 August 1988.