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Phytoplankton Populations in Relation to Different Trophic Levels at Winnepesaukee Lake, New Hampshire, USA

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ABSTRACT

The composition, abundance, and seasonal periodicity of phytoplankton at Lake Winnipesaukee were determined. Trophic levels were evaluated for the entire lake and for eight individual stations. The study afforded an opportunity to compare the trophic levels of Lake Winnipesaukee with Newfound and Winnisquam Lakes.

Monthly collections were made at four stations (Alton, Wolfeboro, Weirs, and Center Harbor) from July 1969 to August 1970, while four other stations (Winter Harbor, Melvin Bay, Meredith Bay, and Paugus Bay) were studied during July through August 1970. Samples of phytoplankton were taken from three to six depths at each station with a 4-liter Van Dorn water sampler. Water samples were also taken for nutrient analyses of orthophosphate, total phosphates, nitrate-nitrogen and silicon dioxide. Living materials were used in the identification of taxa at each station. Phytoplankton cell numbers were determined using an inverted microscope and fixed materials. The primary productivity of natural phytoplankton population were evaluated in situ and in the laboratory. Seasonal and spatial variations of primary productivity were evaluated, as well as the response of phytoplankton to nutrient enrichments of nitrates, phosphates and silicates.

The differences in phytoplankton numbers (cell/ml) and nutrient levels were compared with previous records at Winnisquam

and Newfound Lakes. The nutrient levels at Winnipesaukee were in excess of those previously found at Newfound and Winnisquam Lakes. However, the species diversity at Winnipesaukee Lake was much greater than at either of the other two lakes.

The species composition at the different stations was dependent upon their trophic levels. The blue-green algae were the dominant phytoplankters at all stations, and they usually comprised the major portion of the cell counts. The concept of phytoplankton associations was useful in evaluating the trophic level of Lake Winnipesaukee. Although dominated by a Eutrophic Myxophycean Plankton, there were oligotrophic phytoplankton associations also evident.

The application of the phytoplankton quotient concept, to the individual stations provided a mesotrophic rating for the Weirs, Winter Harbor, Meredith, and Paugus Bay Stations while Alton, Wolfeboro, Melvin Bay and Center Harbor were categorized as eutrophic. A collective interpretation of the representative phytoplankton associations, also indicated mesotrophy as the trophic level of the overall lake. The most striking examples of eutrophy were found at the Wolfeboro and Melvin Bay Stations.

INTRODUCTION

During the past six years extensive studies have been made of phytoplankton populations associated with different levels of water quality at Newfound and Winnisquam Lakes in New Hampshire. One paper dealing with a part of this work has been published (Gruendling and Mathieson, 1969) and another has been submitted for publication (Gruendling and Mathieson, in press). In both instances, an attempt was made to evaluate the interrelationships between the composition, periodicity and abundance of phytoplankton species in relation to nutrient levels at Newfound and Winnisquam Lakes. With the continued interest and support of the Water Resources Research Center of the University of New Hampshire, phase II of the above project was implemented at Lake Winnipesaukee.

Scenic splendor is unquestionably true of Lake Winnipesaukee. In fact, the Aquedoctan and Chocoruan Indians called the Lake "Beautiful Water in a High Place" or Winnipesaukee (Blaisdell, 1936). The lake is surrounded by mountains, The Belknaps are to the Southwest, the Ossipee Range is to the North and the famed White Mountains lie to the Northwest (Goldthwait et al., 1951). "The Oldest Summer Resort in America" is located in Wolfeboro. Lake Winnipesaukee has long been a fisherman's paradise, a boater's haven, and a key subject for artists and photographers alike. The economic importance of Lake Winnipesaukee is immeasureable in terms of real estate development, recreational

applications, and tourist revenue.

The objectives of this study were as follows: (1) to contribute to our understanding of New Hampshire Lakes; (2) to better interpret water quality characterization in terms of biological indicators; (3) to extend and improve the usage of phytoplankton quotients; (4) to allow a more functional understanding of the role of nutrients and phytoplankton growth; (5) to compare and contrast species composition, periodicity, and abundance of algal populations recorded at Newfound and Winnisquam Lakes with those at Lake Winnipesaukee; (6) to compare the primary productivity of phytoplankton populations at diverse sites at Lake Winnipesaukee.

METHODS

Monthly collections were made at Lake Winnipesaukee from July 14, 1969 to August 26, 1970, exclusive of the periods of ice formation and ice-out. Four stations were initially established at Alton Bay, Wolfeboro Bay, the Weirs, and Center Harbor, and they were retained throughout the project (Fig. 1). Four other stations (Winter Harbor, Melvin Bay, Meredith Bay and Paugus Bay) were added for the months of July through August of 1970. The eight stations were selected on the premise that different trophic levels could be found in the same lake.

A 4-liter Van Dorn Water Sampler was used to take water

samples (1, 3, 5, 10, 15, and 20 meters) at each station. Twenty-five ml subsamples were employed from each depth for phytoplankton enumeration; these were immediately preserved with three drops of acid Lugol's solution. One liter subsamples were also taken from the 5 meter depth at each station for nutrient analysis. The samples were then placed in polypropylene bottles and refrigerated for laboratory analysis. The techniques of Wood et al. (1967) were used to measure nitrate levels. Orthophosphate levels were determined using the methods of Murphy and Riley (1962). Total phosphorous levels were evaluated using the methods of Menzel and Corwin (1965). The handling of silicate analysis was as outlined in Strickland and Parsons (1960).

Light penetration was determined with a Whitney Underwater Light Meter (Model LMD-8A); the one percent transmission level was recorded. A Model TC-5 Thermistor, also from Whitney Underwater Instruments, was used to determine water temperatures and the relative extent of the epilimnion and hypolimnion layers.

Dissolved oxygen (in parts-per-million) was determined for each depth (1, 3, 5, 10, 15, and 20 m) using a modification of the Winkler Technique devised by Hach Chemical Company. It incorporates the use of powder pillows which greatly expedites the process. Free CO_2 was determined by using phenolphthalein as an indicator and titrating with N/44 Naoh. Bicarbonates were determined using methyl orange as an indicator and titrating with

N/50 H_2SO_4 to a salmon pink end point. The volume (ml) of titrating agent used (both N/44 NaOH and N/50 H_2SO_4) times 10 equaled the parts per million of free CO_2 or HCO_3 alkalinity. The latter two tests were made in Nessler Tubes with 100 ml samples (Anon., 1961). A Beckman pH meter was used in the determination of pH values for each of the above depths.

The primary productivity, or carbon fixation, of the phytoplankton populations at Winnipesaukee Lake was determined by the carbon-14 techniques summarized by Goldman (1961) and Gentile (1966). The methods measure the net productivity (photosynthesis) or the rate of storage of energy in excess of that used for respiration. The values are expressed as mg of carbon fixed/ m^3. The source of the radioactive C-14 was $NaHC^{14}O_3$. Incubations were made in the field and in temperature-light controlled incubators (Puffer Hubbard) in the laboratory. The latter experiments were conducted to determine the effects of nutrient enrichments of nitrate-nitrogen, orthophosphates, and silicates on carbon fixation, while the former were not enrichment experiments.

The samples for the field C-14 experiments were collected at 1, 3, 5, 10, 15 and 20 m, depending upon the deepest depth at each station. A 100 ml aliquot of each water sample was placed in a 125 ml pyrex BOD bottle and incubated with 2 ml of $NaHC^{14}O_3$ (= 2 μ curries of C-14). A duplicate dark bottle was also established for each depth in order to evaluate respiration. The light

and dark bottles were subsequently suspended from an inner tube at the same depth from which they were taken. The samples were incubated in the field from 1000 to 1400 EST. After four hours of incubation the samples were killed with 2 ml of formalin. Subsequently they were filtered with a .45 mμ Millipore HA Membrane Filter. Ten ml of 10-3 N HCL was used to remove any absorbed radioactivity; this was followed by a final rinse with 20 cc of distilled water. The assimilated radioactive carbon was counted on the membrane filters with a Baird Atomic Proportional Counter with a Model 135 Scaler-Timer. The counts per minute were converted to disintegrations per minute and ultimately to mg C/ m^3, according to the formulas given in Goldman (1961).

The 5 m samples at each site were used for the laboratory nitrient enrichment experiments. Table I summarizes the enrichment schedule employed. The procedures used in the laboratory experiments were identical to the field studies, except for the following deviations:

(1) the incubation period was 24 hours

(2) the illumination was adjusted to approximate field conditions

(3) continuous illumination was employed

(4) the enrichments

The nutrient experiments were initially conducted in the field, but a 4 hour incubation period was inadequate - hence the longer laboratory incubation. The enhancement or inhibition of primary

productivity was determined after a comparison with control (enriched) samples. The experiments were conducted for 3-14 consecutive months, depending upon the station.

A #25 Turtox Plankton Net was employed in making vertical hauls (20 meters in depth) at each station in order to concentrate living phytoplankton for identification. The samples were refrigerated and returned to the laboratory. The phytoplankton were enumerated according to the inverted microscope technique outlined by Lund, Kippling, and Le Cren (1958), using a Unitron inverted microscope (Model Bi-4777). A one ml unconcentrated sample was added to a sedimentation tube, allowed to settle for 15 hours, and then counts were made of the total number of cells per species under 200X magnification.

The identification of most organisms was made from living samples, except for the nannoplankton which were treated by sedimentation of fixed samples. The texts of Smith (1950) and Prescott (1951) were chiefly used for generic designations. Specific identifications were obtained from various sources as follows: Bourrelly (1957, 1968), Boyer (1916), Brandt and Apstein (1964), Cleve (1894), Cleve-Euler (1932), Croasdale (1935), Desikachary (1959), Drouet (1968), Drouet and Daily (1956), Forest (1954), Hustedt (1930), Irenie-Marie (1938), Palmer (1959), Ralfs (1848), Randhawa (1959), Tilden (1910), Uherkovich (1966), Van Heurck (1896), West and Fritsch (1927),

Whitford and Schumacher (1969), and Wolle (1887, 1892). A variety of other references listed in Gruendling and Mathieson (1969) were also employed.

DESCRIPTION OF LAKE AND ENVIRONMENTAL FACTORS

Lake Winnipesaukee is located at approximately 43°27' to 43°44' latitude and 71°30' to 71°10' longitude (Fig. 1). It has an area of 18,000 hectares or 180 km^2, a maximum depth of 51 meters, and it is the second largest lake in New England (Frey, 1963). The long axis of the lake lies in a northwest to southeast direction, which was that of the Pleistocene glacial scour (Goldthwait, et al., 1951). The glaciation impact easily eroded the weak Devonian bedrock of medium to coarse grained Kinsman Quartz Monzonite and Winnipesaukee Quartz Diorite (Billings, 1956). The lower Paugus and Alton Bay areas differ in that they are underlain by micaceous quartzite and coarse grained mica schist. Lake Winnipeasukee's ragged peripheral configuration is a result of this glacial excavation of weak bedrock areas and deep preglacial weathering (Goldthwait, et al., 1951), and it may be said to be a composite of the rock basin and drift damned lake types (Hoover, 1938).

The physical-chemical characteristics of Lake Winnipesaukee showed it to be a soft water lake with methyl orange alkalinity values ranging from 6.0-11.6 ppm and a pH range of 7.0-7.4. Figures 2 and 3 summarize the seasonal variation of methyl orange

alkalinity (HCO_3) at the 8 stations. All of the samples were taken at 5 m. Station 1 exhibited the greatest fluctuations, with peaks of 13.5-14.5 and minima of 1.5-6.0. The maximum alkalinity value for each station was recorded during the summer of 1969. No phenophthalein alkalinity was detected from the 5 m samples at the 8 stations. Free CO_2 values at the same depth varied from 1-6 ppm (see Figs. 3 and 4). No seasonal trend was evident for free CO_2 values. Stations 1 and 4 exhibited the maximum free CO_2 values.

Figures 5 to 9 illustrate the variation of pH at each station. The values were recorded at the surface, 3, 10, 15 and 20 m, depending upon the maximum depth at each site. The pH values at stations 1-4 were more variable during the summer of 1969 than during subsequent months. The pH values at stations 5-8 were relatively constant during the summer of 1970 (see Fig. 9).

Oxygen concentrations at the eight sites ranged from 4.6-16.2 ppm (Fig. 10-14). The highest values were usually found during the late winter, while the lowest readings were generally present during the summer and early fall. The lowest oxygen values were found in the 15 and 20 m samples during the late summer (Figs. 11-14).

Figures 15-19 show the spatial and temporal variations of water temperatures at Lake Winnipesaukee. The seasonal variations of temperatures at the different stations were very similar.

Maximum surface water temperatures (26.5-29.3 C) were recorded during July and August. In September, the surface temperatures diminished rapidly as did those for the 3, 5 and 10 m levels; by mid October the upper 10 m were isothermal. By late October, the entire water column was isothermal at 13.6 C. During January to March, 1970 the temperatures under the ice ranged from 1.9 to 2.6 C, and a slight inversed stratification was evident. Ice cover ranged from 60-75 cm, and ice-out occurred April 28, 1970. The spring overturn then occurred and the water temperatures increased rapidly; thermal stratification was established by mid May. At the times of highest surface water temperatures, stratification was evident at all stations. The hypolimnion temperature ranged from 7.5-17 C.

Figure 20 illustrates the depth of 1% surface light at stations 2-4; station 1 is not included as it was quite shallow, and a 1% light level was rarely present. The 1% light level at stations 2-4 ranged from 16-19 m in July to 6-12 m in March, under the ice. The ice cover (60-75 cm), plus the variable coverage of snow, greatly reduced light penetration during the winter months. Generally the light penetration decreased from June until ice-out, at which time it increased again. Increased particulate matter from run-off, lake turnover, pollen accumulation and wind turbulence undoubtedly contributed to lower light penetration. The summer levels of 1% light penetration at

stations 5-8 were comparable to those of stations 2-4 (Fig. 21).

The seasonal variation of light penetration showed a definite correlation between the total phytoplankton crop (compare Figs. 21 and 69). Thus, as the total phytoplankton increased, the light penetration diminished and vice versa. The greatest number of phytoplankton for all stations occurred at the Weirs (station 3) in August, 1969. It was accompanied by a corresponding drop in the 1% light transmission level from July to August (Fig. 20).

Figures 22-26 illustrate the percentage of surface light available throughout the water column. Peak values were found at station 3 during June and July, while minimal values were evident at stations 1-4 during March - at all depths (see Fig. 22-25). Stations 1 and 2 showed a comparable pattern except that peaks were also found in November-December (Figs. 22 and 23). It should be noted that the latter peaks may be "artifacts" due to differential monitoring periods and varying meterological conditions on a day to day basis. A comparison of Figures 22-26 shows that light penetration at each station was very good.

The seasonal levels of nutrients (orthophosphates, total phosphorous, nitrite-nitrogen, nitrate-nitrogen and silicon dioxide) at 5 m are illustrated in Figs. 27-33 and 53-56. Orthophosphate values at stations 1-4 ranged from 0.4-1.0 mg/l, with peaks occurring in July and August and minimal values in the winter (Fig. 27). The maximum orthophosphate values occurred at

Meredith Bay (39.2 mg/l) and Paugus Bay (1.38 mg/l) - see Figs. 27 and 53-56. Figures 28 and 29 illustrate the seasonal values of total phosphorous at stations 1-8. Peak values were evident during the summer, particularly at stations 1, 2 and 8.

The nitrite and nitrate-nitrogen values were more variable than total phosphorous and orthophosphate (Figs. 30-32 and 53-56). The maximum values of nitrite-nitrogen at stations 1-4 were found during June-August, 1969 (Fig. 30). Thereafter the levels decreased, either drastically or moderately, and intermediate levels were subsequently found during the fall and winter. A decline in nitrite-nitrogen was evident at each site during the spring (Fig. 30). Relatively few records of nitrite-nitrogen were summarized for stations 5-8, and no consistent trend was apparent (Fig. 31). Station 8 had the highest nitrite-nitrogen levels of all the stations (Figs. 30 and 31). The seasonal cycle of nitrate-nitrogen at stations 1-4 showed peak summer (except station 3) and late winter levels (Fig. 32). During June of 1970 each of the sites showed consistently low nitrate-nitrogen concentrations (Figs. 53-56). Stations 1 and 2 exhibited the highest nitrate levels (Fig. 32).

The silicon dioxide concentrations at stations 2-4 showed minimal values during the summer and maximum concentrations during the winter and spring (Fig. 33). The peak at station 1 occurred during June, while uniformily high values were found from January

to June at station 4 (Fig. 33). The silicon dioxide concentrations at stations 5-8 are illustrated in Figures 53-56. Station 6 exhibited the maximum value (27.8 mg/l) of silicon dioxide found at any of the stations - during July. Stations 5, 7 and 8 showed relatively low levels of silicon dioxide during the summer of 1970.

Figure 34 is a summary of the mean values of nutrients at each of the 8 stations. Station 6 exhibited the maximum average value of silicon dioxide (12.5 mg/l). Stations 1 and 2 had the highest nitrate-nitrogen levels, while station 7 had the maximum average values of total phosphorous and orthophosphate respectively.

In Situ Primary Productivity

Figures 35-43 summarize the spatial and temporal variations of net primary productivity at the eight stations. The most extensive seasonal observations were made at stations 1-4. At station 1 the maximum net productivity was recorded in October (2.6 and 4.2 mg C/ m^3) and November (5.0 mg C/ m^3), 1969 (Fig. 35). The depth of maximum carbon fixation occurred between 1-3 m. A decrease was evident with an increase in depth, and no net carbon fixation was evident at 15 m. Most of the other stations exhibited their maximum productivity in 1-5 m during July and/or August (compare Figs. 36-43). Stations 2, 3, 4 and 5 even showed

a net productivity at 20 m on a few occasions (Figs. 37-40).

Surface light inhibition was evident on one or more occasions at each of the 8 sites, for the primary productivity at the surface was less than at 1-5 m (Figs. 35-43). A comparison of the same Figures also shows that there is a wide variation of carbon-14 fixation, both temporally and spatially at Winnipesaukee Lake. Stations 2, 3 and 8 showed the maximum net productivity values. Peaks of 8.9 and 22.6 mg C/ m^3 were recorded in August at Station 2. Values of 11.5 and 65.0 mg C/ m^3 were recorded during July and August, 1969 respectively at station 3. Station 8 showed a peak of 19.0 mg C/ m^3 in August, 1970.

Primary Productivity of Unenriched Laboratory Cultures

Figures 44 and 45 show the seasonal primary productivity of phytoplankton populations from stations 1-4. The water samples were obtained at 5 m, and they were incubated for 24 hours in a Puffer Hubbard Incubator, without any nutrient enrichment. The experiments were conducted at approximately the same temperature and light conditions as found <u>in situ</u> (see Methods and compare Figs. 15-18 and 22-25). The highest carbon fixation rates were found during the summer of 1969. Stations 2 and 3 were the most productive sites, in agreement with the <u>in situ</u> studies (compare Figures 35-43). Station 4 showed a major peak in late October, 1969 (Fig. 45), while station 2 had a winter peak in December (Fig. 44).

Nutrient Enrichment Experiments

Figures 46-48 summarize the results of several "typical" enrichment experiments with supplements of $NaNO_3$, KH_2PO_4 and $NaSiO_3$. $9H_2O$. The rates of C-14 fixation are plotted versus nutrient levels. Two general responses are evident as follows: (1) an enhancement of photosynthesis with increased nutrient levels; (2) an inhibition or lack of photosynthetic enhancement with increased nutrients. The former response is interpreted as a nutrient limited situation, while the latter is considered as one that is saturated with nutrients.

The results of the nitrate enrichment experiments are illustrated in Figures 49-56. The solid line represents the nutrient levels in the control (unenriched) cultures, while the level of maximum photosynthetic enhancement are illustrated by the dashed lines. It should be emphasized that the rates of photosynthesis are not included in the Figures.

At stations 1, 2, 4 and 7 the primary productivity usually increased with a corresponding addition of nitrates to 2000 mg/l, which was the maximum enrichment (Figs. 49, 50, 52 and 55). Station 3 showed a different pattern during mid June-July 1969 and January and February, 1970, for additions of nitrates did not cause a pronounced increase in carbon fixation (Fig. 51). In other words they appeared to be saturated with nitrates. Stations 5, 6 and 8 showed a similar saturation at one or more times during

June to August, 1970 (Figs. 53, 54 and 56).

Figures 53-60 illustrate the results of the phosphate enrichment experiments. Station 1 exhibited phosphate saturation during June and November (Fig. 57), station 3 showed a similar response in June and August 1969 and August 1970 (Fig. 59). Station 4 exhibited a saturation response on one occasion in July (Fig. 60), and station 8 was saturated with phosphates on three of the four times it was evaluated during the summer (Fig. 56). At stations 2, 5, 6 and 7 the primary productivity usually increased with a corresponding addition of phosphates to a level of 2000 mg/l, which was the maximum enrichment (Figs. 53-55 and 58).

A comparison of Figures 53-56 and 61-64 shows that each of the stations, except for station 8 , was saturated with silicon dioxide at some time during the year. Although no consistent trend was apparent, saturation conditions were evident at stations 1-4, at least once, during the fall of 1969 (see Figs. 61-64).

GENERAL COMPOSITION OF THE PHYTOPLANKTON FLORA

A total of 453 taxa of phytoplankton were identified at Lake Winnipesaukee. A listing of the individual species and their seasonal occurrence at each station is summarized in Table II. The Chlorophyceae provided the greatest diversity of organisms with 237 taxa; 91 of the green algae were desmids and 115 were members of the Chlorococcales. The Bacillariophyceae comprised

the second largest class of algae with 83 species; 73 of which belonged to the Pennales and 10 to the Centrales. Although the Cyanophyceae ranked third in numbers of species with 68, their cell counts far exceeded all other classes. The other major components of the phytoplankton flora were as follows: Chrysophyceae (34 species), Dinophyceae (17 species, Crytophyceae (4 species), Euglenophyceae (4 species), and Xanthophyceae (6 species).

Tables III and IV indicate the combined monthly total in numbers of species per class at Stations 1-4 and 5-8 respectively. The Chlorophyceae were the dominant class throughout the study; the Cyanophyceae usually ranked second. The Bacillariophyceae and Chrysophyceae generally ranked third and fourth in numbers of species, while the Dinophyceae, Cryptophyceae, Euglenophyceae, and Xanthophyceae respectively, made relatively small contributions.

The monthly variation in numbers of species at all stations is shown in Figure 66. Stations 1-4 combined had a range of 208 species in July 1969 to 71 in February 1970; thereafter, the numbers of species progressively increased again to 200 in August 1970. Stations 5-8 ranged from 159 in June 1970 to 222 in August 1970.

As suggested earlier, the Cyanophyceae usually dominated the phytoplankton in numbers of cells at all stations. Some of the blue-green algae that were present in greatest abundance were Polycystis aeruginosa, Polycystis incerta, Coelosphaerium

naegelianum, Oscillatoria angustissima, Coelosphaerium pallidum, Gomphosphaeria lacustris, Aphanocapsa elachista, Gomphosphaeria lacustris var. compacta, and Aphanothece nidulans. Although other species made sizeable contributions, they were uncommon in comparison with the above blue-greens. Fewer blue-green species were involved in the Cyanophycean dominance in numbers of cells during the fall and winter seasons than during the spring and summer.

Chlorophycean species were usually the second largest contributors to the phytoplankton at each station, primarily because of their great species diversity. The green algae except for Gloeocystis vesiculosa and Botryococcus braunii were rarely dominant phytoplankters in terms of numbers of cells. The latter two species appeared in comparatively high numbers at all stations during the summer. Botryococcus braunii had peak numbers of $.39 \times 10^6$ cells/l in September 1969 at Alton, while peak numbers of $.26 \times 10^6$ cells/l of Gloeocystis vesiculosa were recorded in August 1970 at the Weirs. The latter counts may be compared with those of two dominant blue-greens, Polycystis aeruginosa and Gomphosphaeria lacustris var. compacta, which had high cell counts of 4.07×10^6 cells/l in October 1969 at Wolfeboro and 2.18×10^6 cells/l in August at the Weirs respectively. Although the latter counts were usually high, they exemplified the important contribution of the blue-green algae to the phytoplankton. Two other

examples of green algae which were dominant phytoplankton components were as follows: Actinastrum hantzschii var. fluviatile with a count of .4 x 10^6 cells/l in July 1970 at Wolfeboro and Ulothrix variabilis with .41 x 10^6 cells/l in August 1970 at the Weirs. Dictyosphaerium pulchellum, Botryococcus protuberans var. minor, and Cruciqenia truncata were occasionally abundant.

The Chrysophycean respresentatives such as Chrysosphaerella longispina, Dinobryon divergens, Rhizochrysis limnetica, and Uroglenopsis americana were abundant during July to September. The golden brown alga, Dinobryon sertularia var. protuberans, and diatoms such as Melosira ambiqua, Tabellaria fenestrata, Asterionella formosa, Fragillaria crotonensis, and Cyclotella comta then became major phytoplankton components throughout the winter. The peak numbers of diatoms occurred during December-January and May-June.

The Chrysophycean flora was most abundant at Center Harbor and Paugus Bay. Uroglenopsis americana and Dinobryon divergens contributed .45 and .085 x 10^6 cells/l respectively at Center Harbor during July 1969. Rhizochrysis limnetica contributed .133 x 10^6 cells/l in August at Center Harbor and combined with the latter two algae to make the Chrysophyceae the second largest contributor of cells. The cell count of Uroglenopsis americana rose to .71 x 10^6 cells/l in October; a comparable count occurred in November. Uroglenopsis americana, Dinobryon divergens and

Rhizochrysis limnetica were primarily responsible for the Chrysophycean peaks recorded at Center Harbor from July through November 1969. The Chrysophycean peak at Paugus Bay was dominated by Dinobryon bavaricum and Uroglenopsis americana. An unprecedented pulse of 2.01×10^6 cells/l of Chrysosphaerella longispina occurred in August 1970.

PHYTOPLANKTON POPULATIONS AT INDIVIDUAL STATIONS

Alton Bay

A total of 259 taxa of algae were identified from Alton Bay (Table V). The members of the Chlorophyceae were the dominant class, being represented by 118 taxa (Table V). The Cyanophyceae and the Bacillariophyceae followed with 49 and 44 species respectively (Table V). Table VI indicates the total number of species per month at each station. Alton Bay had a maximum of 116 species in July 1969, a general decline to 35 in March and then a progressive rise thereafter. Figure 67 shows the seasonal variation in numbers of species per class. The Chlorophyceae had a maximum of 48 species in September 1969 and a minimum of 8 in March 1970 (while under ice cover). The blue-greens exhibited a high of 27 taxa in July 1969 and a low of 11 in May 1970. The Bacillariophyceae were most numerous in January 1970 with 27 species; only 10 were found in March.

Figure 68 shows the monthly variation in numbers of cells per class, expressed as the mean count for all depths sampled. The Cyanophyceae dominated with a maximum of 5.9 to 10^6 cells/l in September 1969 and a minimum of .35 x 10^6 in February 1970. The Chlorophyceae ranged from a high of .65 x 10^6 cells/l in September to a low of .027 x 10^6 in March 1970. A pulse of .467 x 10^6 cells/l in January 1970 was the high for the Bacillariophyceae; their minimum was .068 x 10^6 in March 1970. The Chrysophyceae occasionally contributed substantially to the total phytoplankton; a maximum of .794 x 10^6 cells/l being recorded in August 1969. A minimum of .006 x 10^6 cells/l was recorded in March 1970.

The Crytophyceae was the fifth largest class, having a range of .047 x 10^6 cells/l in August 1969 to .002 x 10^6 in February 1970. The Dinophyceae, Euglenophyceae, and Xanthophyceae contributed little to the numbers of cells.

Table VII gives the monthly percent composition of total cells per class at Stations 1-8 and the average yearly percent composition of each class. The average yearly percent of Bacillariophyceae was 13%, while the more diverse Chlorophyceae comprised 6.3% and the Chrysophyceae 7.2% of the total phytoplankton. The Cyanophyceae comprised approximately 73% of the yearly phytoplankton composition. The four remaining classes combined only represented .5% of the cell count at Alton Bay.

The seasonal variation in numbers of cells for Stations 1-4 is indicated in Figure 6. A maximum of 7.37 x 10^6 cells/l was noted for August 1969, with a minimum of .667 x 10^6 in March 1970 (under ice cover).

Wolfeboro

The greatest species diversity was found at Wolfeboro (Table V). A total of 283 taxa were identified, comprised of 138 Chlorophyceae, 55 Bacillariophyceae, 46 Cyanophyceae, 27 Chrysophyceae, 7 Dinophyceae, 4 Cryptophyceae and Euglenophyceae, and 2 Xanthophyceae. A maximum of 127 taxa was identified in August 1969, as contrasted to 46 in February 1970 (Table VI). Slight fluctuations occurred from July through October. There was a general decrease in the number of taxa with the advent of winter; thereafter, there was a steady rise after ice-out. The Chlorophyceae ranged from 51 taxa in July 1969 to 14 in February; their numbers then rose again to 61 in August 1970 (Fig. 7). The Cyanophycean species ranged from 33 in July and August of 1969 to 5 in February 1970; subsequently they rose again to 25 in August 1970 (Fig. 70). The Bacillariophyceae and Chrysophyceae rounded out the four largest contributors in species showing a comparable seasonal cycle like that found at Alton Bay.

Once again the Cyanophycean cell count usually exceeded all other classes. A maximum of 8.99 x 10^6 cells/l was found in

September 1969 with a low of .047 x 10^6 in February 1970 (Fig. 71). In contrast the Chlorophycean total cell count ranged from .893 x 10^6 cells/l in July 1969 to .055 x 10^6 in May 1970 (Fig. 71). A pulse of .829 x 10^6 cells/l in January 1970 was the maximal for the Bacillariophyceae; a low of .087 x 10^6 occurred in August 1970 (Fig. 71). A pulse of .536 x 10^6 cells/l of Chrysophyceae was evident in August 1969 and another of .681 x 10^6 in August 1970 (Fig. 71). At the times of these August pulses, the Chrysophyceae ranked third in their contribution to the total cell numbers, behind the Cyanophyceae and Chlorophyceae respectively. The remaining algal classes, by comparison, contributed minimally both to species diversity and to cell numbers. The percent of total cells per class was basically similar to that of Alton Bay (Table VII). The largest phytoplankton count for Wolfeboro was 9.97 x 10^6 cells/l in September 1969; a minimum of .486 x 10^6 was recorded in February 1970 (Fig. 69).

Weirs

The species diversity at the Weirs Station was basically similar to Stations 1 and 2, except for the reduced number of diatoms (Table V). Two hundred and forty-six taxa were identified. The Chlorophyceae dominated the phytoplankton in total species each month (Fig. 72). The 131 algal taxa identified during August 1969 was the highest monthly record for any station (Table VI). The maximum number of species evident during ice cover was

also found at the Weirs (Table VI). Although the proportion of species per class approximates that of other stations, there are some noticeable variances in total cell numbers (Fig. 69). For example, one may note the largest total cell numbers recorded for the project (i.e. 13.6 x 10^6 cells/l in August 1969). Once again the Cyanophyceae contributed the major portion of the total cell count with 12.29 x 10^6 cells/l, the highest individual class count for the entire project (Fig. 65). The Bacillariophyceae, as at other stations, exhibited a January pulse of .855 x 10^6 cells/l (Fig. 65). The latter was the highest diatom count at any station. The diatoms at this station averaged 12% of the yearly total phytoplankton (Table VII). The average yearly contribution of blue-greens was 74%, while the greens contributed 6%, and the golden-browns 7.5%.

Though the January diatom pulse was the highest recorded at any station, it only represented 17.2% of the cells of phytoplankton that month. In contrast, a smaller population of diatoms recorded during June 1970 at the Weirs contributed 44.6% of the monthly cell numbers (compare Fig. 65 and Table VII).

The Chrysophycean impact on the total cell count, as at the other stations, was usually greatest in May and June when it comprised 12-36% of the phytoplankton at the Weirs (Table VII). A Chrysophycean count of .256 x 10^6 cells/l in June of 1970 accounted for 24% of the total phytoplankton.

Center Harbor

Of the 233 taxa found at Center Harbor, 103 were Chlorophyceae, the fewest such species recorded for Stations 1-4 (Table V). A maximum of 104 species was found in November 1969 and a minimum of 59 in March 1970 (Table VI). The usual Chlorophycean dominance of species (Fig. 73) was correlated as in the case of the Cyanophyceae with total cell numbers (Fig. 74).

The highest cell count of Bacillariophyceae was recorded during May 1970 (.399 x 10^6 cell/l) and it resulted in 30% of the total phytoplankton (compare Fig. 74 and Table VII). Thus, the Bacillariophyceae were usually the second largest component in numbers of cells (Fig. 74). The average yearly contribution of Chrysophycean algae was 14% as contrasted with 12% for the Wolfeboro Station, 7.5% for the Weirs, and 7.2% for Alton Bay (Table VII). The May 1970 Chrysophycean count of .434 x 10^6 cells/l equalled 32% of the phytoplankton (compare Fig. 74 and Table VII). Although the golden-browns exerted a strong influence (percentage-wise) from May through August at Wolfeboro, the total numbers never exceeded those at Center Harbor (compare Table VII and Fig. 74). The seasonal variation in numbers of cells at Center Harbor ranged from a high of 6.13 x 10^6 cells/l in October 1969 to a low of .697 x 10^6 in March 1970 (Fig. 69). Thus, Center Harbor was the least productive of the four major stations in terms of total phytoplankton. It also exhibited the lowest

species diversity, with a minimal number of green algae (Table V).

Winter Harbor

Stations 5-8 cannot be favorably compared with Stations 1-4 because their study encompassed only the summer of 1970. Even so, the same general distribution of species per class existed at Winter Harbor (Station 5) for the 180 taxa (Table V). The blue-green species exceeded the more diverse greens in terms of numbers of cells with 3.59×10^6 cells/l in July (Fig. 75) or 82.1% of the total cell count (Table VII). The Bacillariophyceae composed the second greatest portion of the phytoplankton making up 35% in June and 10.2% in July (Table VII). A pulse of $.659 \times 10^6$ cells/l of Chrysophyceae in August (Fig. 75) produced the second largest portion or 16% (Table VII) of the total. Blue-green cells equalled 64.6% of the phytoplankton during the summer, greens 6.4%, diatoms 16.6% and golden-browns 12% (Table VII). The July count was the greatest recorded with 4.33×10^6 cells/l (Fig. 76).

Melvin Bay

Melvin Bay (Station 6) had the fewest species for Stations 5-8 with 174 taxa (Table VI). The blue-greens contributed 54.6% of the total phytoplankton cell numbers, and the Chrysophyceae, Chlorophyceae, and Bacillariophyceae 17.7, 15.3, and 11.6% respectively (Table VII). A Chrysophycean pulse of $.326 \times 10^6$

cells/l (Fig. 75) accounted for 36% (Table VII) of the June phytoplankton. The diatoms with .245 x 10^6 cells/l (Fig. 75) made up 27.2%, the greens 23%, and the blue-greens 12.1% of the June phytoplankton (Table VII). As at other stations, the blue-greens were the primary phytoplankton component during August, composing 78.1% of the total cell count (Table VII). The largest number of Chlorophycean species recorded during the study was found in August at Melvin Bay. However, the 62 species of greens (Fig. 77) comprised only 9% of the total phytoplankton (6.87 x 10^6 cells/l). Compare Table VII and Figure 76 for this interpretation.

Meredith Bay

One hundred and seventy-five taxa of phytoplankton were found at Meredith Bay (Table V). The Bacillariophyceae with .490 x 10^6 cells/l (Fig. 75) made up 47% and the Chrysophyceae 29% of the June phytoplankton (Table VII). The blue-greens dominated in numbers of cells during July (Fig. 75). In August, they equalled 82.5% (Table VII) of the phytoplankton with a count of 4.99 x 10^6 cells/l (Fig. 75). An August pulse of .659 x 10^6 cells/l of Chrysophyceae (Fig. 75) resulted in 10% (Table VII) of the phytoplankton; the remainder was primarily composed of Cyanophycean cells. The maximum phytoplankton count recorded was 6.08 x 10^6 in August 1970 (Fig. 76).

Paugus Bay

Paugus Bay had the largest number of taxa (186) of stations 5-8 (Table V). In addition, it had the greatest phytoplankton counts of the latter stations with 6.94 x 10^6 cells/l in July (Fig. 13). The Cyanophyceae composed 58% of the total phytoplankton during the summer (Table VIII). A strong pulse of Chrysophyceae (i.e. 2.12 x 10^6 cells/l) accounted for 30.1% of the August phytoplankton (Fig. 11).

CALCULATION OF PHYTOPLANKTON INDICES

The trophic level of Winnipesaukee was evaluated using a variety of phytoplankton indices such as the Chlorophycean Quotient of Thunmark (1945), and the Myxophycean, Diatom, Euglenine, and Compound Quotients of Nygaard (1949). A summary of the indices' values and the suggested trophic levels for Lake Winnipesaukee and for each station is found in Table IX and X. Since summer is the more optimal growth time for green and blue-green algae, Nygaard felt that all of the indices were best applied during June through August, with the exception of the Diatom Index.

A summary of the quotients and their interpretations is as follows:

QUOTIENT	OLIGOTROPHIC	EUTROPHIC
Chlorophycean =		
$\frac{\text{Chlorococcales}}{\text{Desmidiaceae}}$	< 1.0	> 1.0
Myxophycean =		
$\frac{\text{Myxophyceae}}{\text{Desmidiaceae}}$	< 0.4	0.1 - 3.0
Diatom =		
$\frac{\text{Centrales}}{\text{Pennales}}$	< 0.3	> 0.3
Euglenine =		
$\frac{\text{Euglenine}}{\text{Myxo. + Chlorophyceae}}$	< 0.2	0.0 - 1.0
Compound =		
$\frac{\text{Myxo. + Chlor. + Cent. + Euglen.}}{\text{Desmidiaceae}}$	< 1.0	2.5

The above indices were applied to the total species found throughout the project, to winter (Diatom Index), and to summer species listings for the entire lake (Table VIII). Further applications of the phytoplankton quotients were made on each of the eight stations studied (Table IX). Whereas the indices for Stations 1-4 represented the combined summer species of 1969 and 1970, those for the more briefly studied Stations 5-8 are only for the June through August listings of 1970.

The Diatom and Euglenophyte Indices when applied to the entire lake characterized it as oligotrophic, the Compound Index

indicated a mesotrophic state, and the Chlorophycean and Myxophycean Indices indicated eutrophy (Table VIII). Use of the five indices on individual stations indicated that Alton Bay, Wolfeboro, and Center Harbor were basically eutrophic, while the Weirs was mesotrophic (Table VIII). Although Stations 5-8 were only evaluated for one summer, three of the five indices showed mesotrophy at Winter Harbor, Meredith Bay and Paugus Bay; two indicated Melvin Bay as being eutrophic. Whether rating the entire Lake or the individual stations, the five phytoplankton quotients collectively indicated a mesotrophic status for Lake Winnipesaukee. The Compound Index provided for fairer estimate of trophic status, because it incorporated the five major phytoplankton components (i.e. Myxophyceae, Chlorococcales, Centric diatoms, Euglenophyceae, and Desmidiaceae). The Chlorophycean Index values, while greater than 1 in most cases, were borderline ratings. As such, they provided further credence to a mesotrophic ration of Lake Winnipesaukee.

DISCUSSION

Prescott (1951) categorized inland lakes according to their hydrographic features. Lake Winnipesaukee fits well into his cateogry of a soft water drainage lake; that is, one having an inlet and an outlet, and low calcium and half-bound carbon dioxide. The lake is similar to most temperate lakes in that it is dimictic

in nature, having both spring and fall overturns (Ruttner, 1963).

The origin of Lake Winnipesaukee probably dates back to the more recent Wisconsin Glaciation Period, the erosive impact of which resulted in the formation of this rock basinned, drift damned lake (Goldthwait, et al., 1951). Frey (1963) cited calcium values of 2.7 and 3.9 ppm for Lake Winnipesaukee, which agreed with those values recorded for several Wisconsin soft water drainage lakes (Prescott, 1951). Few blue-greens and numerous green algal species were characteristic of most soft water drainage lakes studied by Prescott (1951). The same was true of Winnipesaukee, which had 68 species of blue-green and 237 species of green algae. Prescott (1951) referred to the phytoplankton species of soft water drainage lakes as sparse. He suggested that the relatively high available total nitrogen of such lakes could be coupled with other essential nutrients and might result in greater productivity. A comparison was made between the green and blue-green algal species number of Winnipesaukee, and those previously recorded for Lakes Newfound and Winnisquam (Gruendling and Mathieson, 1969). Newfound had 10 blue-green and 43 green taxa, while Winnisquam had 10 blue-green and 93 green taxa. Thus, it is seen that the composition of blue-green and green species of these three lakes is similar to previous findings of Prescott (1951) for other soft water drainage lakes.

An examination of the physical and chemical characteristics

of Lake Winnipesaukee showed similar findings to those cited by Gruendling and Mathieson (in press). Newfound and Winnisquam Lakes had pH ranges of 6.7 - 7.2 and 6.2 - 7.2 respectively, while the Winnipesaukee pH ranged from 7.0 - 7.4. The Methyl orange alkalinity at Winnipesaukee ranged from 6. - 11.6 ppm comparing favorably with the 5.0- 9.0 and 5.0 - 11.0 ppm respectively for Newfound and Winnisquam. The above findings, including the CO_2 range of 1 - 6 ppm at Winnipesaukee corresponded with Prescott's (1951) findings at other soft water lakes. Newfound Lake had over 90% oxygen saturation throughout the water column and never had an oxygen deficiency in the hypolimnion. Winnipesaukee had ample oxygen (4.6 - 16.2 ppm) at all depths throughout the year whereas Lake Winnisquam had an oxygen depletion in the hypolimnion during the summer months. The temperature regime at Newfound and Winnisquam was similar to that at Winnipesaukee where the minimal value was recorded beneath the ice (1.9° C), and the maximum was found in late summer (29.3° C) - a typical pattern of most temperate lakes. The 1% light transmission at Winnipesaukee ranged from 5 - 19 m at Stations 1 - 8. Similar values were recorded at Newfound. However, the maximal transparency (10 m) at Winnisquam was much less than at Winnipesaukee.

Hutchinson (1957) relates the nutrient levels of soft water drainage lakes to the size of the drainage basin, and to the geochemical nature of the surrounding watershed. Since Lake

Winnipesaukee has a surface area of 180 km^2 (Frey, 1963) and it drains both sedimentary and igneous type rock (Billings, 1956) the high nutrient levels are more easily understood. Most of the silicates, phosphates, and nitrates of lakes are derived from the surrounding mountain ranges and lowlands via the leaching process of water runoff (Hutchinson, 1957).

In addition it should be emphasized that Lake Winnipesaukee is a major recreational site, and the highest nutrient levels appear during the summer with the influx of tourists, increased boating, swimming and camping. Particularly conspicuous were the July reading of 49.9 mg/l of orthophosphates and 39.2 mg/l of total phosphates at Meredith Bay. Maximum Myxophycean populations (non-heterocyst forms) usually occur during the summer, and they may exhaust all available nitrates (Prescott, 1951). However, at Winnipesaukee the peaks in nitrate levels occurred during June through August, when maximal numbers of blue-green cells were recorded. The high summer nitrate levels seemed to be a direct result of increased recreational activity. Although sewage treatment occurs in the proximity of most stations studied, their effluent is not stripped of nutrients. In recent years recreational applications have increased so much that temporary closings of major beaches (e.g. Weirs) have occurred. Such closings are contingent upon high coliform counts during the bathing season, and not upon nutrient readings.

The nutrient concentrations found at Winnipesaukee exceeded those recorded at Newfound and Winnisquam (Gruendling and Mathieson, in press). Although nitrients were not limiting factors for algal growth, as seen by the monthly phytoplankton patterns for each station (Figs. 69 and 76), additional nutrient enrichments usually caused increased primary productivity (Figs. 49-64). Thus, increased eutrophication of Lake Winnipesaukee will probably be associated with increased algal blooms, as at Winnisquam Lake (Gruendling and Mathieson, in press), unless the nutrient enrichment of Winnipesaukee is halted.

The Weirs and Wolfeboro stations exhibited the greatest cell counts of stations 1-4, with peaks of 13.6 and 9.96 x 10^6 cells/l respectively in August and September of 1969 (Fig. 69). In addition they also exhibited some of the highest primary productivity rates (compare Figs. 35-60). The peaks of cell numbers found at Lake Winnipesaukee were much higher than those found at Newfound Lake (12.7 x 10^5 in August, 1966) by Gruendling and Mathieson (in press). However, they fell far short of the maximum value of 1.7 x 10^8 recorded in September, 1967 at Winnisquam Lake (Gruendling and Mathieson, in press). The latter result is easily understood when one realizes the immensity of treated sewage effluent received in Winnisquam Lake daily.

Comparative carbon-14 experiments have been conducted at three other New Hampshire sites: Winnisquam Lake (eutrophic),

Newfound Lake (oligotrophic), Hampton Stabilization Pond (eutrophic) and the Old Reservoir on the University of New Hampshire campus (eutrophic). In general there is a correlation between cell counts and the level of primary productivity - i.e. high cell counts are associated with high productivity and vice versa. In addition, the more oligotrophic sites tend to show a greater enhancement of primary productivity with supplements of nutrients. As suggested previously one would anticipate greater enhancement of primary productivity if nutrients were limiting or not in excess. A comparison of Figures 49-64 shows that there were very few times when nutrients were saturating at Lake Winnipesaukee. However, this is not the case at Winnisquam Lake, the Old Reservoir, and at the Hampton Stabilization Pond (Mathieson, unpublished data). It is our conclusion that comparative nutrient enrichment experiments can be a fundamental tool in evaluating the trophic status of a lake or embayments on a single lake.

Aphanizomenon flos-aquae is the major bloom organism at Winnisquam Lake (Gruendling and Mathieson, in press). It is present at Winnipesaukee, as well as three other potentially troublesome blue green algae - Anabaena scheremetievi, Coelosphaerium kuetzingianum and Gloetrichia echinulata. The four species of blue green algae can cause conspicuous algal blooms and possibly also obnoxious odors (Jackson, 1964).

Although species diversity is a major characteristic of the

Lake Winnipesaukee phytoplankton, the flora might best be referred to as a Myxophycean Plankton, or one dominated by Polycystis, Aphanizomenon, or Anabaena which may form extensive water blooms (Hutchinson, 1967). A summer flora dominated by blue-greens is typical of the more productive lakes of temperate regions and in many shallow tropical watersheds.

The seasonal dominance of Myxophycean cell numbers was evident at all stations. Rarely, as in February, May and June 1970, when blue-green cell numbers were appreciably diminished, did another class (the Bacillariophyceae) dominate the phytoplankton. A few of the organisms contributing significantly to the total Myxophycean Phytoplankton at all stations were Polycystis aeruginosa, Polycystis incerta, Coelosphaerium naegelianum, Oscillatoria angustissima, Coelosphaerium pallidum, Gomphosphaeria lacustris and Gomphosphaeria lacustris var. compacta.

It is interesting to contrast the Myxophycean dominance in numbers of cells with that of the Chlorophyceae in the number of species. Of the former there were 68 taxa, whereas the latter had 237. Figures 67, 70, 72, 73 and 77 clearly show the prevalence of green algal species at all stations. The Bacillariophyceae and Cyanophyceae slightly exceeded the greens in numbers of species during January - April 1970 at Alton Bay and Center Harbor. Rarely did the Chlorophyceae have representatives amongst the dominant phytoplankters in numbers of cells. During the

summer, Gloeocystis vesiculosa and Botryococcus braunii were common at all stations, and they appeared in significant numbers. Only two other examples of dominance occurred of green algae. The peaks of Actinastrum hantzschii var. fluviatile and Ulothrix variabilis were previously cited.

A comparison was made of the taxa of phytoplankton recorded by Gruendling and Mathieson (1969) for Newfound and Winnisquam Lakes and those found at Winnipesaukee. One hundred taxa were found at Newfound and 142 were found at Winnisquam. Of these, 92 were in common between Newfound and Winnipesaukee and 121 between Winnisquam and Winnipesaukee. The gross similarity of the floras at the three lakes is thus apparent.

A definite seasonal pattern of phytoplankton development occurred at Winnipesaukee with maximal numbers of cells in the summer and minimal winter counts (compare Figs. 69 and 76). The peak at Center Harbor was exceptional in that it occurred during early fall (October). The summer peak of phytoplankton coincided with maximal nutrients and high water temperatures, while the minimal records occurred during periods of ice cover and very low water temperatures (compare Figs. 69 and 76 with Figs. 15-19).

The green and blue-green algae were the major structural components of the seasonal patterns described above (compare Fig. 66 and Table VI). The Cyanophyceae were usually the second largest contributors to species numbers, except during the winter

and spring when the diatoms replaced them. The number of diatom cells in the spring occasionally exceeded those of the Cyanophyceae. The Chrysophyceae generally ranked fourth in numbers of species; they exhibited maximal counts in August of 1969 and 1970. The Cryptophyceae, Dinophyceae, Euglenophyceae, and Xanthophyceae usually composed 0.5% of the monthly phytoplankton at each station. Thus, the latter classes were of little importance in the overall phytoplankton.

It is obvious that lakes differ both in the quantity and quality of their phytoplankton. Such phenomena led to a trophic system of lake classification based on phytoplankton indices (Nygaard, 1949). Oligotrophy is indicated when algal species are many, phytoplankton numbers are meager, water blooms are rare, and diurnal migration is extensive (Rawson, 1956). The eutrophic state presents the reverse condition. Thus Nygaard (1949) states that lakes may be characterized as being either less productive and more transparent (pH usually less than 7.0, Ca less than 10 mg/l), or more productive and less transparent (pH usually over 7.0, Ca more than 10 mg/l).

Phytoplankton quotients seem of little value by themselves in the determination of trophic levels. As pointed out by Rawson (1956) it is difficult to determine whether edaphic or morphometric factors are more influential in determining oligotrophic levels. It should also be noted that the dominance of

an alga, expressed in cell numbers, may not be significant when compared with the total unit and percentage volumes of other species. Likewise, the determination of a trophic level from Chlorococcalean and desmid species numbers seems futile when, for example, 74% of the total phytoplankton is Myxophycean.

The same may be said of the other phytoplankton quotients applied within this text. Even Nygaard's Compound Index which is based on five major groups of algae does not include Chrysophycean species which comprised 7.2 - 30.1% of the phytoplankton found at all of the stations. Rather it might be best to examine trophic levels using a composite of tools, such as the contributions of cell numbers versus cell volumes, the types, abundance and quality of different phytoplankton associations, and the edaphic changes in a water body during successive years.

When the above interpretations are amassed, a fairer estimate of trophic status may be obtained, particularly for those water bodies of a more intermediate trophic level. The collective interpretation of the phytoplankton indices assigns a mesotrophic status to Lake Winnipesaukee. It should be emphasized that the designations of phytoplankton indices are very controversial. Thus, it is felt that a closer look at the coexisting phytoplankton associations peculiar to different trophic levels (Hutchinson, 1967) should also be considered, particularly in bodies of water with transitional trophic levels. Although the

principal phytoplankton association at Winnipesaukee is Myxophycean (indicative of eutrophy) there are other associations which are more typical of oligotrophy. Hutchinson (1967) reports on Oligotrophic Desmid Association that is peculiar to slightly acid waters. Ninety-one species of desmids were identified at Winnipesaukee. Newell (1960) and Hoover (1938) both cited lower pH values for Winnipesaukee than those recorded here. Several genera (Sphaerocystis, Gloeocystis, Rhizosolenia, and Tabellaria) typical of the Oligotrophic Desmid Association were frequently found at Winnipesaukee. An Oligotrophic Diatom Association also existed at Winnipesaukee. Unlike the Desmid Association, which was dominant in the numbers of species, the Diatom Association was represented by a dominance in cell numbers of its representative genera. The dominant genera of the Oligotrophic Diatom Plankton were Cyclotella, Tabellaria, and Melosira.

The occurrence of abundant Botryococcus further supports a previous oligotrophic status, for Hutchinson (1967) cites a Botryococcus Association as characteristic of oligotrophic waters. The same may be said of the existence of a well-developed Chrysophycean Plankton; the dominant components being species of Dinobryon. Hutchinson (1967) also speaks of phytoplankton associations peculiar to the more mature waters such as a Eutrophic Diatom Plankton. The latter associations, however, are not as strongly in evidence as the oligotrophic associations cited above.

Hutchinson (1967) characterizes a Chrysophycean Plankton as one peculiar to nutrient depleted waters. However, Lake Winnipesaukee does not seem to have a shortage of nutrients, and peak numbers of Chrysophyceae occurred during periods of high nutrients (particularly in July through September). Would the Chrysophyceae play an even larger role in the phytoplankton if the recreational pursuits of man were reduced?

Different trophic levels do exist in Lake Winnipesaukee. When a collective interpretation of the five phytoplankton indices was made (Table VIII and IX) a mesotrophic status was accorded the Weirs, Winter Harbor, Meredith Bay, and Paugus Bay Stations. The four remaining stations were characterized as eutrophic. The Diatom, Euglenophyte, and Compound Indices characterized Lake Winnipesaukee as either oligotrophic or mesotrophic. The Chlorophycean Index gave an oligotrophic classification to Winter Harbor. It also signified border-line values favoring mesotrophy at the Weirs and Meredith Bay and lent further support for their mesotrophic rating.

When the phytoplankton quotients were applied to the entire lake the Chlorophycean and Myxophycean Indices designated a eutrophic rating, whereas the Diatom and Euglenophyte values signified oligotrophy (Table VIII). The Compound Index denoted a mesotrophic state. Thus, it is seen that the overall values for the lake compliment those for the individual stations in

connoting a mesotrophic evaluation. The borderline values found at many stations further indicated the changing trophic levels of the lake.

Of the four stations characterized as eutrophic (Alton, Wolfeboro, Center Harbor, and Melvin Bay), Wolfeboro showed the largest number of Chlorococcalean species (Table V). The Chlorophycean and Compound Indices incorporate Chlorococcalean species numbers. Hence, the values recorded for both indices showed that Wolfeboro was second only to Melvin Bay with its rating of eutrophy. Not only did the large number of Chlorococcales (67) and diatom species (55) affect the indices ratings at Wolfeboro, but they also served to augment the Eutrophic Diatom and Chlorococcalean Plankton Associations. Palmer (1969) has compiled a listing (from 165 investigators) of algae tolerant to high organic pollution. He states that organic pollution influences fresh water algal floras more than any other factor. Of particular interest was his listing of the 60 most tolerant genera and the 80 most tolerant species. The Wolfeboro flora had 45 of the genera and 33 of the species listed by Palmer (1969).

SUMMARY AND CONCLUSIONS

The composition, abundance, and seasonal periodicity of the phytoplankton at Lake Winnipesaukee were determined. Eight stations were established in order to identify their phytoplankton

floras and trophic levels. The following general conclusions were reached:

1) Lake Winnipesaukee is a dimictic, soft water drainage basin characterized by a Myxophycean Plankton. A large flora was apparent, for 453 taxa were recorded. Two hundred and thirty-seven taxa alone were members of the Chlorophyceae. The Chlorophycean species usually dominated each monthly count.

2) The nutrient levels at Winnipesaukee exceeded all of those previously recorded for Newfound and Winnisquam Lakes, (Gruendling and Mathieson, in press). Thus, aside from nutrients, the most influential factors affecting algal growth were light, temperature, and organic pollution. Nutrient enrichment experiments were conducted to evaluate their effect on primary productivity of natural phytoplankton populations.

3) A typical pattern of phytoplankton abundance was apparent with peak counts occurring in late summer and minimal values during the winter (under ice). The rise or fall of the phytoplankton counts usually coincided with an increase or decrease in nutrient levels, water temperatures, or light penetration. High cell counts were associated with high primary productivity levels and vice versa.

4) The phytoplankton was primarily comprised of four classes of algae: the Chlorophyceae, Cyanophyceae, Bacillariophyceae, and Chrysophyceae. The Cyanophyceae usually dominated the

phytoplankton in the number of cells although not in the number of species.

5) The phytoplankton quotients of Thunmark (1945) and Nygaard (1949) were applied to each station and to the overall lake. A mesotrophic status was accorded the Weirs, Winter Harbor, Meredith, and Paugus Bay Stations. The Diatom and Euglenophyte Indices usually gave oligotrophic values to the stations, whereas the Compound Index values were mesotrophic for the four stations cited above. The Chlorophycean Index values also approximated a mesotrophic rating. When applied to the entire lake, the indices collectively designated a mesotrophic status to Lake Winnipesaukee. Thus it is seen that different trophic levels may exist in the same lake.

6) The Compound Index was the most useful in designating the trophic levels. The application of this index, together with a knowledge of the phytoplankton associations described by Hutchinson (1967), allowed the fairest evaluation of trophic levels.

7) Alton, Wolfeboro, Center Harbor, and Melvin Bay Stations were classed as eutrophic. Wolfeboro and Melvin Bay were the most striking examples of eutrophy.

8) Of the 100 taxa listed by Gruendling and Mathieson (1969) for Newfound Lake and the 142 taxa cited for Lake Winnisquam, 92 and 121 taxa respectively were common to Winnipesaukee. Thus,

the three lakes have similar floras except that Winnipesaukee has a far greater number of species. The greater species diversity and the presence of residual oligotrophic algal associations (Hutchinson, 1967) lend support for postulating a former oligotrophic state of Winnipesaukee.

9) The presence of 45 of the 60 algal genera listed by Palmer (1969) as being most tolerant to organic pollution indicates the large impact of organic pollution in Winnipesaukee. Inadequate treatment of sewage effluent in the vicinity of the stations is indicated.

10) The Weirs Station exhibited the greatest productivity of all the stations. Center Harbor and Winter Harbor were the least productive in total phytoplankton cell counts.

11) Several potentially troublesome taxa of algae (Aphanizomenon flos-aquae, Anabaena flos-aquae, Gloeotrichia echinulata, Polycystis aeruginosa, and Anabaena scheremetievi) were found throughout the Lake. Further enrichment of the lake may result in serious blooms and obnoxious odors similar to those experienced at Winnisquam.

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LIST OF TABLES

Table I

Nutrient Enrichments for Carbon-14 Experiments

Sources:

Silicates: $NaSiO_3 \cdot 9H_2O$

Nitrates: $NANO_3$

Phosphates: KH_2PO_4

Levels of additions for nitrates, phosphates and silicates:

(1)	2000 mg/l	= 2000 PPT*
(2)	1000 mg/l	= 1000 PPT
(3)	200 mg/l	= 200 PPT
(4)	100 mg/l	= 100 PPT
(5)	20 mg/l	= 20 PPT
(6)	10 mg/l	= 10 PPT
(7)	2 mg/l	= 2 PPT
(8)	1 mg/l	= 1 PPT

*PPT = parts per thousand

Table II

Seasonal Occurrence of Phytoplankton at Lake Winnipesaukee

	1969										1970						
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
CHLOROPHYCEAE																	
Actinastrum hantzschii var. elongatum G.M. Smith											4						
Actinastrum hantzschii var. fluviatile Schroeder.	2	1,2,4	2,3	1									2	2			7
Actidesmium hookerii Reinsch					4												
Ankistrodesmus braunii (Naeg.) Brunnthaler.						3	3						3	3		7	
Ankistrodesmus falcatus (Corda) Ralfs.	2-4	1-4	2,3	3,4		2,3	1-3		1,3		1,2,4	1-4	1-3	3,4	6,7	6-8	5-8
Ankistrodesmus falcatus var. acicularis (A. Braun) G.S. West.	2-4	2,4	2		2	2	2				1			2			
Ankistrodesmus falcatus var. mirabilis (West & West) G.S. West.							1							4			
Ankistrodesmus falcatus var. stipitatus (Chod.) Lemmermann.		2															
Ankistrodesmus falcatus var. tumidus (West & West) G.S. West.	1,2	1,2	1,2	1-3	1	1	1	1			1		3	1			7
Ankistrodesmus spiralis (Turner) Lemmermann.											1						
Arthrodesmus constrictus G.M. Smith			3														
Arthrodesmus incus (DeBreb.) Hass.	1-4	1-4	1-3	1-4	1,2,4	1-3	1,2,4		3,4		4	2,4	1-4	1-4	5,6,8	5-8	5-8
Arthrodesmus phimus Turner.				4							1,2						
Arthrodesmus quiriferus W. & G.S. West.		2,3				3							3	3		5,7,8	
Arthrodesmus ralfsii W.West.				1							1,2		1		6	5	5,7
Arthrodesmus ralfsii forma latiuscula West & G.S. West.													2				
Arthrodesmus subulatus Keutzing.			1			3						1,2,4			7		
Arthrodesmus subulatus var. nordstedtii var. nov. Keutzing.												3			5,8	7	
Arthrodesmus triangularis Lagerheim.	1-3										4	1-4		1	5-8		
Arthrodesmus triangularis var. subtriangularis (Borge) W.& G.S. West.				2	2	2											5
Botryococcus braunii Keutzing.	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	2	3,4		1,4	2-4	1,3,4	2	6-8	6-8	5-8
Botryococcus protuberans var. minor G.M. Smith	1-4	1-4	2,3	1-4	2,4	1-3	1-4		4		1,2,4	1-4	2,3	2-4	5-8	5-8	5-8
Botryococcus sudeticus Lemmermann.											2	2			5		
Bulbochaete scrobiculata (Tiff.) Tiffany		3					3					3					
Characium gracilipes Lambert.	1													4			5
Characium limneticum Lemmermann.						3									7	7	7
Characium stipitatum (Bachm.) Wille.												1			6		
Chlamydomonas dinobryonii G.M. Smith											4	1	1				

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Dactylococcus infusionum Naegeli.	2-4	2-4	2,3	2-4	2	2	2					2,4				7	
Desmidium baileyi (Ralfs) Nordst.														2			
Desmidium swartzii C.A. Agardh.																8	8
Dictyosphaerium ehrenberghianum Naegeli.		3	3								2		1,3		6	5,7	6,8
Dictyosphaerium pulchellum Wood.	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	2	1,3		4	1,2	2	1-3	8	5,6,8	5-8
Dimorphococcus lunatus A. Braun.		1	1,2	2		1-3						2	1,3	3,4	8	7	6,7
Dispora crucigenioides Printz.									3								
Elakatothrix gelatinosa Wille.	2	2		1	1		1										
Elakatothrix viridis (Snow) Printz.			1			3											
Euastrum denticulatum (Kirch.) Gay.	1												4	1,3,4	6	7,8	7
Euastrum pulchellum DeBrebisson.	2-4	2-4	2,3	1-3								4					
Eudorina elegans Ehrenberg.	2,3	2,3	1,3	1-3	2	3	2,4				4	1-3	1-3	2-4	5,6	6-8	6-8
Eudorina unicocca G.M. Smith														2			
Gloeoactinium limneticum G.M. Smith																	7
Gloeocystis ampla (Kuetz.) Lagerheim.	1	1	3	3								3			6,7	6,7	7,8
Gloeocystis gigas (Kuetz.) Lagerheim.				4													
Gloeocystis major Gerneck.	3						2						2	2		8	
Gloeocystis planctonica (West & West) Lemmermann.	2,4	1,2	1	4								2				6	7
Gloeocystis vesiculosa Naegeli.	1,3,4	1-4	1-3	2-4	2,4	2,3	2-4		3		4	4	1-4	1-4	6-8	5-8	5-8
Golenkinia paucispina West & West.						3							1,2,4	4		8	5,8
Golenkinia radiata (Chod.) Wille.	4	1-4	1,2	1-4	1		2				1,2,4	1,3,4	1,2,4	1,2,4	5,7,8	5-8	5-8
Gonatozygon aculeatum Hastings.																	5
Gonatozygon kinahani (Arch.) Rabenhorst.												3			5		
Gonatozygon monotaenium DeBary.	4							2			2,4	4		2		5	6
Gonatozygon pilosum Wolle.												2					5
Gonium pectorale Mueller.			3														
Gymnozyga moniliformis ehrenb. forma maxima f. nov.														4			
Hormidium klebsii G.M. Smith																8	
Hyalotheca dissiliens (Smith) DeBrebisson.														2			
Hyalotheca mucosa (Dillwyn) Ehrenberg.													1				
Kerchneriella contorta (Schmidle) Bohlin.		3	2	3										3			

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Chlamydomonas polypyrenoideum Prescott.																	
Chlamydomonas sphagnicola Fritsch & Takeda.			3														5,8
Chlorella ellipsoides Gerneck.		2	1	2	2	1,2	1						2				
Chlorella vulgaris Beyerinck.	3		1,2	3													
Cladophora oligoclona Kuetzing.	2																
Closterium aciculare (Tuffen) West.												1					
Closterium kuetzingii DeBrebisson.	1					2	2	1	3		4 1,2,4	2-4	2		5,7,8	5	
Closterium rostratum Ehrenberg.											1,4						
Coelastrum augustae var. ornatum Skuja.											4	2			8		
Coelastrum cambricum Archer.			1			3									5	8	
Coelastrum microporum Naegeli.	1,2,4	1,2,4	2	2,4		2			3,4			2				6	
Coelastrum scabrum Reinsch.						3											
Coleochaete pulvinata A. Braun																8	
Cosmarium bioculatum DeBrebisson.	2,4	1,2,4	1,2	1,2,4	1		1							1-3		6	5,6,8
Cosmarium bipunctatum Borge.																	5
Cosmarium contractum Kirchner.																	7
Cosmarium contractum var. papillatum forma minor G.M. Smith		1			1,4	2	2						3	1-4		8	5-8
Cosmarium depressum (Nag.) Lundell.		3		4									3	1,2,4		7	5,7
Cosmarium moniliforme (Turp.) Ralfs.												2,3					
Cosmarium norvegicum Strom.	1-4	1,4	1,2	4							4		3,4	1-3			5,6,8
Cosmarium obtusatum Schmidle.					4												
Cosmarium ornatum Ralfs.		3														5	
Cosmarium phaseolus breb. fa. minor Boldt.														3			
Cosmarium punctulatum DeBrebisson.												3				7	5-8
Cosmarium scrobicula Kuetzing																	
Cosmarium trilobulatum Reinsch.					2			2			1		1-4	1-4		7	5-8
Cosmocladium hitchcockii Wolle G.M. Smith	1,2	1,2,4	1,2	1-4	4	3	3,4		3,4		2,4	2-4	1,3,4	1-4	5-8	5-8	5-8
Crucigenia quadrata Morren.	3,4	3,4	3	3,4	2,4	2	2,3	1,2			4	1,2,4	1-4	1-4	5-8	5-8	5-8
Crucigenia rectangularis (A. Braun) Gay.	1-4	1-4	1-3	1,2,4	1,2,4	1-3	1,2	1,2	1		1,2	1	3,4		6-8	6	6 8
Crucigenia tetrapedia (Kirch.) West & West	1-4	1,2	1-3	1-4	1,2,4	1-3	1-4	1	1,3,4		2	2,4	3	1	5-8	6-8	6,8
Crucigenia truncata G.M. Smith	1-4	1-4	1-3	1-4													

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Kerchneriella elongata G.M. Smith																	6
Kerchneriella lunaris (Kirch) Moebius.	2	3	3													8	6
Kerchneriella lunaris var. dianae Bohlin.		2										2			8		
Kerchneriella obesa (W. West) Schmidle	1,2	1,2,4	1,3	1,2	2,4	1,2						2	1-4	2,3	8	5,8	6-8
Kerchneriella obesa var. aperta (Teil.) Brunnthaler				3		2,3											
Kerchneriella subsolitaria G.S. West		2	1,2	1-4		3						4		2		6	6
Micrasterias pinnatifida (Kuetz.) Ralfs.																8	
Micrasterias radiosa Ralfs.	1							2									
Micractinium pusillum Fresenius.	1,2	2,4	1-3	1									2				8
Micractinium pusillum var. elegans G.M. Smith			1														
Mougeotia spp.		1-3		1,2	1,4	1		2	3		2,4	1-4	1-4	1-4	5-8	5,8	5,6,8
Nephrocytium agardhianum Naegeli.			3	2,3	2,4		2					4	1,3	2		5,7,8	6,7
Nephrocytium ecdysiscepanum W. West.																6	
Nephrocytium limneticum (G.M. Smith) G.M. Smith	1-3	2-4	2,3	1-3	1,4	2,3						3	1,4	2,3		5,8	5-8
Nephrocytium lunatum W. West.												2			8		
Nephrocytium obesum West & West.												3	1			8	7,8
Netrium digitus Itzigsohn et Rothe.																5	
Oedogonium spp.												4	3		5-7	7	5,7,8
Odcystis borgei Snow.											2			3		8	
Oocystis elliptica W. West.	1	1	1	2		2								1,2,4		5	5-7
Oocystis gigas Archer.	4			4								1		3			5
Oocystis lacustris Chodat.	1-4	1-4	1-3	1-3	1,2,4	1-3	1-4	1,2	1,3,4		1,2,4	1-4	1-4	1-4	5-8	5-8	5-8
Oocystis nodulosa West & West.	2																
Oocystis parva W.& G.S. West.	1-4	1-4	1-3	1-4	2,4	1-3	1-4		4		1,2,4	1,4					
Oocystis pusilla Hansgirg.				3		4							2	3			8
Oocystis pyriformis Prescott.				3													
Palmella mucosa Kuetzing.	2	3		3		3	3						4	1,2		6-8	8
Palmodictyon varium (Naeg.) Lemmermann	2																
Palmodictyon viride Kuetzing.	1																
Pandorina morum (Muell.) Bory.	1,2	1,2	1	3								1,2,4	1,3,4	2,3		7,8	5,7,8
Pediastrum araneosum (Racib.) G.M. Smith											1						

Table II - continued

	1969						1970										
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Pediastrum araneosum var.rugulosum (G.S. West) G.M. Smith	1,2			3,4	2,4	1-3	1,3							2,3		6,7	5,6,8
Pediastrum boryanum (Turp.) Meneghini.	1-3	3,4				2,3					4	3,4	3,4	2	6	5,7,8	6
Pediastrum duplex Meyen.	1,3	2,3	1		2,4	1-3	2				1,4	3,4	3,4	1,2,4	5,8	5-8	5-8
Pediastrum duplex var. clathratum (A. Braun) Lagerheim.														2,3		7	
Pediastrum duplex var. cohaerens Bohlin.							1					2	3				
Pediastrum duplex var. gracillimum West & West.	2	2										2	2	2		5	5
Pediastrum duplex var. reticulatum Lagerheim.	1															6	
Pediastrum duplex var. rotundatum Lucks.												2					
Pediastrum duplex var. rugulosum Racibroski.												2	4			5,7	6
Pediastrum kawraiskyi Schmidle.												2					
Pediastrum sculptatum G.M. Smith			3	3							2	3	2	4	6		
Pediastrum simplex var. duodenarium (Bailey) Rabenhorst.															7		6
Pediastrum tetras (Ehren.) Ralfs.		1,2	2,3		2								4	2,4	6	6,8	5
Pediastrum tetras var. tetraodon (Corda.) Rabenhorst.	1-4	1-4	1-3	1-4	1,4	3	1				4	3	2,4	1,2,4	5-8	6,8	5-8
Pleodorina californica Shaw.			3				2										
Pleurotaenium ehrenberghii (De Brebisson) Debary.											2					5	
Quadrigula chodatii (Tanner-Fullman) G.M. Smith				4										4			
Quadrigula closterioides (Bohlin) Printz.	1-4	1-4	1,2	1-4	1,2,4	2,3	2				2,4	1,2,4	2,3	1,2,4	6,8	5,7,8	5,6,8
Quadrigula lacustris (Chod.) G.M. Smith	3,4	1-4	1-3	1-4	1,2,4	1-3	1-4	2	3		4	1,3,4	1-4	1-4	5-8	5-8	5-8
Rhizoclonium spp.					1												5
Scenedesmus acuminatus (Lagerh.) Chodat.			3										2	3			
Scenedesmus acutus f. costulatus (Chod.) Uherkov.													2				
Scenedesmus arcuatus var. platydisca G.M. Smith	2,3	3	1,3	1-3		3						2		3	8	6	6,7
Scenedesmus bicaudatus (Hansg.) Chodat.	2																
Scenedesmus bijuga (Turp.) Lagerheim.	1															6	8
Scenedesmus bijuga var. alternans (Reinsch) Hansgirg.		3															
Scenedesmus brasiliensis Bohlin.				3													
Scenedesmus coalitus Hortob.																	
Scenedesmus ecornis (Ralfs.) Chodat.	1-4	1-4	1-3	1-4	1,4	1,3	4	3	1			1	1,2,4	1-4	5-8	5,6,8	5-8
Scenedesmus denticulatus Lagerheim.														2			6
Scenedesmus granulatus W. & G.S. West.														2			

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Scenedesmus incrassatulus Bohlin.	1,3	1,3,4	3	1,3										1,2	5,7	6,8	6,8
Scenedesmus incrassatulus var. [illegible] G.M. Smith	2-4	1-4	1-3	1,2	1,2,4							4	1,2	1,2,4	6-8	6	5,6,8
Scenedesmus longus var. naegeli (DeBreb.) G.M. Smith														2			
Scenedesmus quadricauda (Turp.) DeBrebisson.													2	1,2			6
Scenedesmus quadricauda var. longispina (Chod.) G.M. Smith	2												2	2	6	8	
Scenedesmus quadricauda var. maximus West & West.													2				6
Scenedesmus quadricauda var. parvus G.M. Smith	3,4											2	2	2	6,7		6
Scenedesmus quadricauda var. quadrispina (Chod.) G.M. Smith			2														
Scenedesmus quadricauda var. westii G.M. Smith													2		6		
Scenedesmus quadricauda var. westii f. heterospinous (Hortob) Uherkov.														2			
Shroederia ancora G.M. Smith							3		3								
Shroederia judayii G.M. Smith	3,4	3,4		3,4	4	3	3,4		3		4	3,4	1,3,4	1,3,4	5,6,8	5-7	6-8
Shroederia setigera (Schroed.) Lemmermann.				3		3	3	2	3		2	2		2,3	5,8	8	6,8
Sphaerocystis shroeteri Chodat.	2-4	1-4	1-3	1-4	1	2,3	1,3					2,3	1,3,4	2-4	8	7,8	5-8
Sphaerozosma excavata Ralfs.									4								
Sphaerozosma excavatum var. subquadratum (Ralfs.) W. & G. S. West.												3					
Sphaerozosma exiguum Turner.								1					1				
Sphaerozosma granulatum Roy & Bissett.	1,2	1,2,4		1,3,4	1,4	1-3	2-4	2	3				1	2,3	6	5,7	5,7,8
Spirogyra spp.													1,4	2,3	8	7	5,6
Spondylosium moniliforme Lundell.											4					8	
Spondylosium planum (Wolle) W. & G.S. West.	2,3	3			2	2,3	1-3	1	3,4		1,2	1-4	1,3,4	2	5,8	7,8	7,8
Spondylosium secedens (DeBary) Archer.		3		2,4	2								3			5	
Staurastrum americanum (W. & G.S. West) G.M. Smith	2	3															
Staurastrum anatinum var. denticulatum var. nov. G.M. Smith				4								3					
Staurastrum anatinum var. longibrachiatum W. & G.S. West.																	
Staurastrum arctiscon (Ehr.) Lundell.		2										1			8	7	
Staurastrum brachiatum Ralfs.		1		1-3	4	1-3								2-4			7,8
Staurastrum brevispinum DeBisson.			3			3						4	3			7	
Staurastrum brevispinum var. retusum Borge.																5	
Staurastrum cumbricum West.											2						
Staurastrum cuspidatum DeBrebisson.	3,4	1-3	2	4	1,2,4	1,2							3	3		5-8	7,8

Table II -continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Staurastrum denticulatum (Neg.) Arch.	3	3	1	1-3	2,4									1,2		5,8	5-8
Staurastrum granulosum (Ehrenb.) Ralfs.											1						
Staurastrum johnsonnii W. & G.S. West	1-3	1,4		2,3	1,4	2,3	3					1-4	1,2	2-4		6-8	5-8
Staurastrum johnsonnii var.depauperatum G.M.Smith		3	3		2	3					4		3	1	8		5,7
Staurastrum lacustre G.M. Smith				2													
Staurastrum leptocladum var. denticulatum G.M. Smith															5		
Staurastrum limneticum Schmidle.	1-3	1,3	1-3	1-4	1,2,4	1-3	1,2	1	1,3				1,2,4	1,3		5,6	5-7
Staurastrum limneticum var. cornutum G.M. Smith	2	1-3	3	1	2	1,2								1-4			5-8
Staurastrum longiradiatum W. & G.S. West.			2	1	1	1						3					6-8
Staurastrum lunatum Ralfs.													1				
Staurastrum lunatum var. planctonicum W.			3										3	2		7	
Staurastrum manfeldtii Delp.	1,2	1-3		1-3	4	2							1,2,4	1-3		5,6,8	5,7,8
Staurastrum megacanthum Lundell.	1-4	1-4	1,3	2-4	2,4	1-4	3		3		4	3,4	1-4	1-3		5-8	5-8
Staurastrum megacanthum var. scoticum W. & G.S. West.			1		2	1,2							2	3,4			5,7,8
Staurastrum muticum DeBrebisson.	1,2,4	1-3	3	3,4		2	2				1			3,4			5,7,8
Staurastrum ophiura Lundell.											1						
Staurastrum orbiculare Ralfs.														3			7
Staurastrum pachyrhynchum Nordst.													3				
Staurastrum paradoxum Meyen.	1-4	1-3	1-3	1,2,4	1,2,4	1-3	1		3		1,2,4	1,3,4	1,3,4	1-4	5,6,8	6-8	5-8
Staurastrum paradoxum var. longipes Nordst.	1	2			4		2					2	1,3,4	1-4			5,8
Staurastrum paradoxum var. parvum W. West			1									2					8
Staurastrum pentacerum (Wolle) G.M. Smith											1,4						
Staurastrum pentacerum var. tetracerum (Wolle) G.M. Smith	1-4	1-4	1,3	1,3	1,2,4	2,3	1-4	1	3,4		4	4	1-4	1-4	5,8	5-8	5-8
Staurastrum pingue Teiling	1-3	1	3											1-4	8		8
Staurastrum punctulatum var. kjellmani Wille.															8		
Staurastrum setigerum Cleve.				1,3		3						1,3,4	3		8	7,8	5,8
Staurastrum spiculiferum G.M. Smith					2							3					
Staurastrum sublaevispinum W. West.				4								2,4	1-3				
Staurastrum subpygmaeum var. subangulatum var. nov. West.											2						
Staurastrum tetracerum Ralfs.											2,4	1-3			6		
Stichococcus bacillaris Naegeli.			3														

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Stylosphaeridium stipitatum (Bachm.) Geitler & Gimesi.	1-4	1-4	1-3	1-4	1,2	2,3	1,2	1,2	3,4		2,4	1-4	1-4	2-4	8	5-8	5-8
Tetraedron asymmetricum Prescott.												3			7		
Tetraedron caudatum (Corda) Hansgirg.			2														7
Tetraedron limneticum Borge.	2				1,4	3	1				1	2					
Tetraedron lobulatum var. polyfurcatum G.M. Smith.													4				
Tetraedron minimum (A. Braun) Hansgirg.	3,4	1	1,3			3									6	6	8
Tetraedron muticum fa. punctulatum (Reinsch) DeToni													2				
Tetraedron planctonicum G.M. Smith			2											2			
Tetraedron regulare Kuetzing.													2				5
Tetraspora lamellosa Prescott.																	6,8
Tetrastrum staurogeniaeforme (Shroeder) Lemmermann.													1				8
Treubaria setigerum (Archer) G.M. Smith		2										4					
Trochiscia obtusa (Reinsch) Hansgirg.																	7
Ulothrix subconstricta G.S. West.				3	1								2	1,2			5-7
Ulothrix subtillissima Rabenhorst.		3	1,3		2							1	1	3		5	7,8
Ulothrix variabilis Kuetzing.		1	1,3	2	2						2						
Volvox tertius A. Meyer.							3							3			
Westella botryoides (W. West) de Wildemann.						3			1,3			2		3		6,7	5-7
Westella linearis G.M. Smith		1									4		2				
Xanthidium antilopaeum var. polymazum Nordst.											4						6,7
Xanthidium cristatum DeBrebisson.																	8
Xanthidium subhastiferum W. West.																	
Zygnema spp.																	
BACILLARIOPHYCEAE																	
Achnanthes inflata (Kuetzing) Grunow.				1													
Amphora ovalis Kuetzing.	3		1			3	2		4								
Asterionella bleakeleyi W. Smith.											2						
Asterionella formosa Hass.	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1,2	3,4		1,2,4	1-4	1-4	1-4	5-8	5-8	5-8
Asterionella formosa var. gracillima (Hantz.) Grunow.	1-4	2,3	1,2	2,3	1,2,4	1-3	1-4	1,2	1,3,4		1,2,4	1,3,4	1-4	1	5-8	5-8	5-8
Caloneis amphisbaena (Bory.) Cleve.					2												

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Cocconeis diminuta Ehrenberg.	3	3		3	2,4	3	1,2,4	1	1,4		1,2	1,3	1,4	1,2,4	6-8	5,7	5,7,8
Cyclotella bodanica Eulenst.	1-4	1-4	1-3	1-4	1,2,4	1-3	1-3	1,2	3,4		1,2,4	1-4	1,3		6-8	5-8	8
Cyclotella comta (Ehrenberg) Kuetzing.	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1,2	1,3,4		1,2,4	1-4	1-4	1-4	5-8	5-8	5-8
Cyclotella glomerata Kuetzing.	1	1		2		2	2							2			5
Cyclotella kuetzingiana W. Smith											2						
Cyclotella meneghiniana Kuetzing	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1	4		1,2,4	1-4	1-4	1-4	6,8	5-8	5,6,8
Cyclotella stelligera Cleve & Grunow.																6	
Cymatopleura solea (Breb.) W. Smith		4			2	2	2		4								
Cymbella affinis Kuetzing.	3	2,3			2	2,3	2		4		2,4	3,4		4	7	7	6
Cymbella cistula (Hemp.) Grunow	4			2	2	3									6		
Cymbella gracilis (Rabh.) Cleve.																	5
Cymbella mexicana Ehrenberg.													3				
Cymbella naviculiformis Auerswold.											1						
Cymbella obtusiuscula (Kutz.) Grunow.												3					
Cymbella tumida (Breb.) Van Heurck.		4			4												
Cymbella turgida (Greg.) Cleve.																	5
Cymbella turgidula Grunow.															8		
Cymbella ventricosa Kuetzing.	1,4	4			4						1,2	2,4			5,8	5,8	
Diatoma anceps (Ehrenb.) Kirchn.												4					
Diatoma hiemale (Lyngb.) Hieb.															8		
Diatoma vulgare Bory											2	2					
Diploneis smithii Boyer.											2						
Eunotia pectinalis (Kuetz.) Rabenhorst.				1	2	1		1				1		1			
Eunotia pectinalis var. minor Rabenhorst.				3				1									
Eunotia pecinalis var. minor forma impressa Rabenhorst.							2										
Eunotia pectinalis var. undulata Ralfs.	1	4					1,2		4		2						
Fragillaria brevistriata Grunow.	4			3													
Fragillaria brevistriata var. inflata (Pant.) Hustedt.							2										
Fragillaria brevistriata var. trigibbe Grunow.											2						
Fragillaria construens (Ehrenb.) Grunow.	3																
Fragillaria crotonensis Kitton.	1-3	1-4	1-3	1-4	1,2,4	1-3	1-4	1,2	3,4		1,2,4	1-4	1-4	1-4	5-8	5-8	5-8

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Fragillaria intermedia Grunow.	2					3					1	1					
Frustulia rhomboides (Ehr.) DeToni.					2	1	2								5	5	5
Gomphonema constrictum Ehrenberg.				2		3	2	1	4		2						
Gomphonema olivaceum (Lyngb.) Kuetzing.								1			1,2						
Gyrosigma kuetzingii (Grun.) Cleve.							1										
Melosira ambigua (Grun.) Mueller.	1-4	2,3	2,3	1,3,4	1,2,4	1-3	1-4	1,2	1,3,4		1,2,4	1-4	4	2-4	5-8	5-8	5,6,8
Melosira distans (Ehrenberg) Kuetzing.	1	3	1	1	1		1,2		1,4		1				6	6	6
Melosira islandica O. Muller.	1,3,4	3,4		2-4	2,4	2,3	3		3,4		2,4	2-4	4	2	6		5,6
Melosira italica (Ehrenberg) Kuetzing.			2	2	4		1		2			2					
Meridion circulare (Grev.) Agardh.				2		2					1		1		6		
Navicula exigua Greg.															6		
Navicula rhyncocephala Kuetzing.		4										3					
Neidium dubium (Ehrenberg) Cleve.				1													
Nitzschia acicularis W. Smith	3	3	3		4	3	3		4		2,4	3			6,8		6
Nitzschia filiformis Hass.	1,2,4	1-3	1,3	1,3,4	2,4	2,3	1,4		3,4			4	1,2,4	1-3	8	8	7,8
Nitzschia holsatica Grunow.	3	3,4	1,3	2-4	4	3	1,4		3		4	4	3	3	5,6,8	5	5,7
Nitzschia linearis W. Smith				4													
Nitzschia macilenta Greg.												2					
Nitzschia palea (Krasske) W. Smith	3	3							4			4			6,7	5,7	5,6
Nitzschia sigmoidea (Ehr.) W. Smith	2		2	2	1,4	2	1,2		3		2,4	3,4		4			
Opephora martyi Heribaud.			1,2	2			1,2										
Pinnularia acrosphaeria DeBrebisson.															7		
Pinnularia gibba Ehrenberg.									4						8		
Pinnularia major (Kuetzing) W. Smith	1,2			2		2	2				2						
Pinnularia mesolepta Ehrenberg.		3		2													
Pinnularia nobilis Ehrenberg.					4							2					
Pinnularia tabellaria Ehrenberg																7	
Pleurosigma delicatulum W. Smith	1,4	2							4								6
Rhizosolenia eriensis H.L. Smith	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1,2	3,4		1,2,4	1-4	1-4	1-4	5-8	5-8	5-7
Rhizosolenia eriensis var. morsa W. & G. S. West.	1																
Stauroneis acuta W. Smith												3					
Stauroneis anceps Ehrenberg.						2											

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Stauroneis phoenicentron Ehrenberg.	2			3			1				4				5		5
Surirella ovalis DeBrebisson.	1	3	3	2	4	2,3			4		1	1,4	4	1,4	6		
Surirella ovata Kuetzing.							1,2									6	
Surirella robusta Ehrenberg.				3								3					
Synedra actinastroides Lemmermann.	1,2,4	1,2,4	1,2	1,2,4	1,2	1,2	1,2,4	1,2	1,3,4		1,2	1-4			5-7	6	
Synedra acus Kuetzing.	1																
Synedra acus var. angustissima Grunow.	2-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1,2	1,3,4		1,2,4	1-4	1-4	1-4	5-8	5-8	5-8
Synedra fasciculata (Ag.) Kuetzing.	1																
Synedra parasitica A. Boyer.				2													
Synedra rumpens Kuetzing.		1	1														
Synedra ulna (Nitzsch) Ehrenberg.	1-4	1-4	3	2-4	2,4	2	1,2,4	1	4		1,2,4	1,4	1-3	1,2,4	8	6-8	6,8
Synedra vaucheriae Kuetzing.															8		
Tabellaria fenestrata (Lyngbye) Kuetzing.	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1,2	1,3,4		1,2,4	1-4	1-4	1-4	5-8	5-8	5-8
Tabellaria flocculosa (Roth) Kuetzing.	1-4	1-4	2,3	1-3	1,4	1,3	1-3		1		1,2	2-4	1,2	1	5,6,8	6,8	6,8
CYANOPHYCEAE																	
Anabaena circinalis Rabenhorst.	1-3	1-4	1-3	1,3	1,4	1-3		1			1	4	2,3	1-3			5,7,8
Anabaena flos-aquae (Lyngb.) DeBrebisson.	1-4	2,3	1,3	3,4	2	2	1-4	1	3			1,2,4	1-3	1-4		5-8	5-8
Anabaena levanderi Lemmermann.	3	3	3	3										3			7,8
Anabaena scheremetievi Elenkin.		3	1-3	1,3	1,2	3								3			7,8
Anacystis rupestris (Lyngb.) Drouet & Daily.	1-3	1-4		1,2,4	1,2,4	1	1,2					4	1-3	1-4		5-8	5-8
Aphanizomenon flos-aquae (L.) Rolfs.	1-3	1,3,4	3	3	2	3	3		1,3			3	2,3	3,4	8		7,8
Aphanocapsa delicatissima West & West.	1-3	1-3	2,3	3		2	3		1		1,4					6	5-7
Aphanocapsa elachista West & West.	1-4	1-4	2,3	1-4	2,4	2,3	2-4	1	1		4	2,4	1-4	1-4	5,8	5-7	5-8
Aphanocapsa elachista var. conferta West & West.	4	1-3	1	2-4	2,4	2							4	1,3		7	5-7
Aphanocapsa elachista var. planctonica G.M. Smith.	1-4	1-4	1,2	1-4	1,2,4	1	1,4				4	1,2	3	2,3	5	5-8	6,7
Aphanocapsa grevillei (Hass.) Rabenhorst.	2	2-4	2,3	4	1,2,4	1,2	1-4	1	1		1,2,4	1-4	1-4	1-4	5-8	5-8	5
Aphanocapsa rivularis (Carm.) Rabenhorst.	1	1	1,3	1	1	1							1			5	
Aphanothece clathrata G.S. West.	1	3			4	2	1,4				4	2,3			5	7,8	
Aphanothece gelatinosa (Henn.) Lemmermann.	1-3	2,3	3	3,4		1,2	1				2,4	3			6		
Aphanothece microscopica Naegeli.	1-4	1-4	1-3	1-4	1,4	1-3	2-4		3,4				1-4	1,3,4	5,8	5-8	5-7

Table II - continued

	1969				1970											
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Aphanothece microspora (Menegh.) Rabenhorst.													4				
Aphanothece nidulans P. Richter.	3	3	3	3		3	3		3			3,4	1-4	1-4		5,6,8	5-8
Aphanothece pulverulenta Bachmann.	3	3	3	3		2	3							4	8		6
Chroococcus dispersus (Keissl.) Lemmermann.	2	1	1	3									2	1			
Chroococcus dispersus var. minor G.M. Smith	1	2-4	2,3	3	4	3	4		4			4		2			5
Chroococcus giganteus W. West.																	
Chroococcus limneticus Lemmermann.	1-4	1-4	1-3	1-4	2,4	1-3	2,4		3		1		1-4	1-4	6,8	5,6,8	5-8
Chroococcus limneticus var. elegans. G.M. Smith	1													1-4		5-7	5-7
Chroococcus minimus(Keissl.) Lemmermann.	1	2															7
Chroococcus minor (Kuetz) Naegeli.	1	1						1						1	6		5
Chroococcus minutus (Kuetz.) Naegeli.		1				2						4		2,3			6
Chroococcus prescottii Drouet & Daily.		2		1													7
Chroococcus turgidus (Kuetz.) Naegeli.					1,2,4	3	1,4	2	1		1,4	1	3,4	1,2,4	7,8	5,7	5,6,8
Chroococcus varius A. Braun.	1-4	1-4	1-3	1,2,4				1	4						6		
Coelosphaerium kuetzingianum Naegeli.	1				1,2,4	1-3	1-4	1,2	3,4		2,4	1-4	1-4	1-4	5-8	5-8	5-8
Coelosphaerium naegelianum Unger.	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1,2	1,3,4		2,4	1-4	1,3	1-4	8	5-8	5-8
Coelosphaerium pallidum Lemmermann.	1-4	1-4	1-3	1-4													
Dactylococcopsis acicularis Lemmermann.			2				1						1,2				
Dactylococcopsis fascicularis Lemmermann.	2,3	2,3	1		2	2	2					1	1			8	5
Dactylococcopsis rhaphidiodes Hansgirg.	2		22	2	1,2,4	1-3	2	2	1		2	2,3	1-4	1-4	5-8	5-8	5-8
Dactylococcopsis smithii Chodat & Chodat.	1-4	1-4	1-3	1-4													
Glaucocystis nostochinearum (Itz.) Rabenhorst.			3														
Gloeocapsa punctata Naegeli.		1		1													
Gloeocapsa rupestris Kuetzing.	1-4	2-4	1,2	1	1,2,4	2	1,2,4	1,2	1		1	1,2	2,3				6
Gloeothece linearis Naegeli.														2		5,6	
Gloeotrichia echinulata (J.E. Sm ith) P. Richter.	2	1,4										2		2,4		5,8	
Gloeotrichia pisum (C.A. Ag.) Thuret.	1	2															
Gomphosphaeria aponina Kuetzing.	2	2	2									4					
Gomphosphaeria aponina var. cordiformis Wolle.												4		3			
Gomphosphaeria aponina var. delicatula Virieux.	1,3	1					3						1	3,4			8
Gomphosphaeria aponina var. gelatinosa Prescott.				4													

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Gomphosphaeria lacustris Chodat.	2-4	2-4	1-3	1-4	1,2	2,3	1,2,4	1	1,3,4		1,2	1-4	1-3	1-3	7,8	5-8	5,6,8
Gomphosphaeria lacustris var. compacta Lemmermann.	1-4	1-4	1-3	1-4	1,2,4	1-3	1,2,4		3,4		2,4	2-4	1-4	1-4	5,8	5,7,8	5-8
Holopedium irregulare Lagerheim.				3		3			3			3					7
Lyngbya putealis Montagne.					1												
Marssoniella elegans Lemmermann.	2																
Merismopedia elegans A. Braun.		2	2		1								1				
Merismopedia elegans var. major G.M. Smith						3											
Merismopedia glauca (Ehrenb.) Naegeli.	3	2-4	2,3	2-4	2,4	2,3	1,2							3,4			
Merismopedia punctata Meyen.	1	3			1						4		1,2,4	1-4	6	5-8	5-8
Merismopedia tenuissima Lemmermann.	2-4	1-4	1-3	1-4	1,2,4	1-3	1,3					3		3,4		6	
Oscillatoria angustissima W. & G.S. Smith	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1	1,3,4		1,4	1-4	1,4	1-4	5,6,8	5-7	5-8
Oscillatoria rubescens De Candolle.				3			2				2	2			5		
Oscillatoria splendida Greville.					4		2								5		
Oscillatoria tenuis C.A. Agardh.	1				1,2,4	1-3	2-4	1,2	3,4					3			8
Polycystis aeruginosa Kuetzing.	1-4	1-4	1-3	1-4	1,2	1-3	1-4		3,4		1,2	2-4	1,3	1-4	5,8	5-8	5-8
Polycystis incerta Lemmermann.	1-3	1-4	1-3	1-4									1,2,4	2-4		6,8	5-8
Rhabdoderma gorskii Woloszynska.		1													1		5,7
Rhabdoderma irregulare (Naumann) Geitler.		1,2,4	1	1	1				1			1					
Rhabdoderma lineare Schmidle & Lauterborn.	3	1-3	1-3	3					1				1,4	1-4	6,8	5,8	5-8
Rhabdoderma sigmoidea fa. minor Moore & Carter.	2	2	2,3											1,2	8		
Spirulina major Kuetzing.														4			
Spirulina princeps (West & West) G.S. West.											4						
CHRYSOPHYCEAE																	
Chrysocapsa planctonica (West & West) Pascher.			1														7
Chrysosphaerella longispina Lauterborn.	1-4	1-4	1-8	1-4	1,2	1-3	3				1	1,2,4	1-4	1-4	5-8	5-8	5-8
Diceras phaseolus Pott.	2,3	2,4	1-3	1-4	1,2,4	2,3	1,2,4	1,2	1,3,4		1,4	1,4	2,3	1-3		7,8	6,8
Dinobryon spp.		2											2-4			5,6,8	5
Dinobryon spp.	2	4	2,3								2	3	1,2			8	5,6
Dinobryon acuminatum Ruttner.	3,4	2,4		3,4							1,2,4	1				8	7
Dinobryon bavaricum Imhof.	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1,2	3,4		1,2,4	1-4	1-4	1-4	5-8	5-8	5-8

Table II - continued

	1969						1970											
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Dinobryon calciformis Bachmann.											4				5		
Dinobryon crenulatum W. & G. West.	3	3	2,3	3,4	4	3	3,4		4			2-4	1,3,4	4	6-8	5-7	6
Dinobryon cylindricum Imhof.	1-4	1-4	1,3	1-4	1,2,4	1-3	1-4	1,2	3,4		1,2,4	1-4	1-4	1-3	5-8	5-8	5-8
Dinobryon divergens Imhof.	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4	1,2	1,3,4		1,4	1-4	1-4	1-4	5-8	5-8	5-8
Dinobryon sertularia var. protuberans Krieger (Lemmermann.)	1-4	1-4	1-3	1-4	1,2,4	1-3	1-4		3		1,2,4	1-4	1-4	1-4	5-8	5-8	5-8
Dinobryon vanhoeffenii (Krieg.) Bachmann.	1-4	1-4	1,3	1-4	1,2,4	1,2	1-4	1,2	3,4		2,4	1-4	1-4	1,2,4	5-8	5-8	5-8
Epipyxis tabellariae (Lemm.) Pascher.	3	2,4	2,3	2,3		3	1		4		2,4	1-4	1-3	1,2,4	5-8	5-8	6,8
Epipyxis utriculus Ehrenberg.	1		3										3,4			6,7	
Hyalobryon mucicola (Lemm.) Pascher.	3						1		1								
Mallomonas acaroides Perty.	1,3	1	1	3	2	2	1				1,2,4	1,2	1-3	1	6,8	6-8	5-7
Mallomonas alpina Paschner & Ruttner.	1,2,4	1,2,4	3	2-4	2	2,3	2	2	3		2,4	1,2,4		2	5	7	
Mallomonas apochromatica Conrad.			3								1						
Mallomonas caudata Conrad.	1,2	1,2	1,2	2,4	2	2	3	2	3		1,2	1	2	2	8	6-8	
Mallomonas fastigata Zacharias.	1,4	1,3,4	1,3	1,3,4	1	3	3				1,2,4	1-4	3	1,2,4	6-8	5,6	6-8
Mallomonas producta Iwanoff.	1,3	3	1	3	4	1,3	3,4	2	3		4	3	1,4	2	5,8	8	5-7
Mallomonas pseudocoronata Prescott.	1-4	1-4	1,3	2			1				2,4	1-4	1-4	1-4	5-8	5-8	5,6
Mallomonas tonsurata Teiling.	1-4	3					1				1	1	1		6	6	
Ophiocytium elongatum West & west.																	
Ophiocytium mucronatum (A. Braun) Rabenhorst.																	
Rhizochrysis limnetica G.M. Smith	1-4	1-4	1-3	1-4	1,4		3				1,2	1-4	2,4	1-4	5-8	5-8	5-8
Synura adamsii G.M. Smith	3,4	1,3	1,3	1-4	1,2,4	1-3	2,3	2	3		4		2,4	2,4	7	6-8	6,7
Synura petersenii Korshikov.	2,4				2	2,3	2,3	2			1,2	1,2,4	3	3	8	7	7
Synura uvella Ehrenberg.	1-4	1-3	1-3	1-4	1,2,4	1-3	1-4	1,2	3,4		1,2,4	1,3,4	1,4	1,2,4	5-8	5-8	5-8
Syncrypta janei nov. sp.			3				4				4						7
Uroglena volvox Ehrenberg.	3						4						1,2	2			7
Uroglenopsis americana (Calkins) Lemmermann.	1-4	1-4	1-3	2-4	2,4	2,3	2-4	2	3		1,2,4	1-4	1,2,4	2	5-8	6,8	5-8
Vaucheria spp.																	
DINOPHYCEAE																	
Ceratium hirundinella (O.F. Muell.) Dujardin.			3									1-4	1-4	1-4	5-8	5-8	5-8
Glenodinium armatum Levander.													1	1			

Table II - continued

	1969				1970												
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	J	J	A
Glenodinium gymnodinium Penard.	1,2,4	1-3										2	1	2		5	6
Glenodinium palustre (Lemm.) Schiller.	1,3		3			3					1	1	1	2,3	6,7		6,8
Glenodinium pulvisculus (Ehrenb.) Stein.															8		
Gonyaulax polyedra Stein.																	8
Gymnodinium fuscum (Ehr.) Stein.		2							3					2	5,6,8	8	7
Gymnodinium palustre Schilling.			3			3						1			8		
Hemidinium nasutum Stein.	1													2			8
Peridinium cinctum (Muell.) Ehrenberg.	1,4	2,3	2,3	1,3	2,4	2,3	2,3	1,2	3,4		1,4	1-3	1-4	1-3	5,6	7,8	5,6,8
Peridinium cinctum var. tuberosum (Meunier) Lindemann.							1,3,4	1			4				5		
Peridinium gaslaviense Woloszynska.																5	5
Peridinium inconspicuum Lemmermann.	1,3	3	3		1,2,4	2,3	2,3	1	3		2,4	1-4	1,2,4	1,3,4	5,6	6,8	6
Peridinium limbatum (Stokes) Lemmermann.	1,2		1	3	2						2,4	1,2,4	1-4	2-4	5,7,8	5,7,8	5-8
Peridinium pusillum (Penard) Lemmermann.	1-4	1-4	1-3	2,4							2	4	3		5,7	5,8	8
Peridinium willei Huitfeld-Kass.													1	2			5,7,8
Peridinium wisconsinense Eddy.		1,3	1														
CRYPTOPHYCEAE																	
Cryptomonas erosa Ehrenberg.	1-4	1-4	1-3	1,3,4	1,2,4	1-3	1-4	1,2	1,3,4		1,2,4	1-4	1-4	1-4	5-8	5-8	5-8
Cryptomonas marssonii Skuja.	3,4	3,4	3	3,4	4	3	4				4	2-4	1-4	1-4	5-8	5-8	5-7
Cryptomonas ovata Ehrenberg.	1-4	1-4	1-3	1-3	1,2,4	1-3	1,3	1	1,3		1,2,4	1,3,4	4	2,3	5-7	6,7	6,8
Rhodomonas lacustris Pascher & Ruttner.		2-4	3	4	4	2	3				2		2-4	1-4	6		6-8
EUGLENOPHYCEAE																	
Euglena gracilis Klebs.	1,4											2		2		5,7	5
Colacium arbuscula Stein.	4	1-3	1-2	2	4						4	4		1,2,4			5-8
Colacium vesiculosum Ehrenberg.	1,2	3			2,4							4		3		7,8	5,7,8
Trachelomonas volvocina Ehrenberg.	2					2					2						
XANTHOPHYCEAE																	
Gloeobotrys limneticus (G.M. Smith) Pascher.									4							8	8
Ophiocytium elongatum West & West.								2									
Ophiocytium mucronatum (A. Braun) Rabenhorst.													1				
Peroniella planctonica G.M. Smith								2			2		2-4	1		5,6,8	5-7
Stipitococcus capense Prescott.	3,4	3	1	2,4	1												
Vaucheria spp.																	

Table III

Combined Monthly Totals in Numbers of Species Per Class at Stations 1-4

	1969						1970							
	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Chlorophyceae	81	82	82	82	63	69	51	20	28		61	86	92	100
Cyanophyceae	48	48	39	39	32	34	32	14	23		20	29	30	40
Bacillariophyceae	37	31	23	37	31	32	35	18	24		35	33	19	20
Chrysophyceae	26	23	24	20	18	18	24	12	16		24	22	24	21
Dinophyceae	8	7	7	4	4	3	3	3	3		6	7	10	11
Cryptophyceae	3	4	4	4	4	4	4	2	2		4	3	4	4
Euglenophyceae	4	2	1	1	2	1					2	3	0	3
Xanthophyceae	1	1	1	1	1			2	1		1	0	2	1
Total	208	198	181	188	155	161	149	71	97		153	183	181	200

Table IV

Combined Monthly Totals in Numbers of Species Per Class at Stations 5–8

	1970		
	June	July	August
Chlorophyceae	65	97	111
Cyanophyceae	24	28	38
Bacillariophyceae	33	24	27
Chrysophyceae	21	25	24
Dinophyceae	11	9	13
Cryptophyceae	4	3	4
Euglenophyceae	0	1	3
Xanthophyceae	1	2	2
Total	159	189	222

Table V

Total Number of Species per Class at Each Station

Lake Winnipesaukee

	1	2	3	4	5	6	7	8
Chlorophyceae	118	138	121	103	86	81	87	92
Bacillariophyceae	44	55	36	40	22	28	19	21
Cyanophyceae	49	46	43	44	33	30	31	30
Chrysophyceae	28	27	28	27	20	21	23	22
Dinophyceae	10	7	11	10	11	8	8	13
Cryptophyceae	4	4	4	4	3	4	4	4
Euglenophyceae	3	4	2	3	3	1	2	2
Xanthophyceae	3	2	1	2	2	1	1	2
Total	259	283	246	233	180	174	175	186

Table VI

Monthly Totals of Species Found at Each Station

	J	A	S	O	N	D	J	F	M	A	M	J	J	A
Station No. 1	116	108	113	92	84	70	83	52	35	-	74	83	108	107
2	126	127	104	113	107	108	93	46	-	-	97	101	102	126
3	108	131	126	129	118	-	77	-	67	-	-	89	102	118
4	102	102	103	-	104	-	63	-	59	-	98	102	92	104
5												78	83	109
6												95	89	131
7												69	112	112
8												107	110	113

Table VII

Percent Composition of Total Cell Numbers per Classes at Stations 1-8

	1969 J	A	S	O	N	D	1970 J	F	M	A	M	J	J	A	Yearly Av.	
Chlorophyceae	12.	08.	09.	05.	04.	02.	03.	07.	04.		05.	07.	04.	12.	6.3	
Cyanophyceae	76.	77.	77.	90.6	90.	86.	76.	51.	84.		41.	47.	68.	85.	73.	
Bacillariophyceae	10.	03.1	03.	02.	03.	09.	18.1	40.	10.6		33.	23.	12.	02.	13.	Sta. 1
Chrysophyceae	1.	11.	10.1	02.	02.7	02.6	02.7	01.6	00.8		20.	22.2	15.2	00.7	7.2	
Dinophyceae	.1	00.2	00.2	-	-	-	-	-	-		00.1	00.2	00.5	00.1	.1	
Cryptophyceae	.3	00.6	00.6	00.3	00.2	00.3	00.1	00.3	00.5		00.8	00.5	00.2	00.1	.3	
Euglenophyceae	-	-	-	-	-	-	-	-	-		-	-	-	-	-	
Xanthophyceae	-	-	-	-	-	-	-	-	-		-	-	-	-	-	
Chlorophyceae	20.	08.	05.	03.	06.	04.	03.	11.2			03.	07.	16.	06.	7.7	
Cyanophyceae	62.	81.4	89.4	90.8	84.7	84.6	77.4	10.			23.6	43.	46.	76.6	65.9	
Bacillariophyceae	09.5	03.	02.3	05.	06.	07.2	18.4	45.			44.	20.6	09.	02.	14.	Sta. 2
Chrysophyceae	08.	07.	03.	01.	03.	04.	01.	33.			29.	29.	27.4	15.	12.	
Dinophyceae	00.2	00.1	-	-	-	-	-	-			-	00.1	01.	00.1	.1	
Cryptophyceae	00.2	00.4	00.2	00.1	00.2	00.1	-	00.6			00.2	00.2	00.4	00.1	.2	
Euglenophyceae	-	-	-	-	-	-	-	-			-	-	-	-	-	
Xanthophyceae	-	-	-	-	-	-	-	-			-	-	-	-	-	
Chlorophyceae	06.	06.5	06.4	05.		04.	02.		03.2			10.	07.1	10.	6.	
Cyanophyceae	79.7	90.	81.	89.4		75.3	78.		73.			21.	69.1	88.2	74.	
Bacillariophyceae	06.	02.	05.	02.3		10.2	17.2		17.			44.6	14.	01.2	12.	Sta. 3
Chrysophyceae	08.	01.	07.	03.		10.	02.6		06.5			24.	09.	00.3	7.5	
Dinophyceae	-	-	00.1	-		-	-		-			-	00.1	-	-	
Cryptophyceae	00.2	00.3	00.4	00.2		00.3			00.1			00.2	00.5	00.1	.2	
Euglenophyceae	-	-	-	-		-	-		-			-	-	-	-	
Xanthophyceae	-	-	-	-		-	-		-			-	-	-	-	

Table VII - continued

	J	A	S	O	N	D	J	F	M	A	M	J	J	A	Yearly Av.	
Chlorophyceae	07.	06.		07.3	05.		09.		06.3		15.5	07.1	08.	06.	7.7	
Cyanophyceae	78.2	77.3		77.2	79.1		66.4		66.4		22.1	59.2	67.	78.	66.9	
Baccilariophyceae	03.2	03.1		03.2	02.1		13.2		21.		30.	21.	09.	03.	11.	St. 4
Chrysophyceae	11.	13.		12.	13.4		11.1		06.		32.	12.1	15.	12.7	14.	
Dinophyceae	00.1	00.1		-	-		-		-		00.1	00.1	00.3	-	-	
Cryptophyceae	00.3	00.4		00.1	00.2		00.1		-		00.1	00.3	00.6	00.2	.2	
Euglenophyceae															-	
Xanthophyceae															-	

	St.5			Y.A.	St.6			Y.A.	St.7			Y.A.		St. 8		
	J	J	A		J	J	A		J	J	A		J	J	A	Av.
Chlorophyceae	09.	02.4	08.	6.4	23.	14.2	09.	15.3	09.3	08.1	05.1	7.	18.	15.	07.2	13.3
Cyanophyceae	42.	82.1	70.3	64.6	12.1	74.1	78.1	54.6	14.2	68.2	82.5	55.5	48.2	64.	62	58.7
Bacillariophyceae	35.	10.2	05.4	16.6	27.2	05.2	03.2	11.6	47.	14.1	02.	21.3	22.4	06.	00.4	9.7
Chrysophyceae	13.2	05.	16.	12.	36.	06.	09.3	17.7	29.	08.2	10.	15.6	11.	14.2	30.1	18.
Dinophyceae	00.2	00.1	00.1	.1	00.2	00.1	-	.1	00.1	-	-	-	00.1	00.1	-	-
Cryptophyceae	00.4	00.1	00.1	.2	01.4	00.3	00.3	.6	00.2	01.2	00.2	.5	00.2	00.4	-	.2
Euglenophyceae	-	-	-	-	-	-	-	-	-	-	-		-	-	-	-
Xanthophyceae	-	-	-	-	-	-	-	-	-	-	-		-	00.1	-	-

- denotes less than.1%

Table VIII

Summary of Phytoplankton Indices and Proposed Trophic Status of Lake Winnipesaukee

	Composite	Summer	Winter	Trophic Status
Chlorophycean Index	1.34	1.37	-	eutrophic
Myxophycean Index	.79	.83	-	eutrophic
Diatom Index	.14	.14	.17	oligotrophic
Euglenophyte Index	.01	.02	-	oligotrophic
Compound Index	2.40	2.37	-	mesotrophic

Table IX

Summary of Phytoplankton Indices and Proposed Trophic Status for Stations 1-8

	1	2	3	4	5	6	7	8
Chlorophycean Index	1.11	1.63	1.02	1.29	.89	1.96	1.03	1.20
	E	E	E	E	O	E	E	E
Myxophycean Index	1.28	1.07	.85	1.19	.94	1.30	.86	.86
	E	E	E	E	E	E	E	E
Diatom Index	.33	.30	.22	.21	.38	.42	.27	.24
	E	O	O	O	E	E	O	O
Euglenophyte Index	.022	.024	,013	.024	.025	.009	.025	.016
	O	O	O	O	O	O	O	O
Compound Index	2.67	2.95	2.04	2.74	2.09	3.65	2.08	2.23
	E	E	M	E	M	E	M	M

E denotes eutrophy O denotes oligotrophy M denotes mesotrophy

LIST OF FIGURES

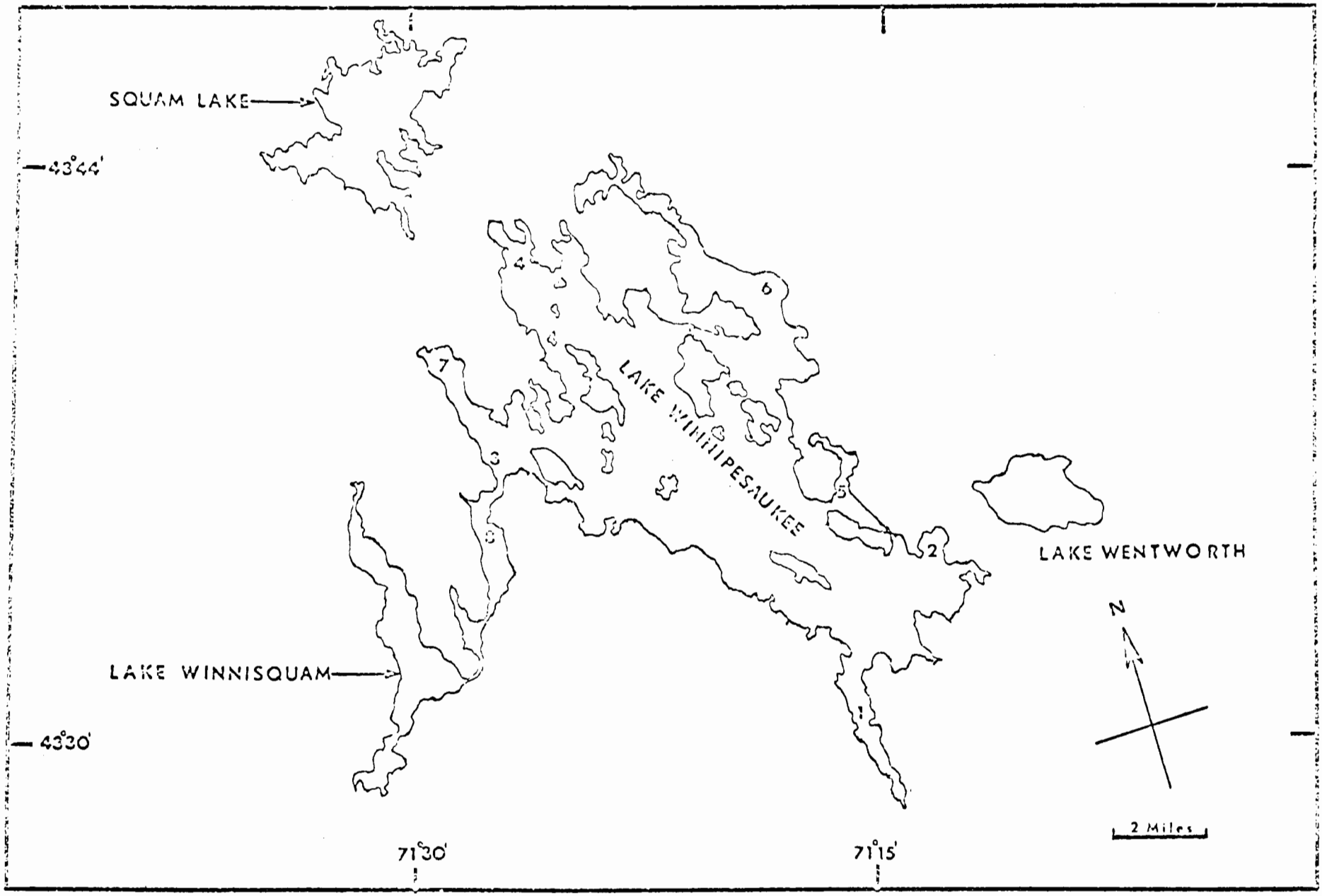
FIGURE I

MAP OF LAKE WINNIPESAUKEE, NEW HAMPSHIRE

LEGEND FOR FIGURE I

Stations:

1. Alton Bay
2. Wolfeboro Bay
3. Weirs
4. Center Harbor
5. Winter Harbor
6. Melvin Bay
7. Meredith Bay
8. Paugus Bay


SQUAM LAKE
43°44'
LAKE WINNISQUAM
43°30'
LAKE WINNIPESAUKEE
LAKE WENTWORTH
1
2
3
4
5
6
7
N
2 Miles
71°30'
71°15'

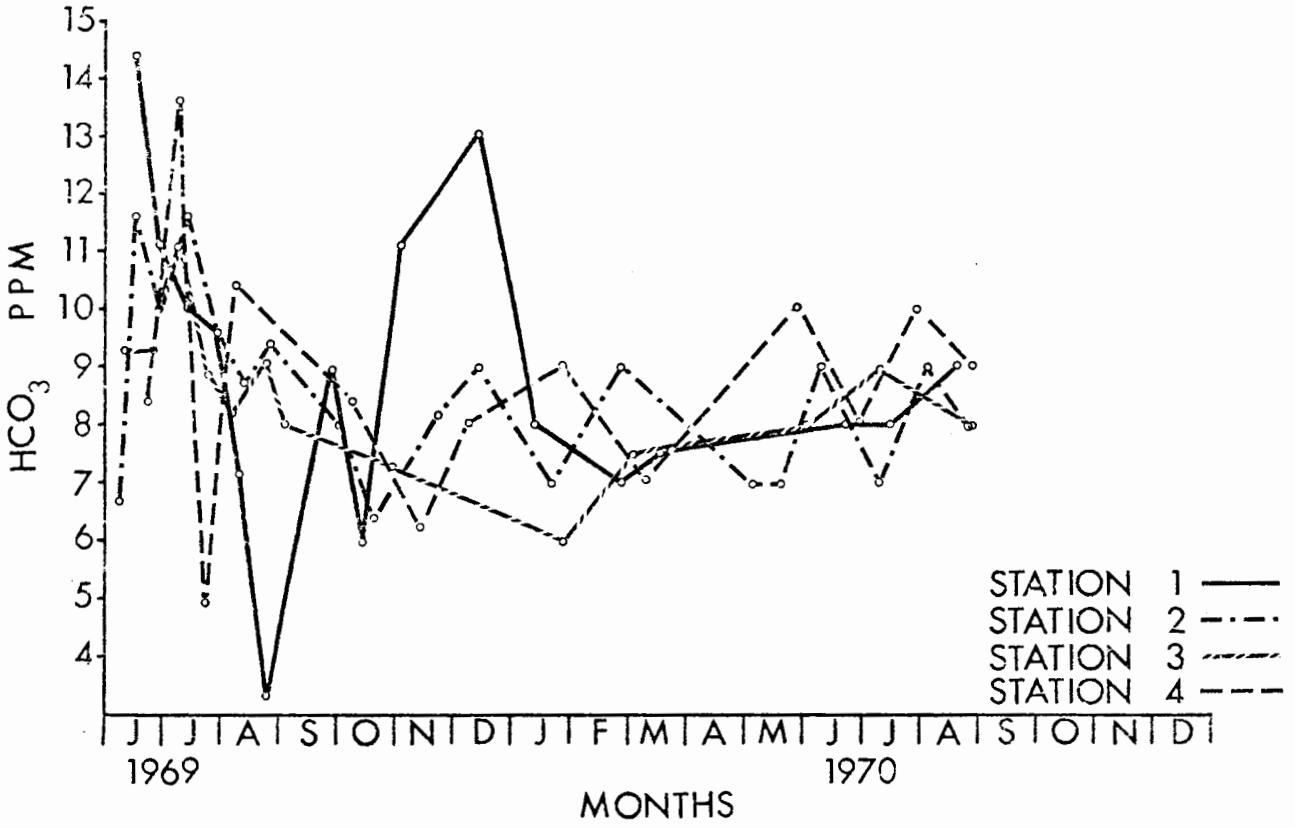


Figure 2. Seasonal variation of methyl orange alkalinity (HCO_3) at stations 1-4.

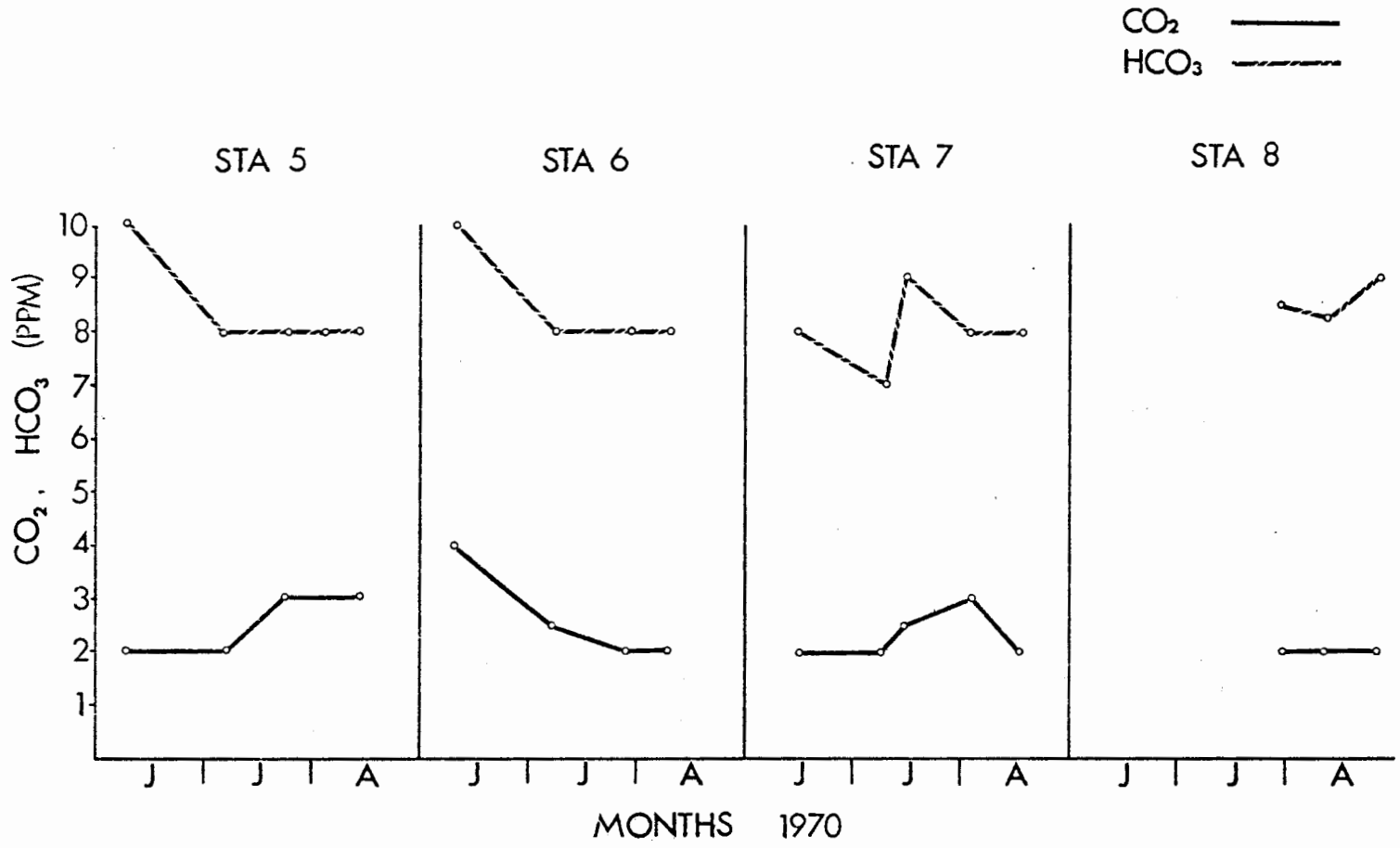


Figure 3. Free CO_2 and methyl orange alkalinity (HCO_3) at stations 5-8.

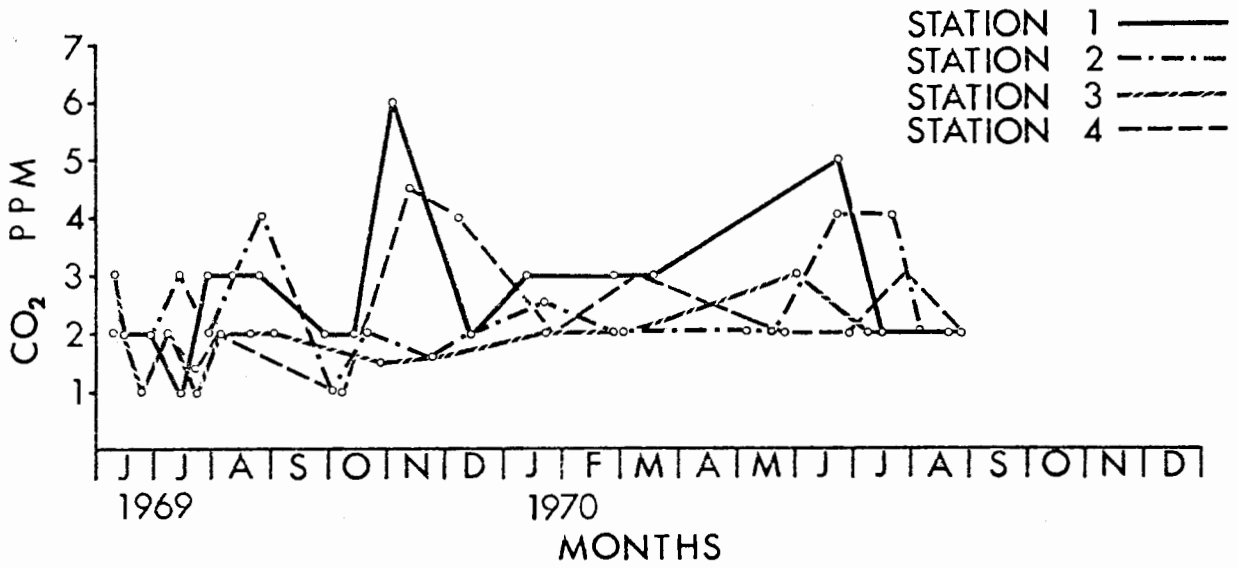


Figure 4. Seasonal variation of free CO_2 at stations 1-4.

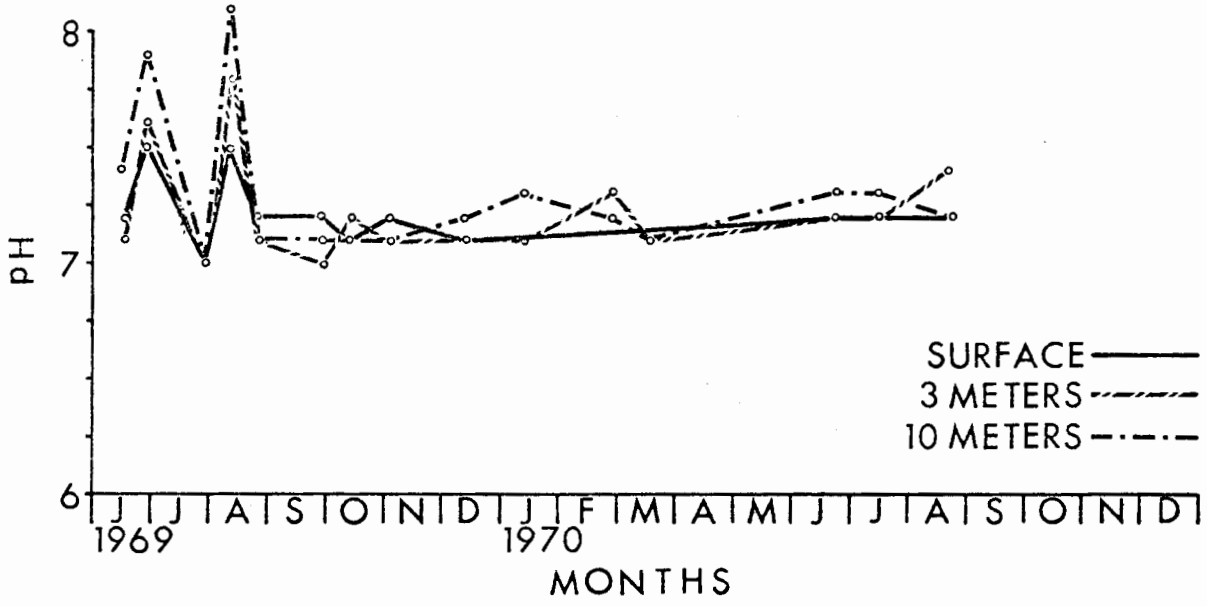


Figure 5. Seasonal variation of pH at station 1.

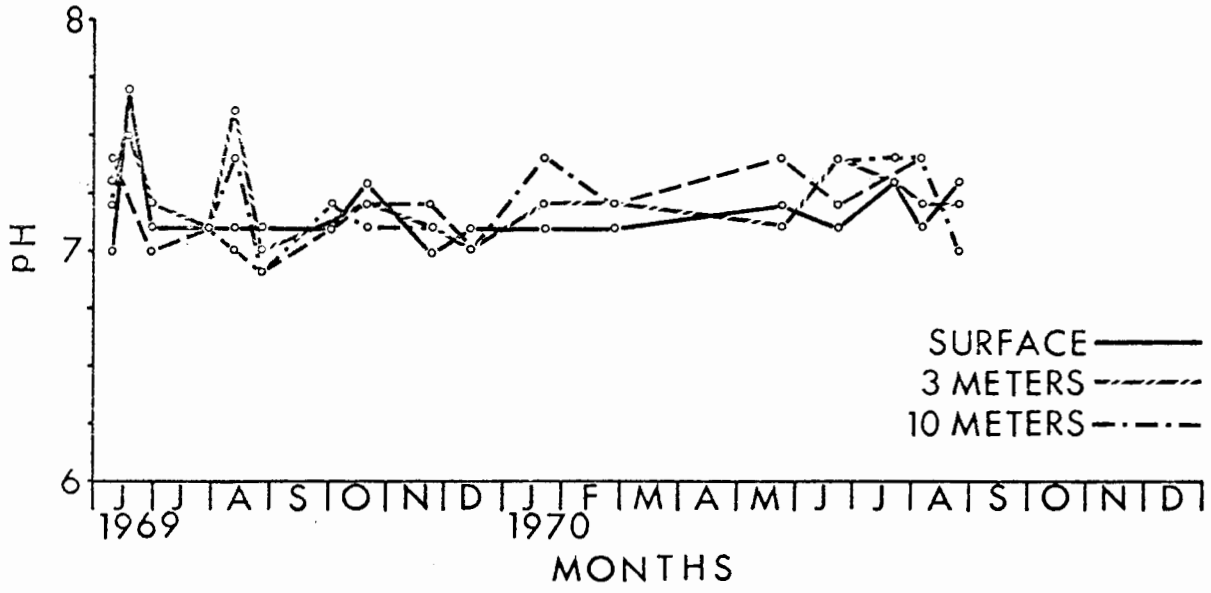


Figure 6. Seasonal variation of pH at station 2.

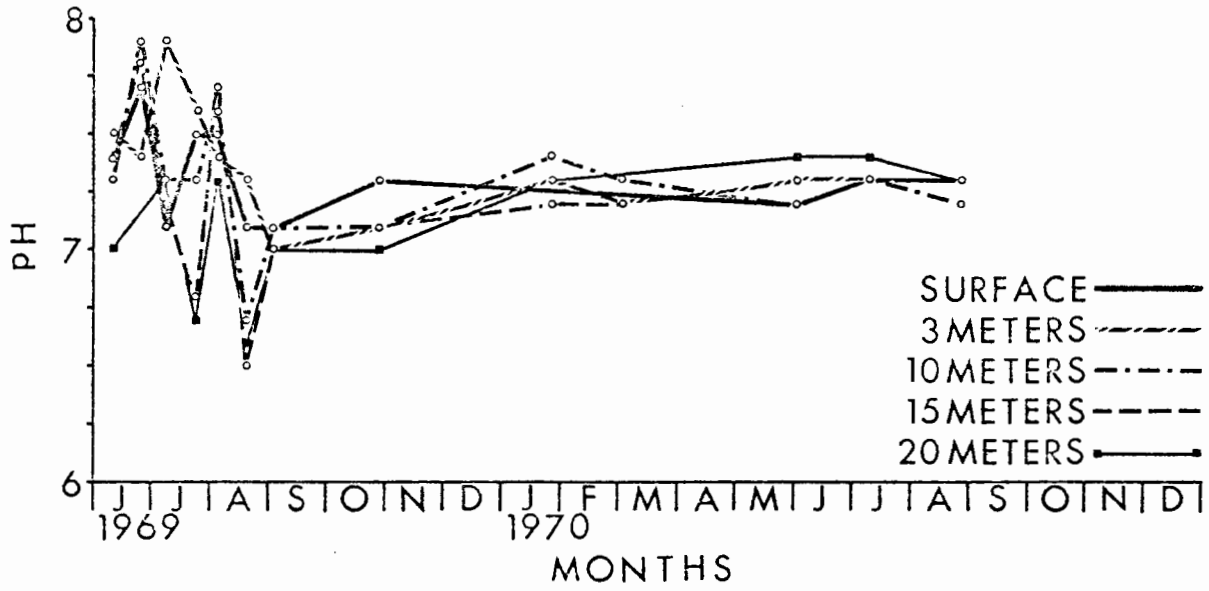


Figure 7. Seasonal variation of pH at station 3.

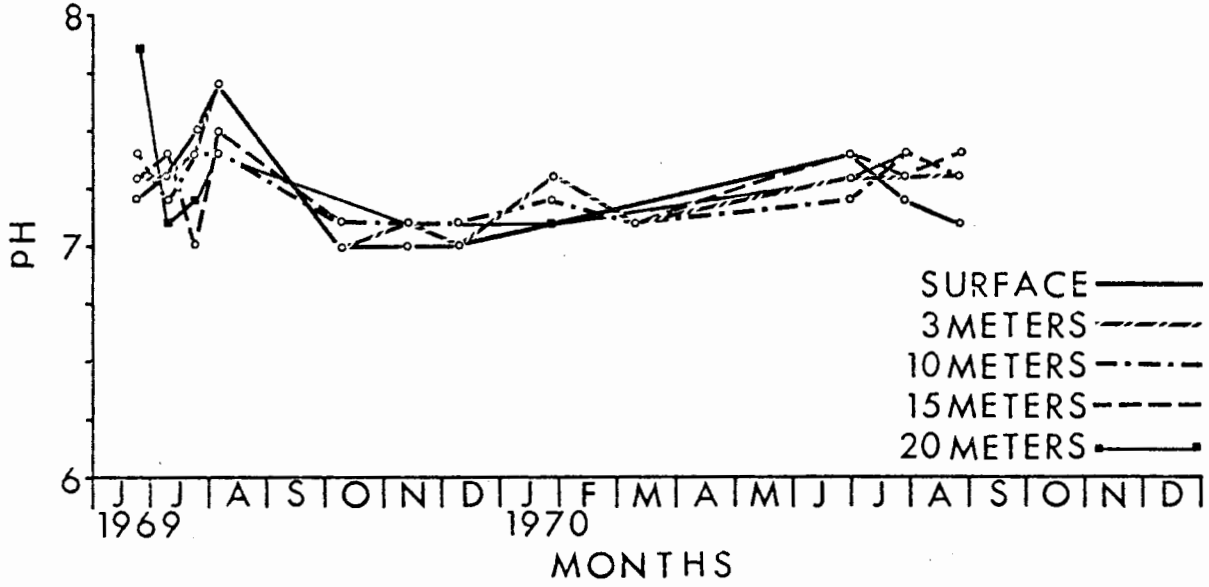


Figure 8. Seasonal variation of pH at station 4.

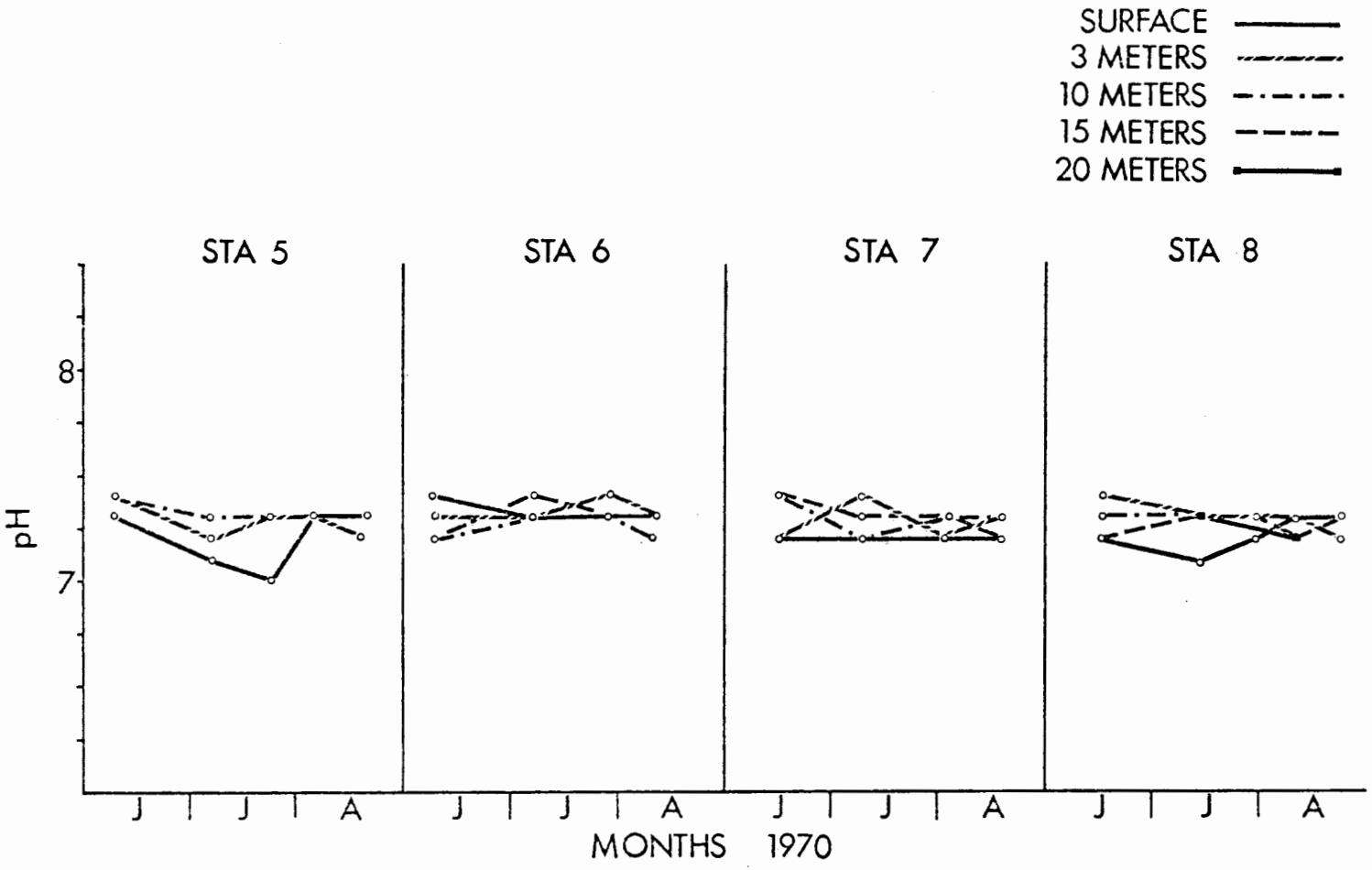


Figure 9. Hydrogen ion (pH) values at stations 5-8.

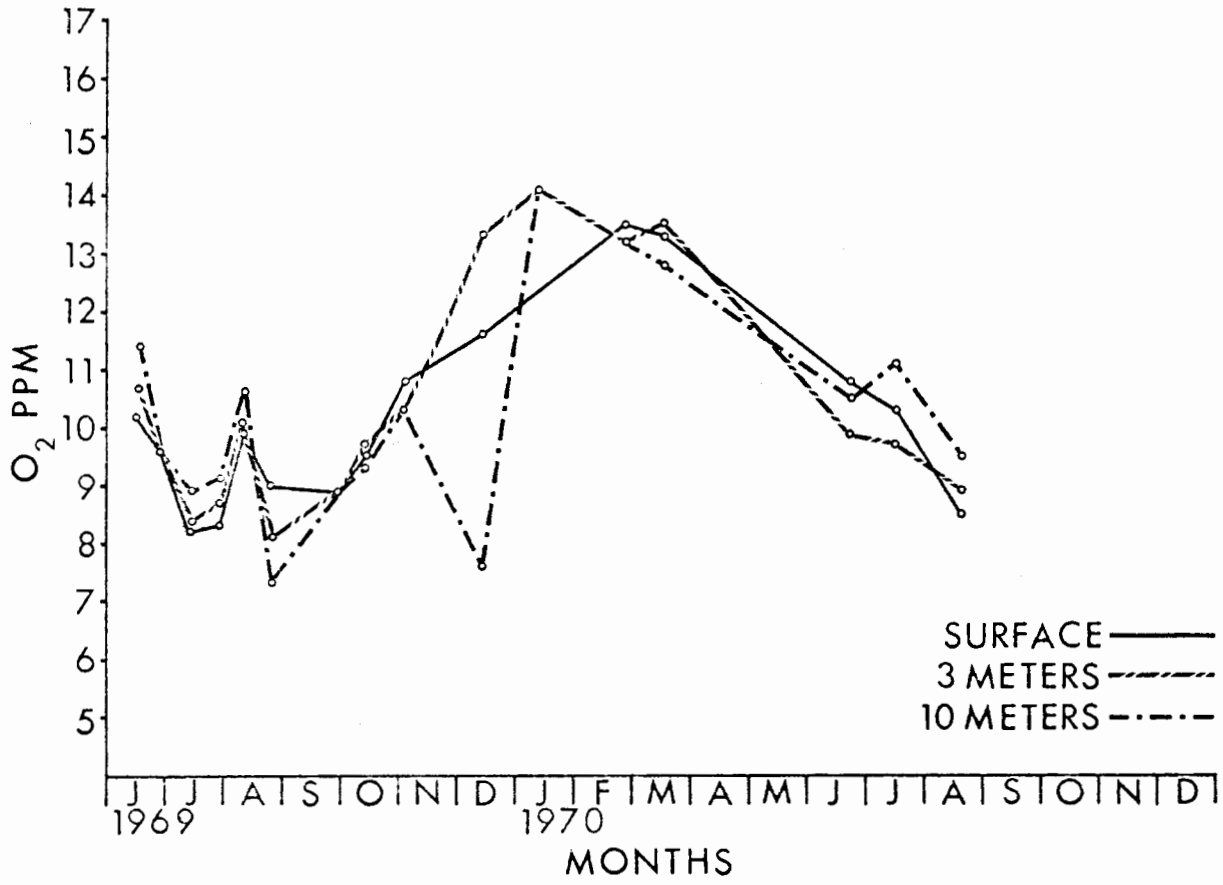


Figure 10. Seasonal variation of dissolved oxygen at station 1.

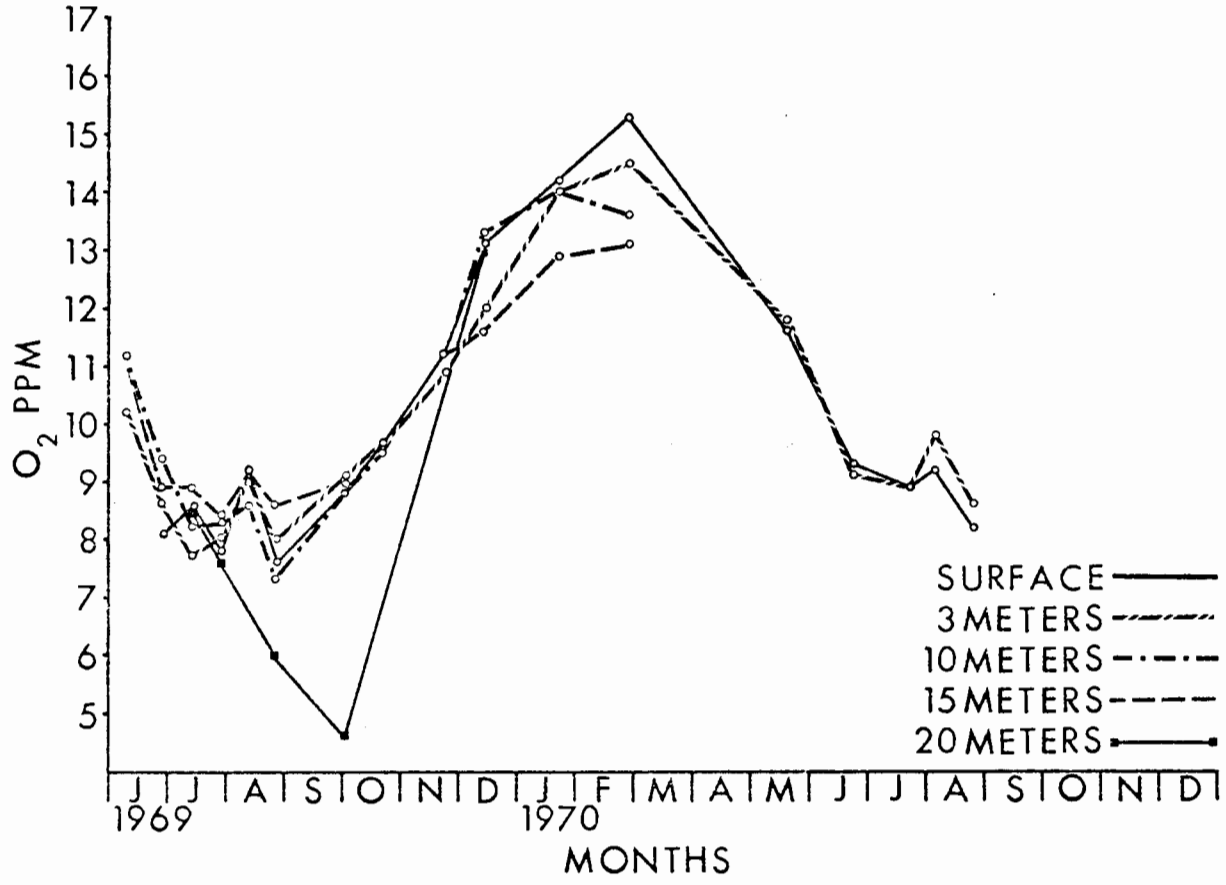


Figure 11. Seasonal variation of dissolved oxygen at station 2.

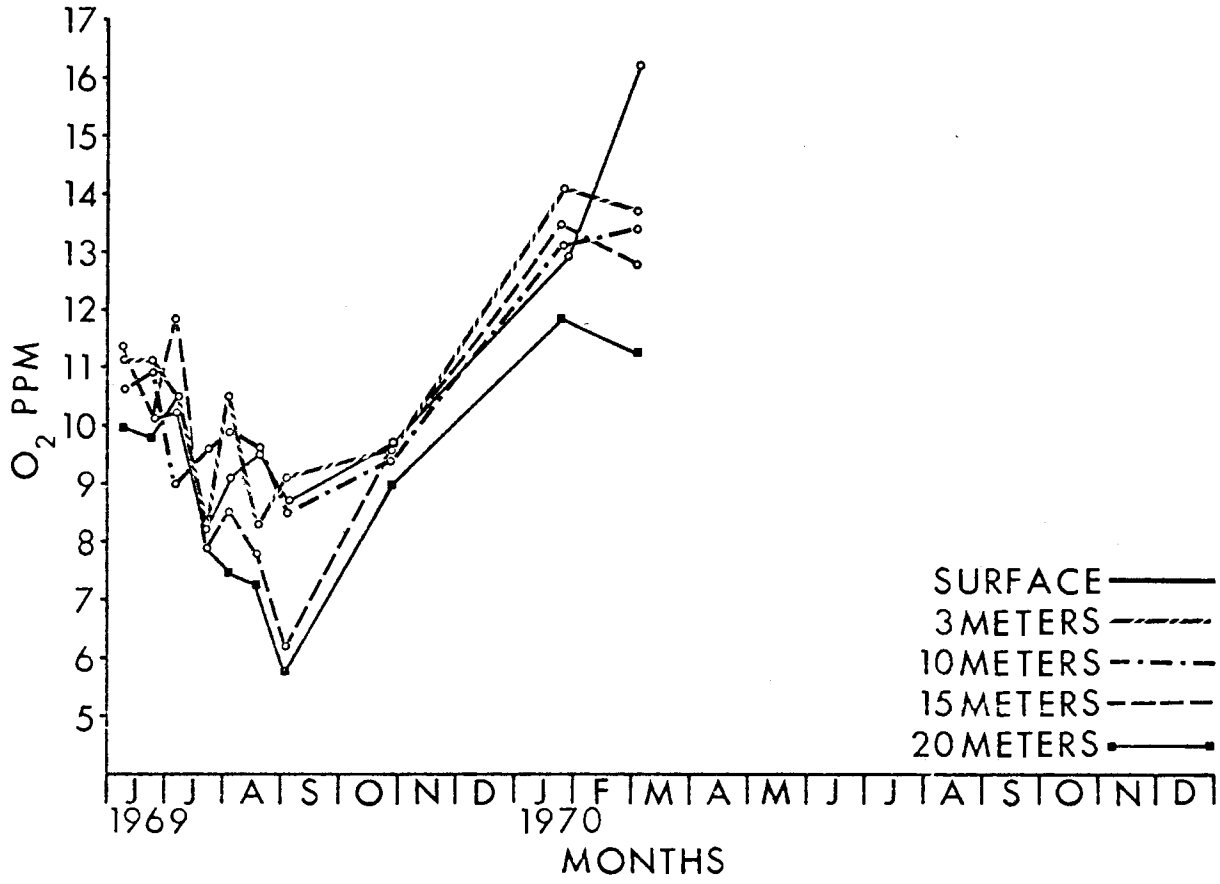


Figure 12. Seasonal variation of dissolved oxygen at station 3.

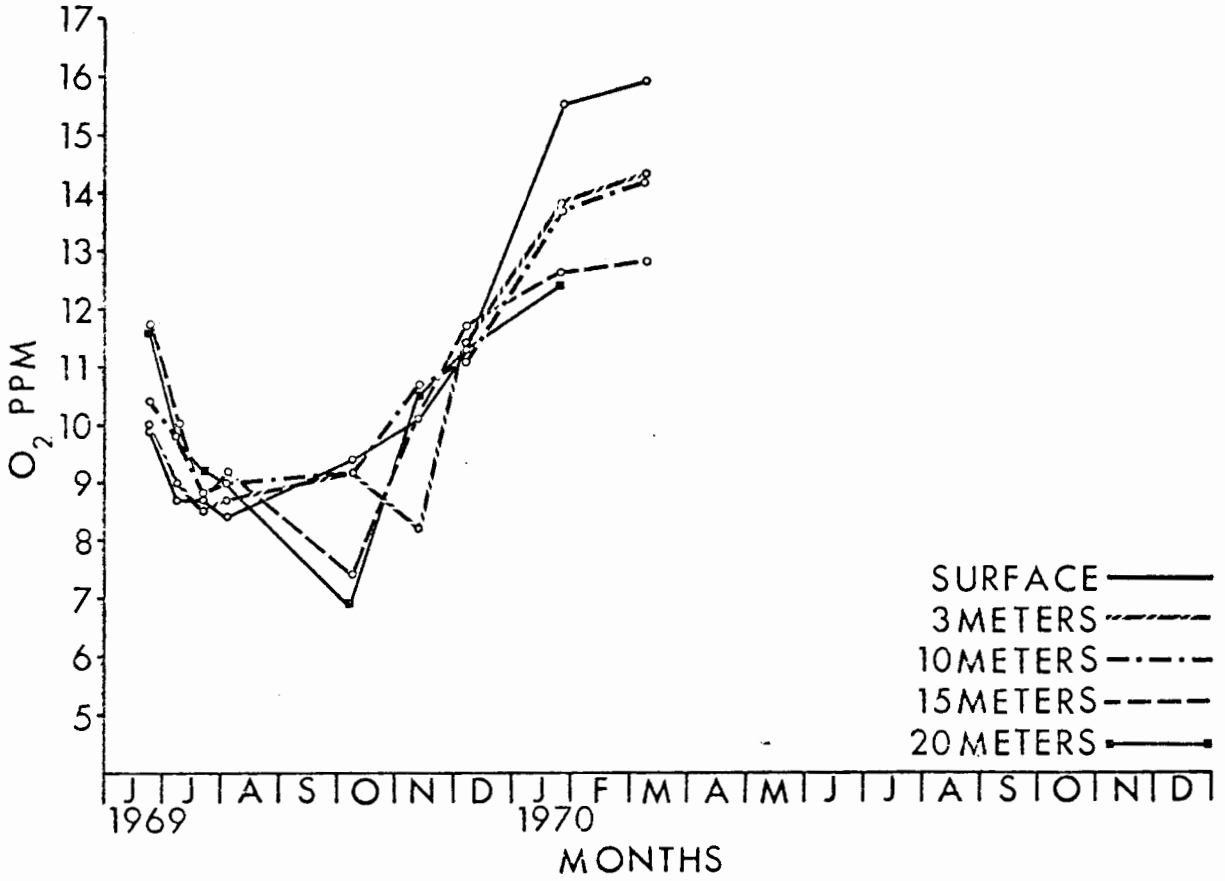


Figure 13. Seasonal variation of dissolved oxygen at station 4.

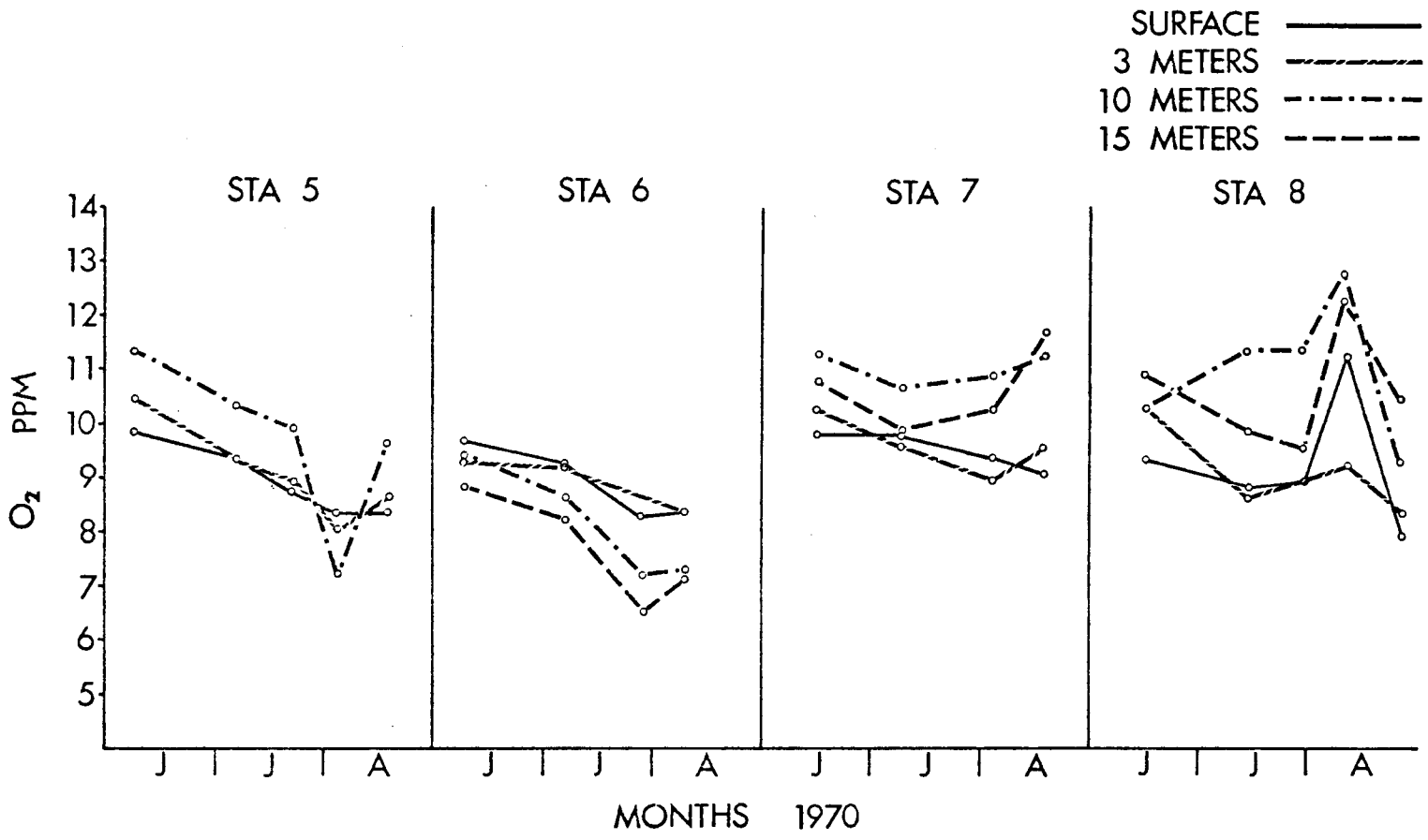


Figure 14. Dissolved oxygen values at stations 5-8.

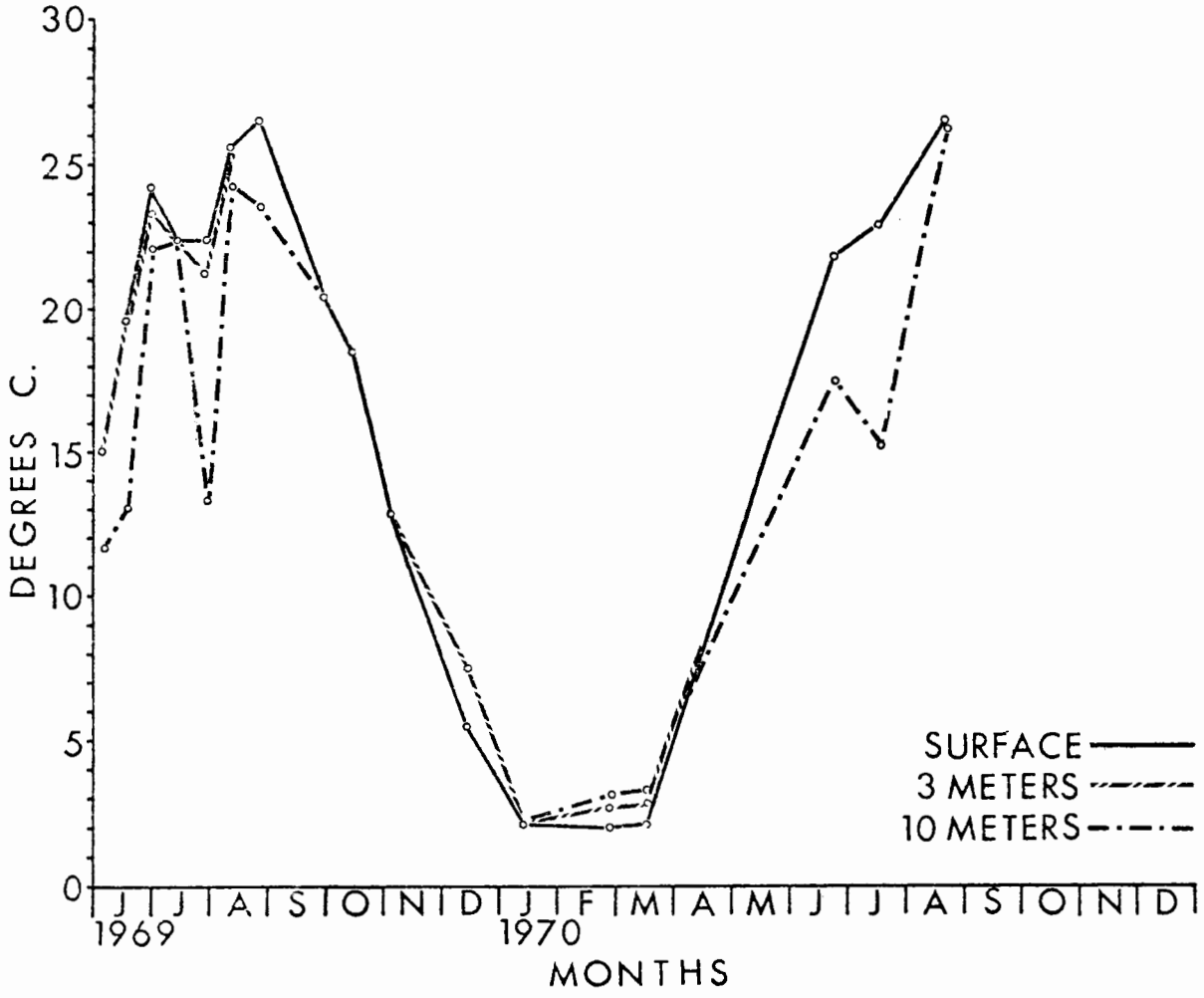


Figure 15. Seasonal temperature variations at station 1.

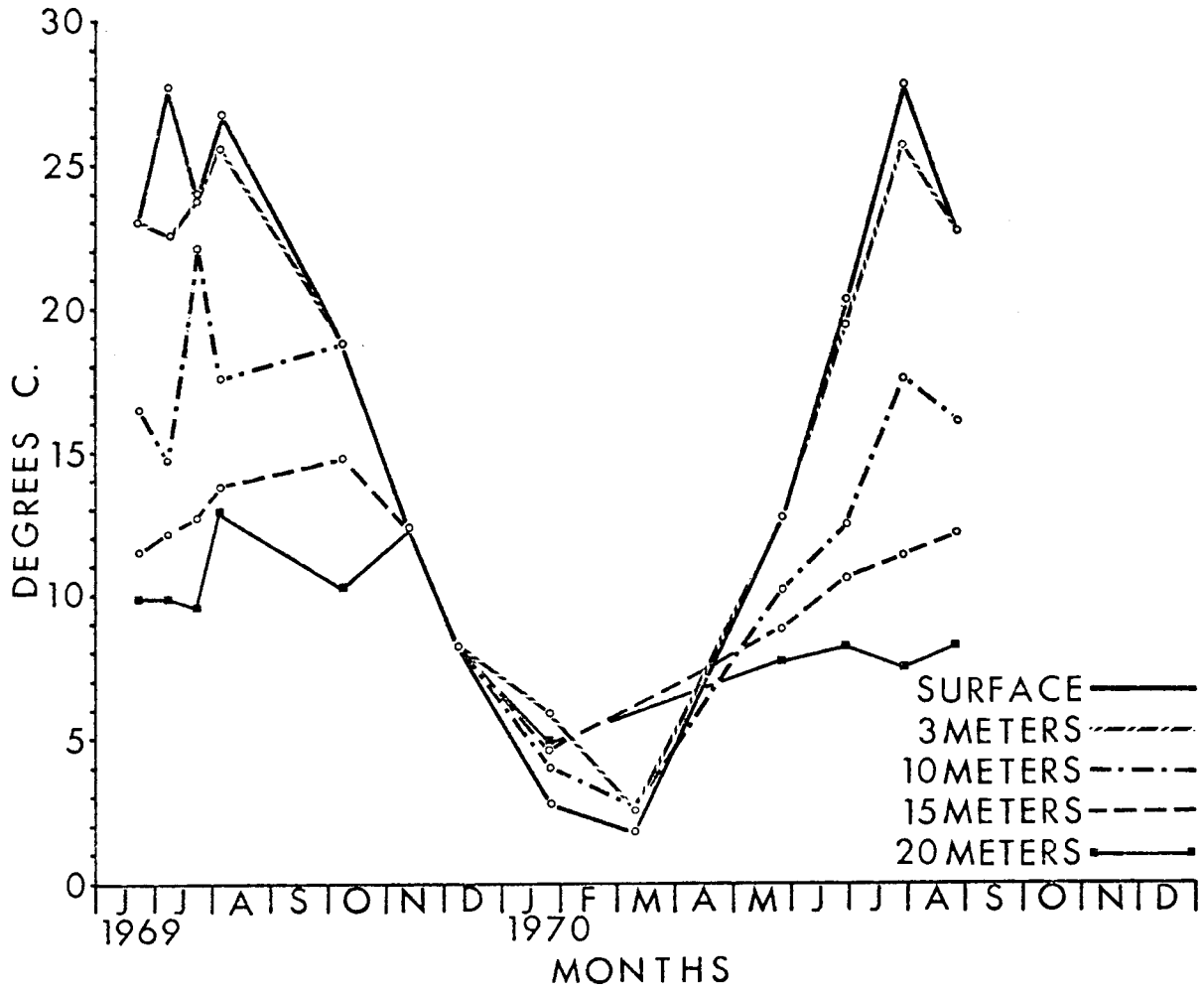


Figure 16. Seasonal temperature variations at station 2.

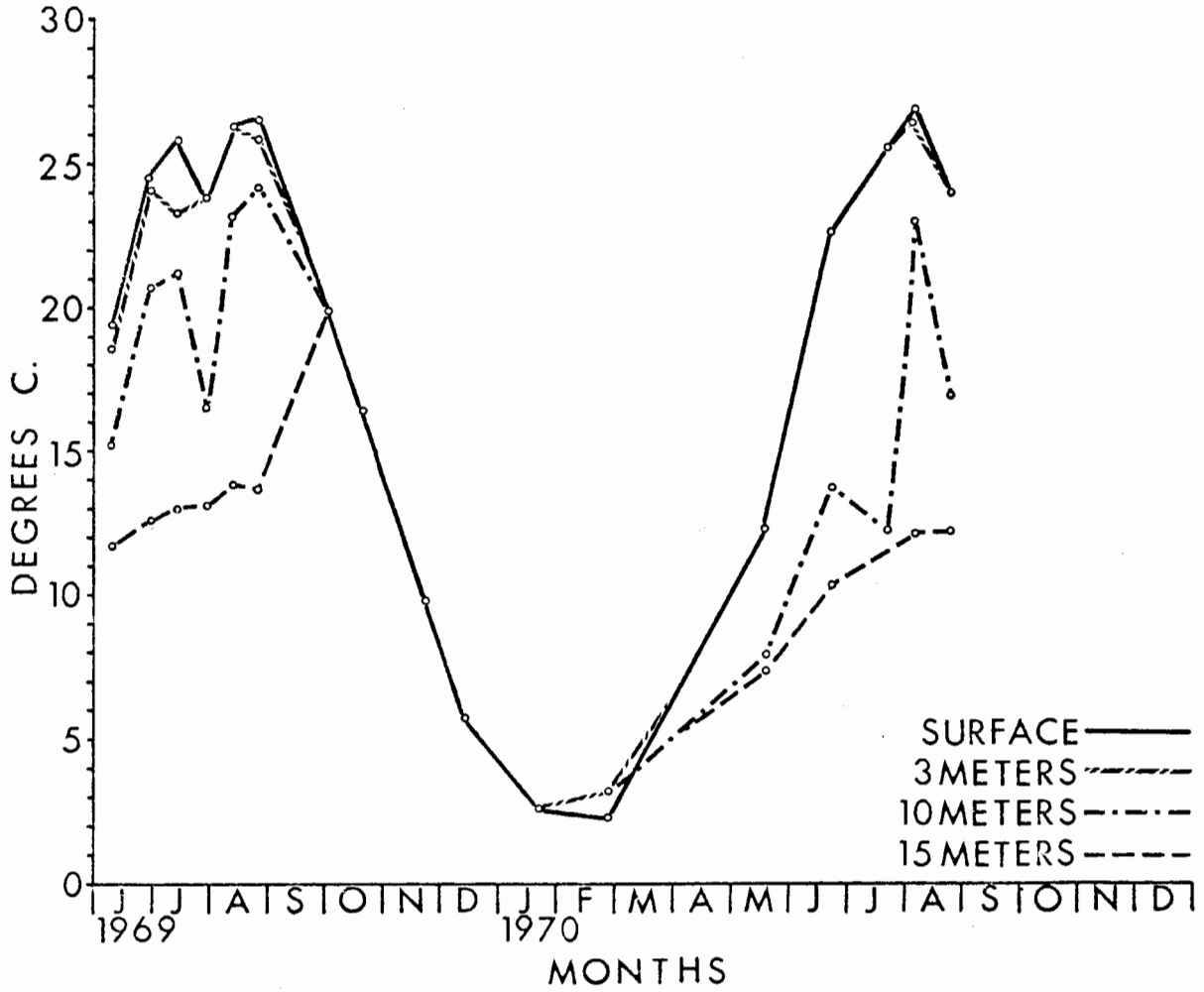


Figure 17. Seasonal temperature variations at station 3.

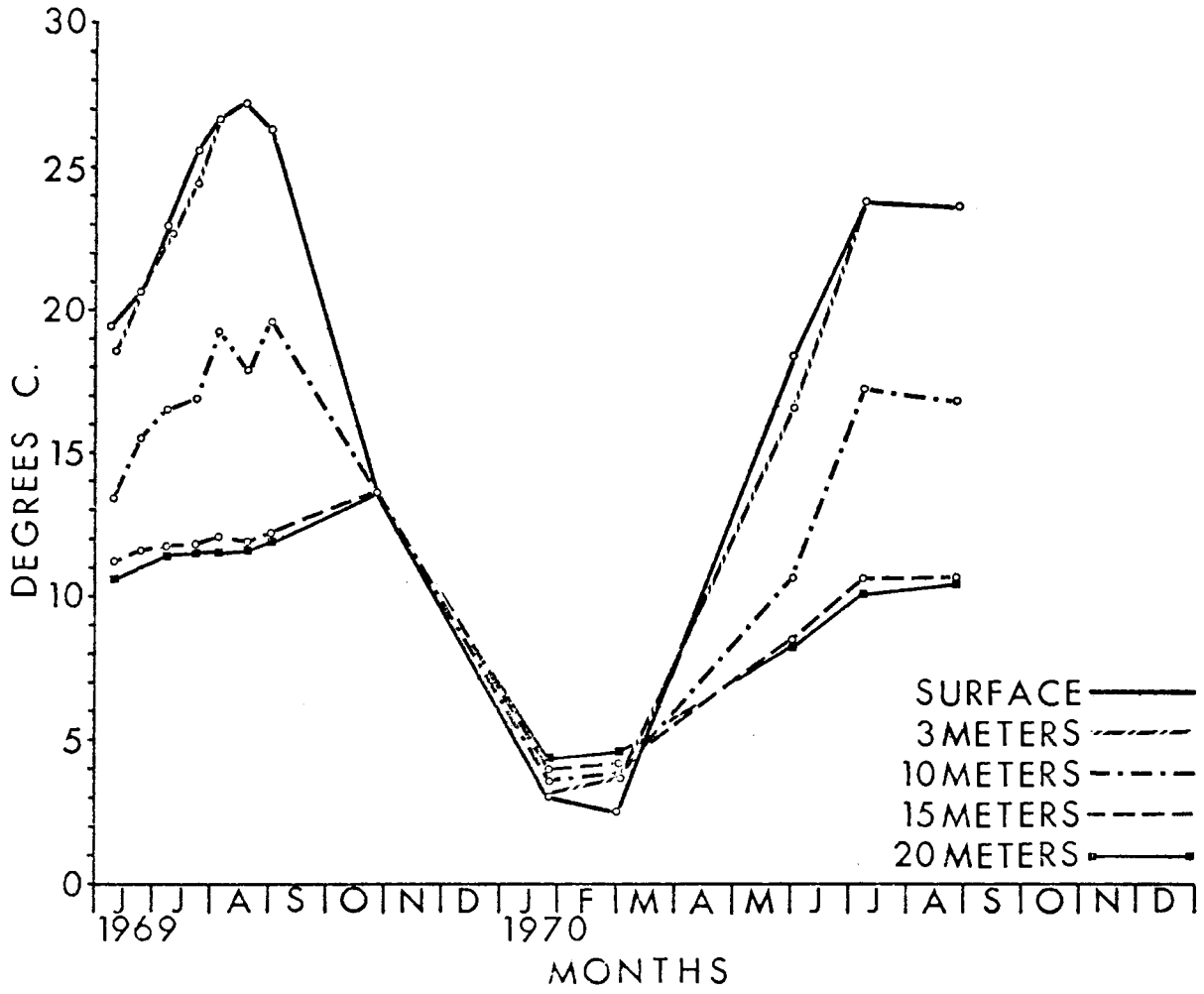


Figure 18. Seasonal temperature variations at station 4.

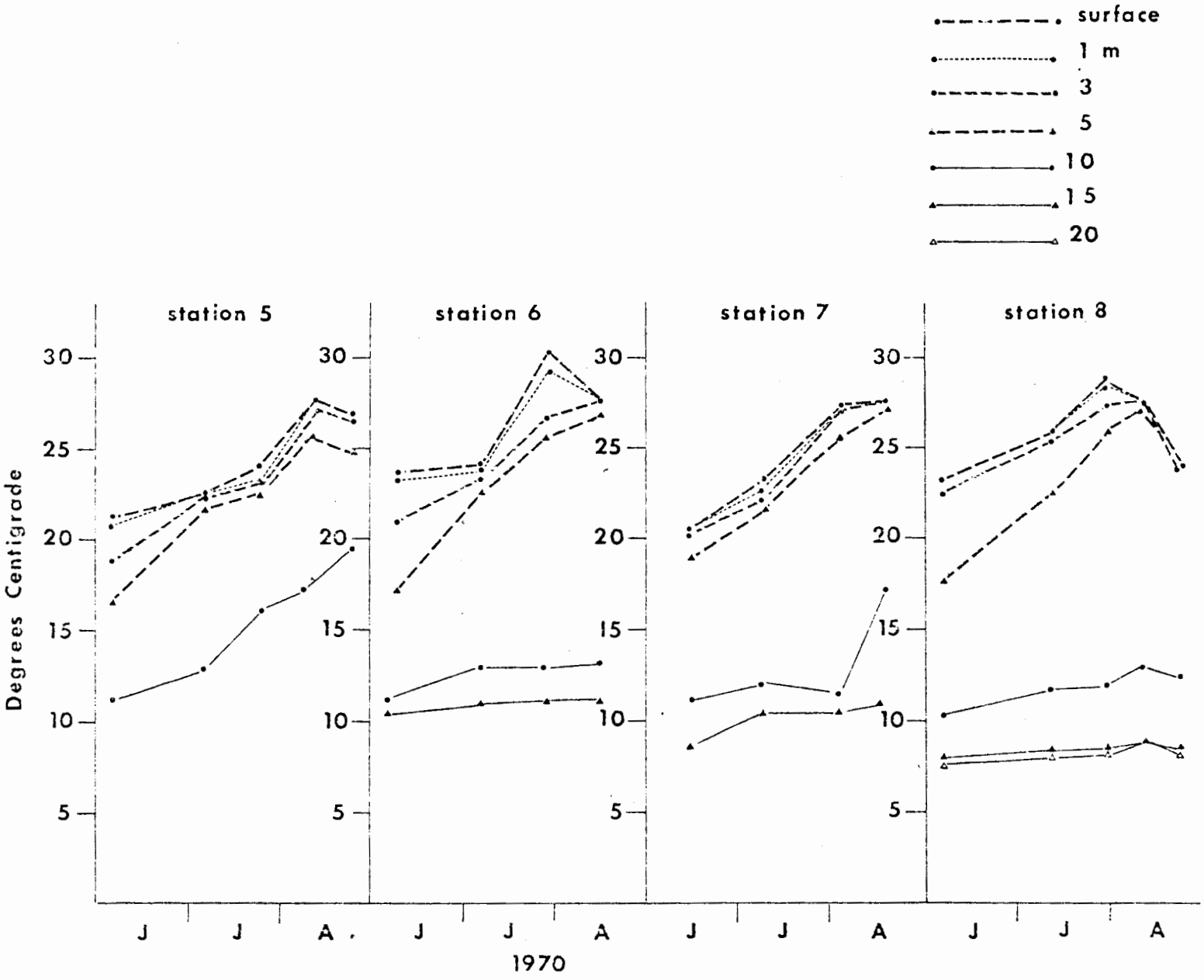


Figure 19. Water temperatures at stations 5-8.

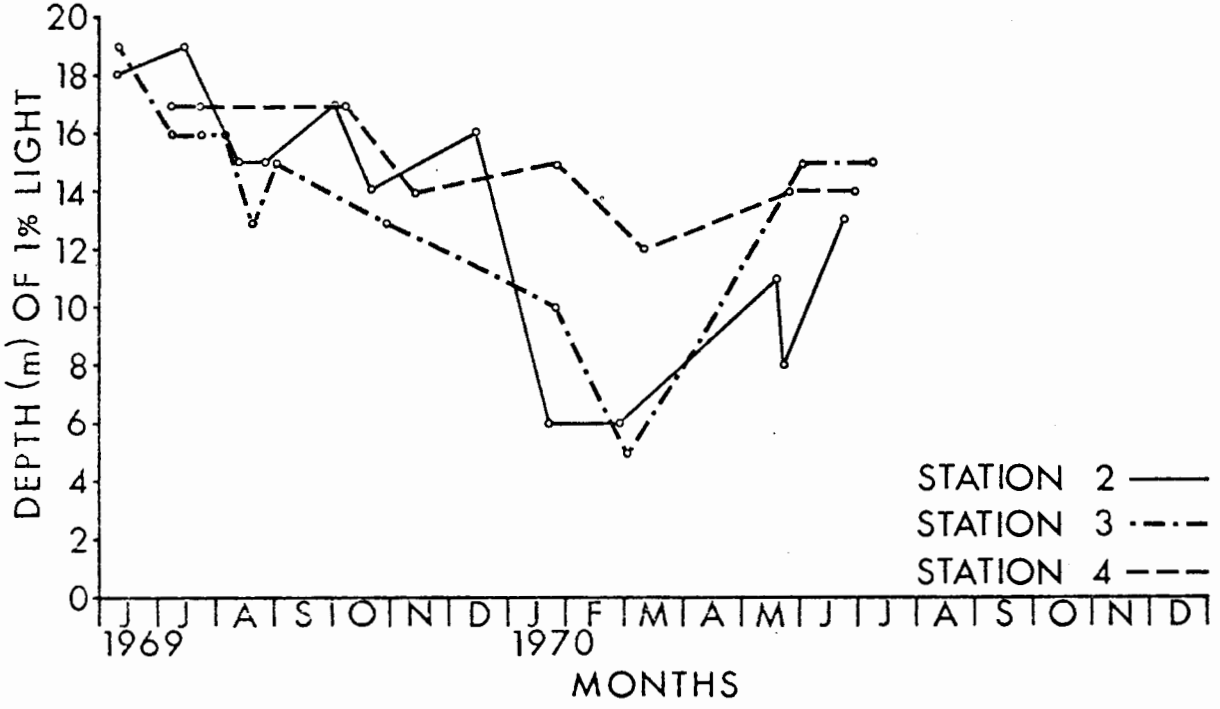


Figure 20. Seasonal variation of light penetration - 1% level.

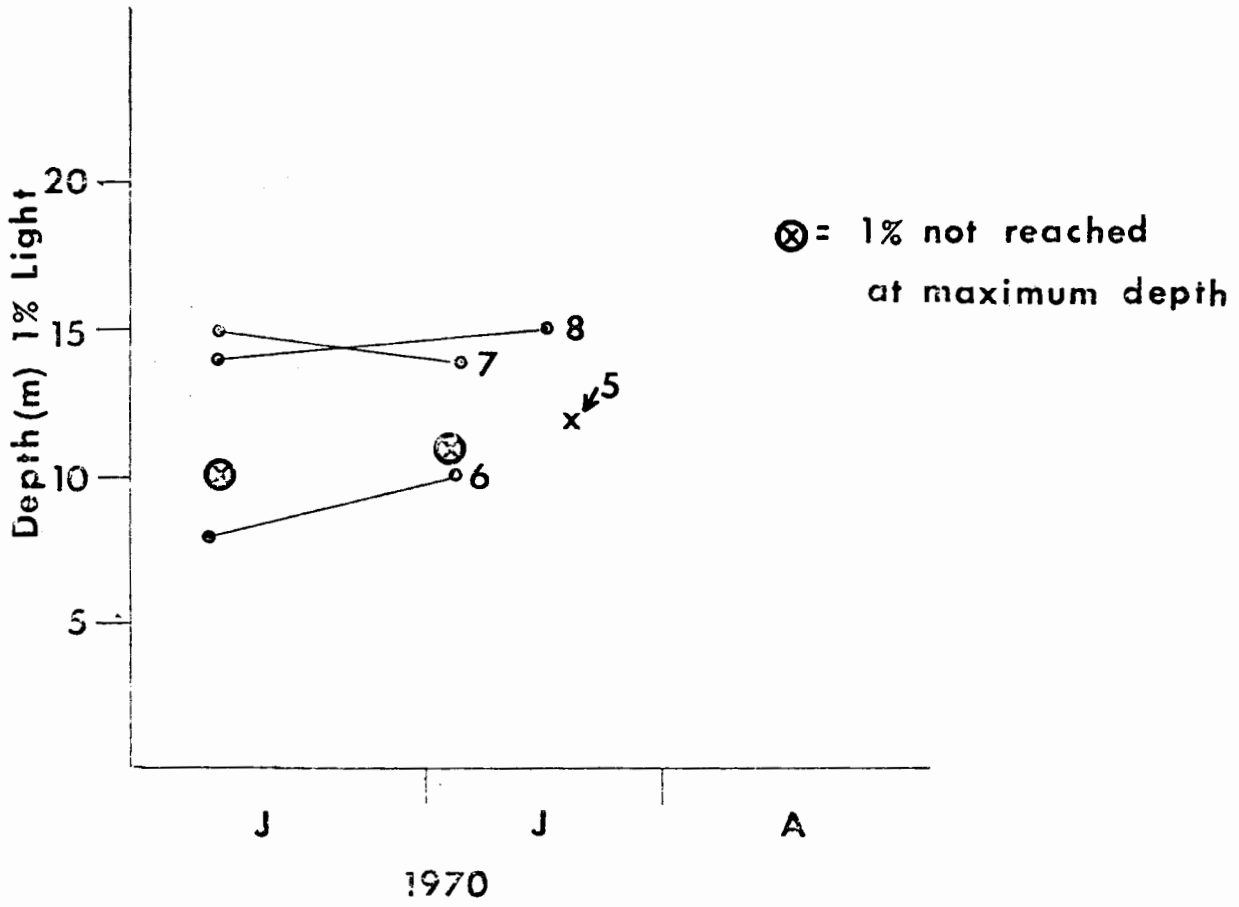


Figure 21. Light penetration (1% level) at stations 5-8.

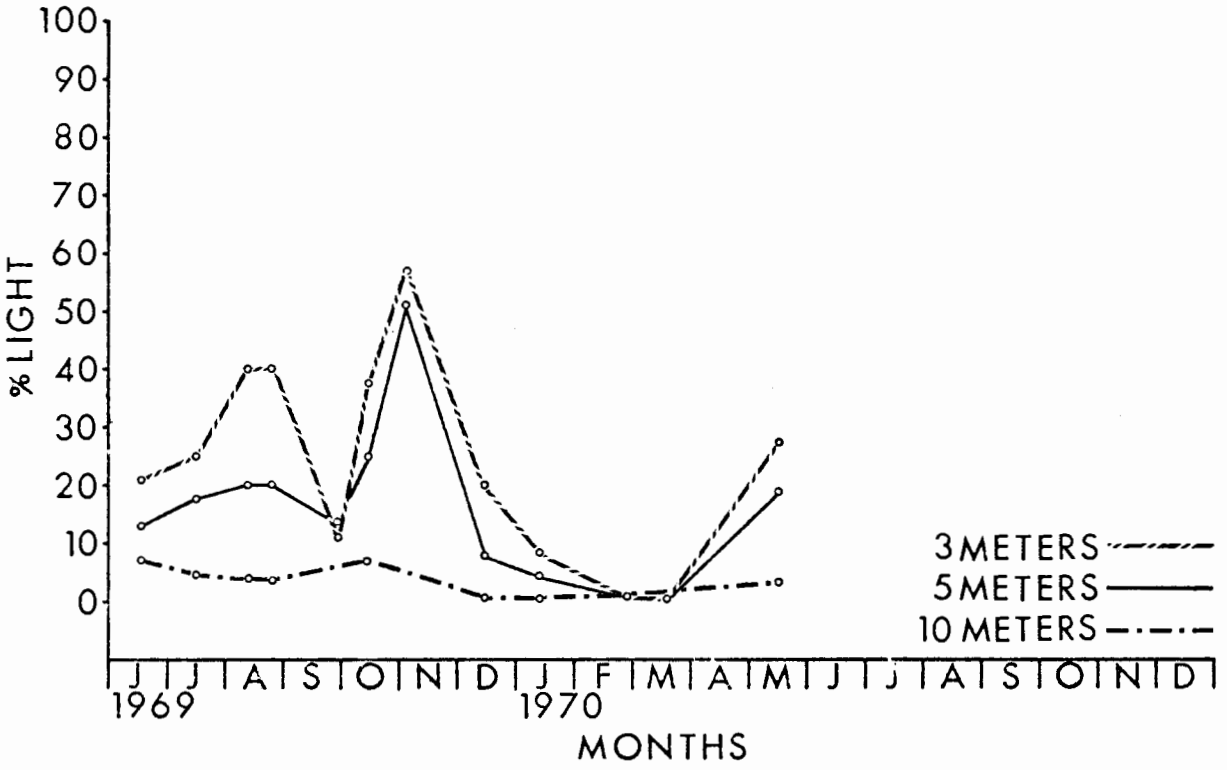


Figure 22. Percentage of surface light throughout the water column at station 1.

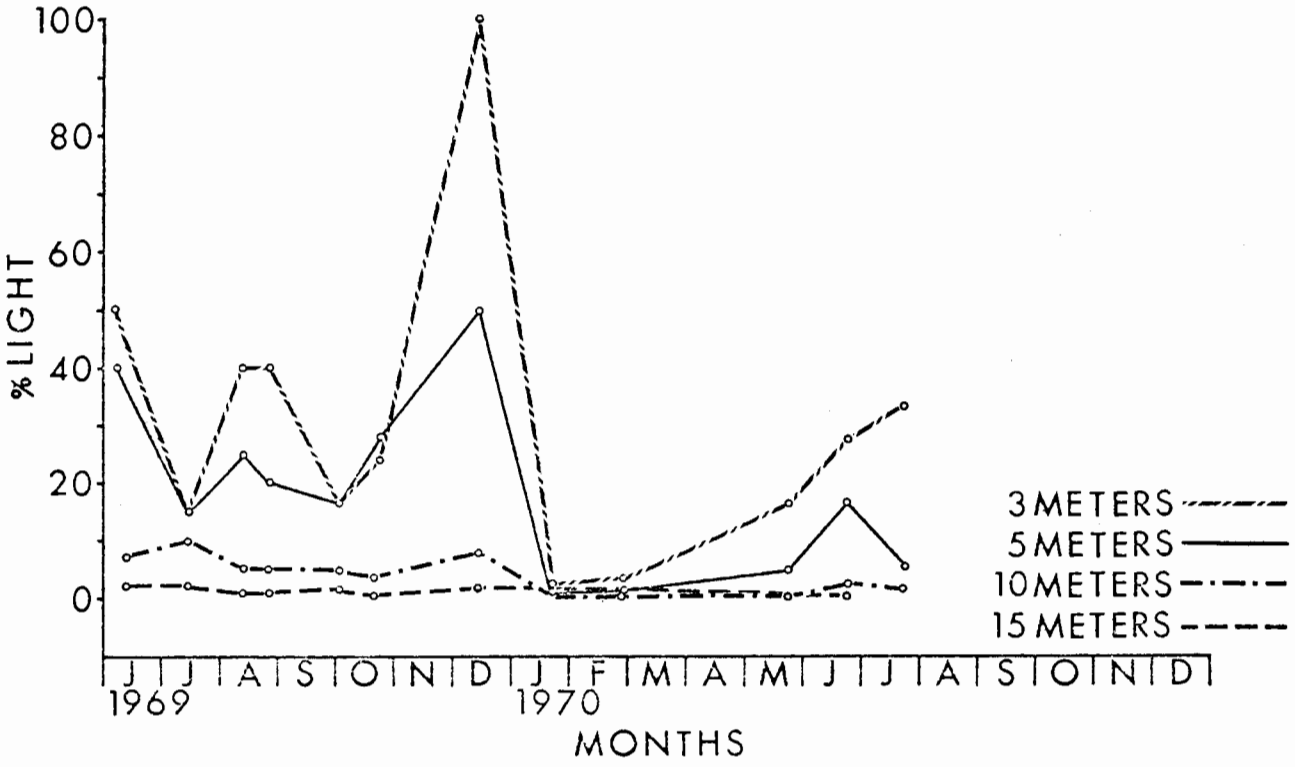


Figure 23. Percentage of surface light throughout the water column at station 2.

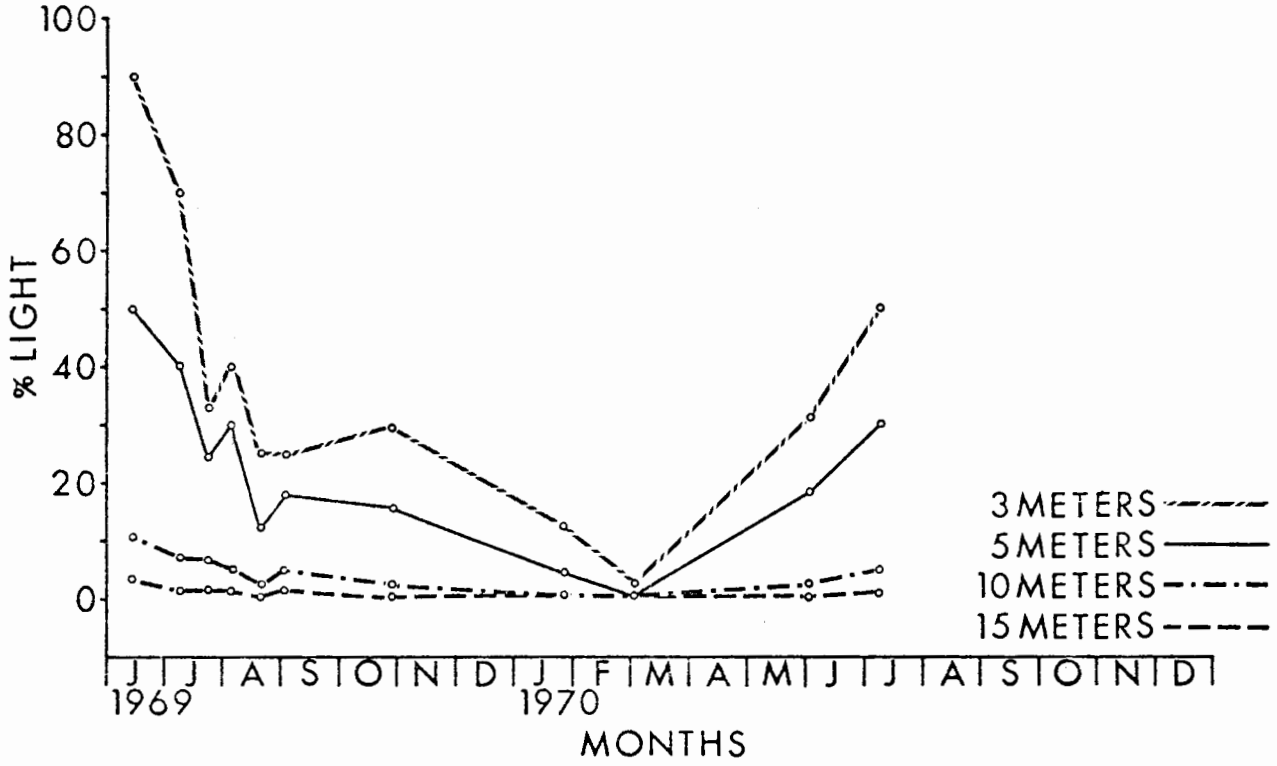


Figure 24. Percentage of surface light throughout the water column at station 3.

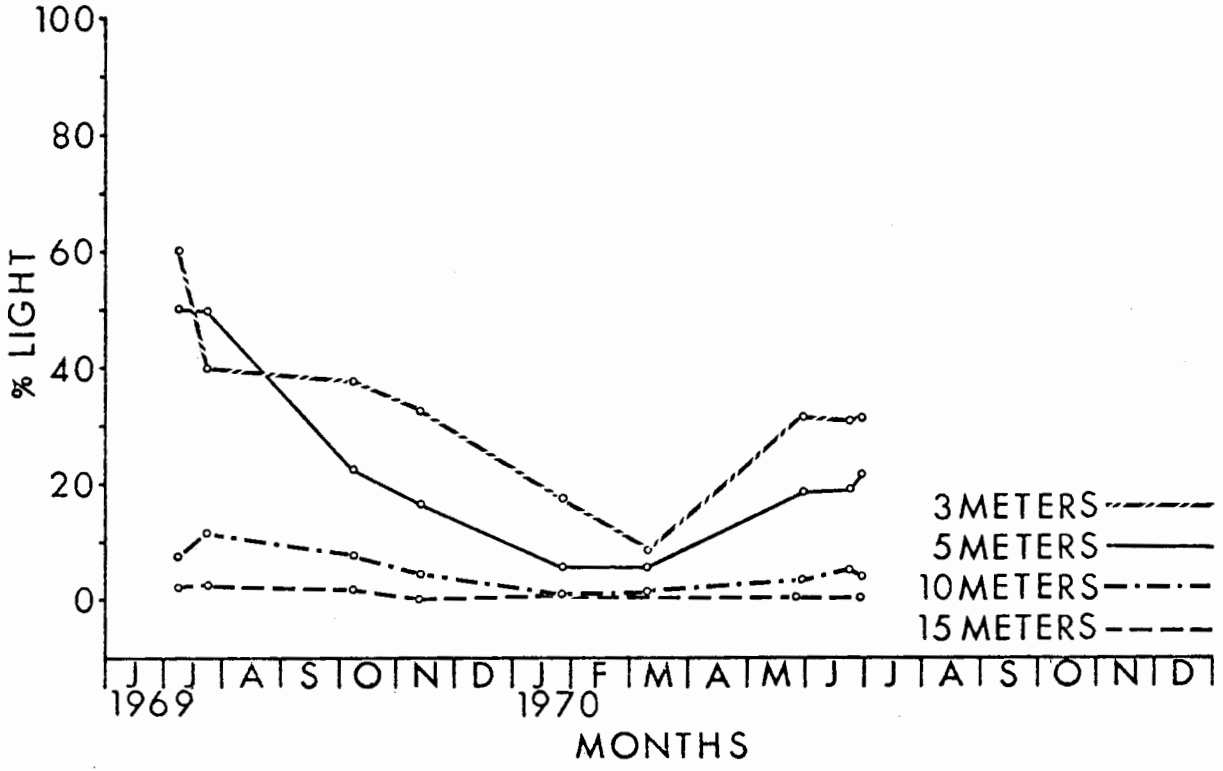


Figure 25. Percentage of surface light throughout the water column at station 4.

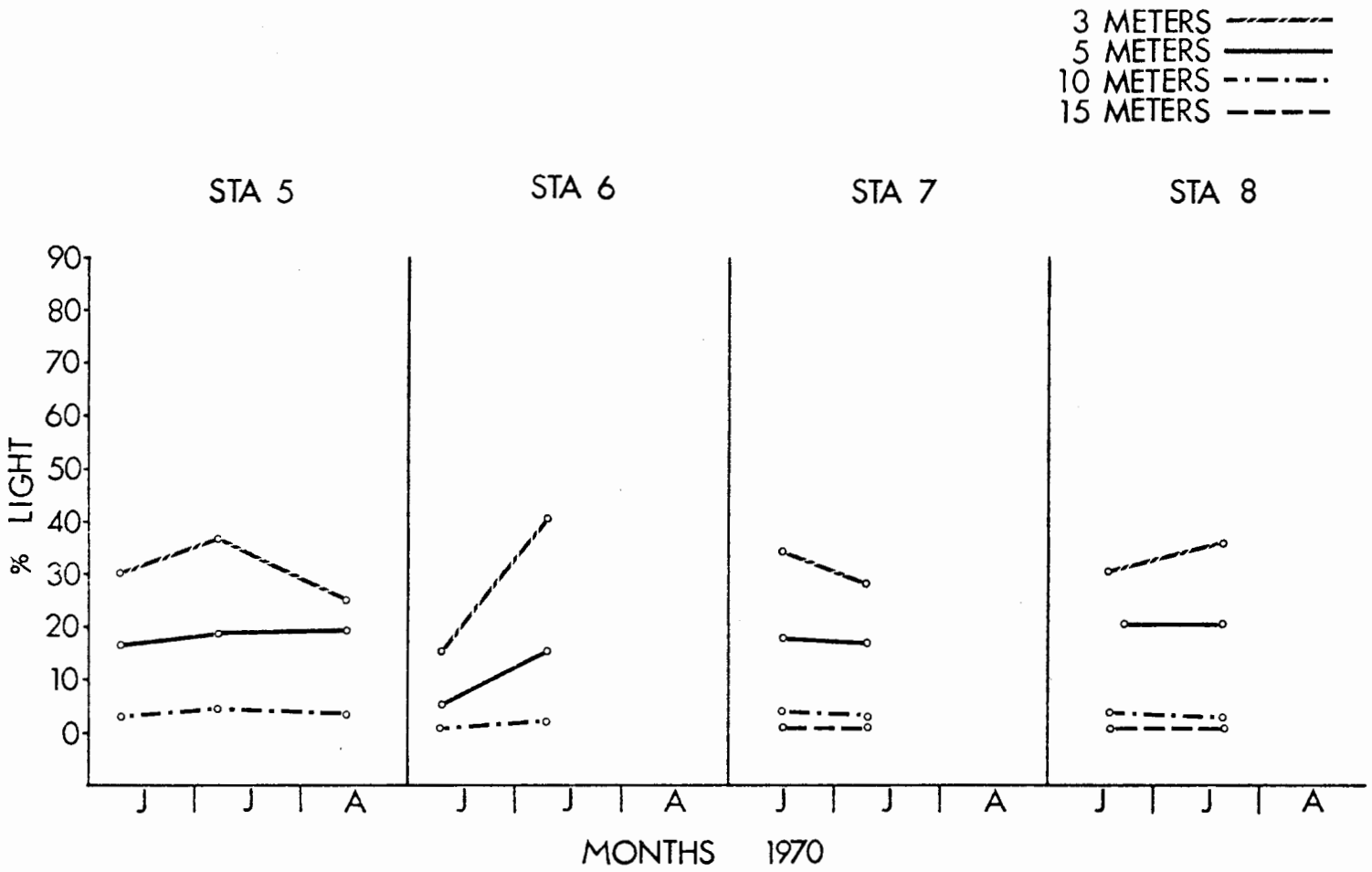


Figure 26. Percentage of surface light throughout the water column at stations 5-8.

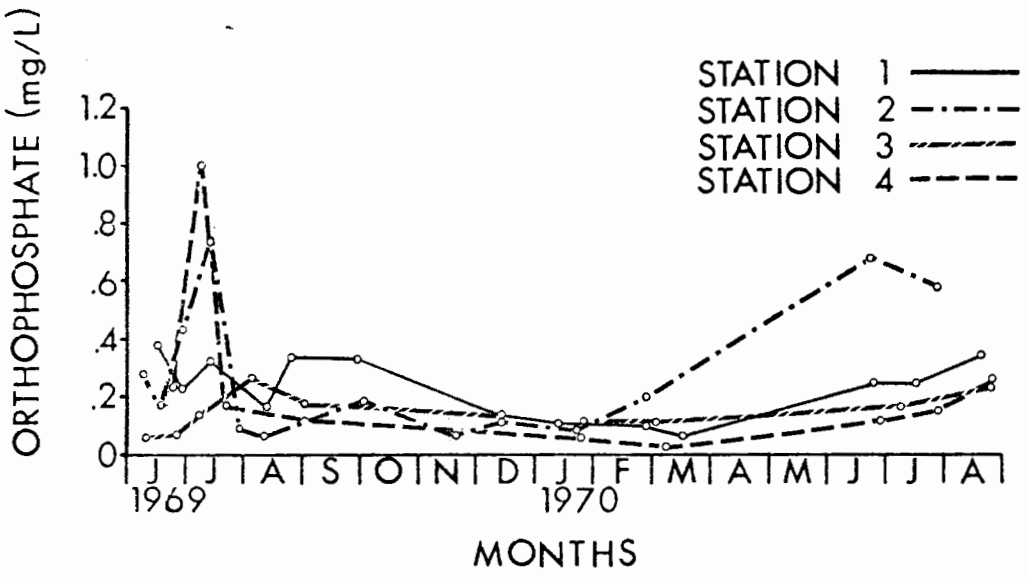


Figure 27. Seasonal variation of orthophosphate values at stations 1-4.

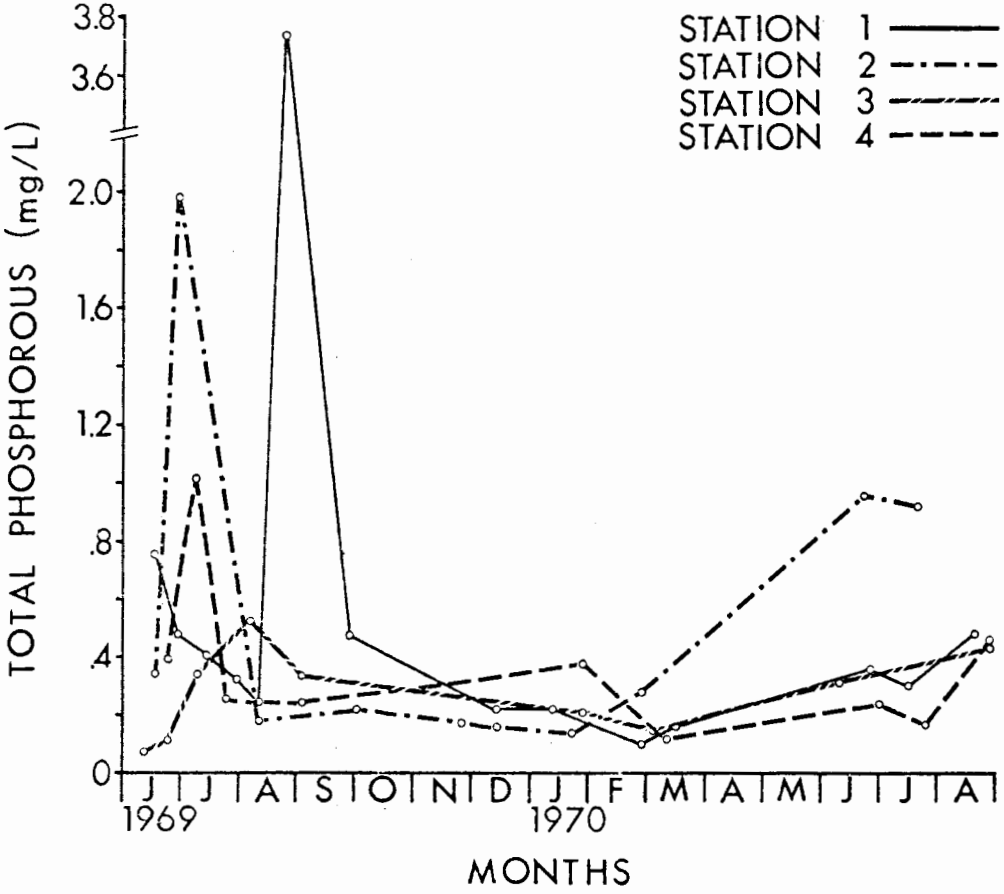


Figure 28. Seasonal variation of total phosphorous at stations 1-4.

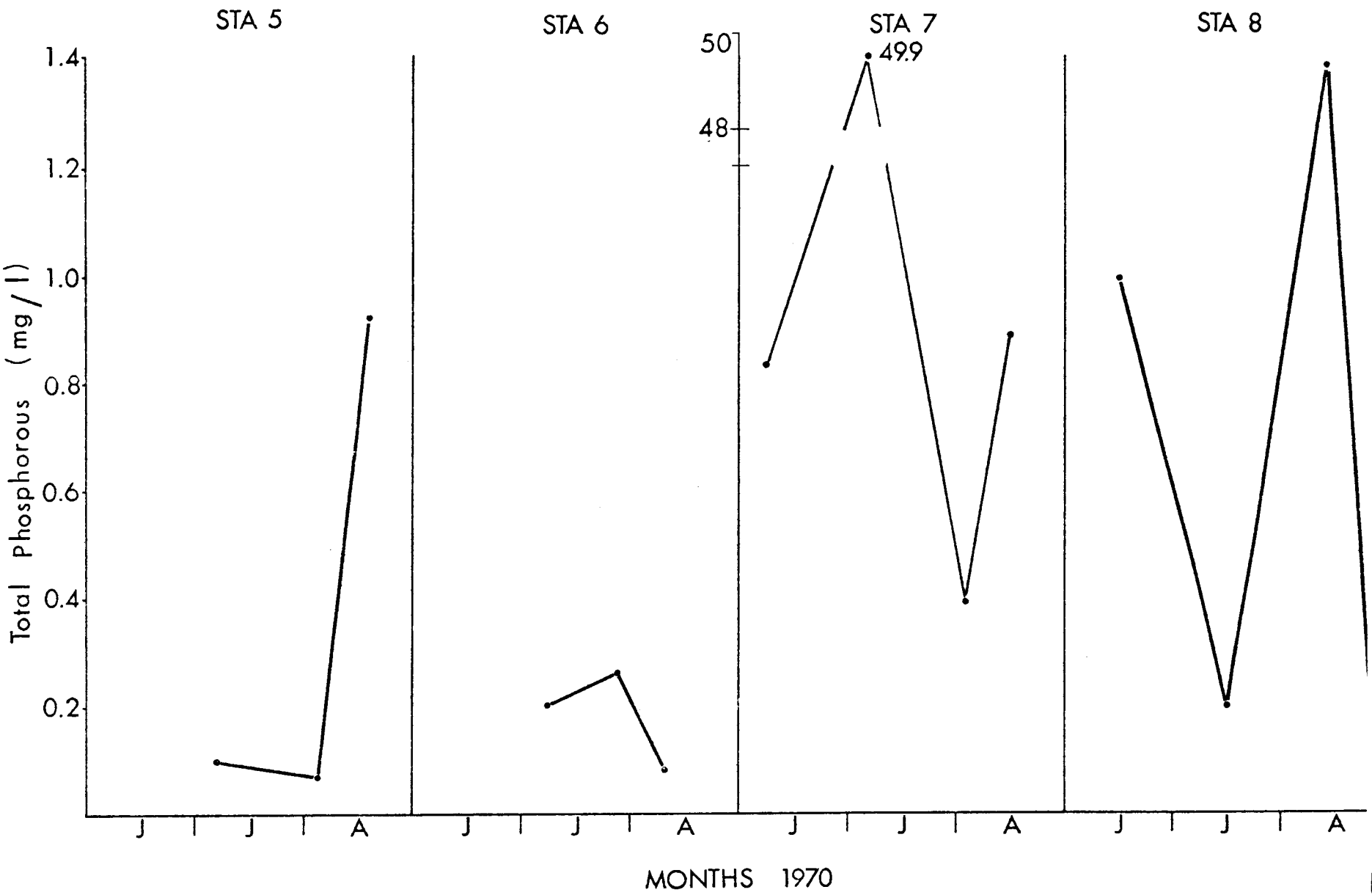


Figure 29. Total phosphorous values at stations 5-8.

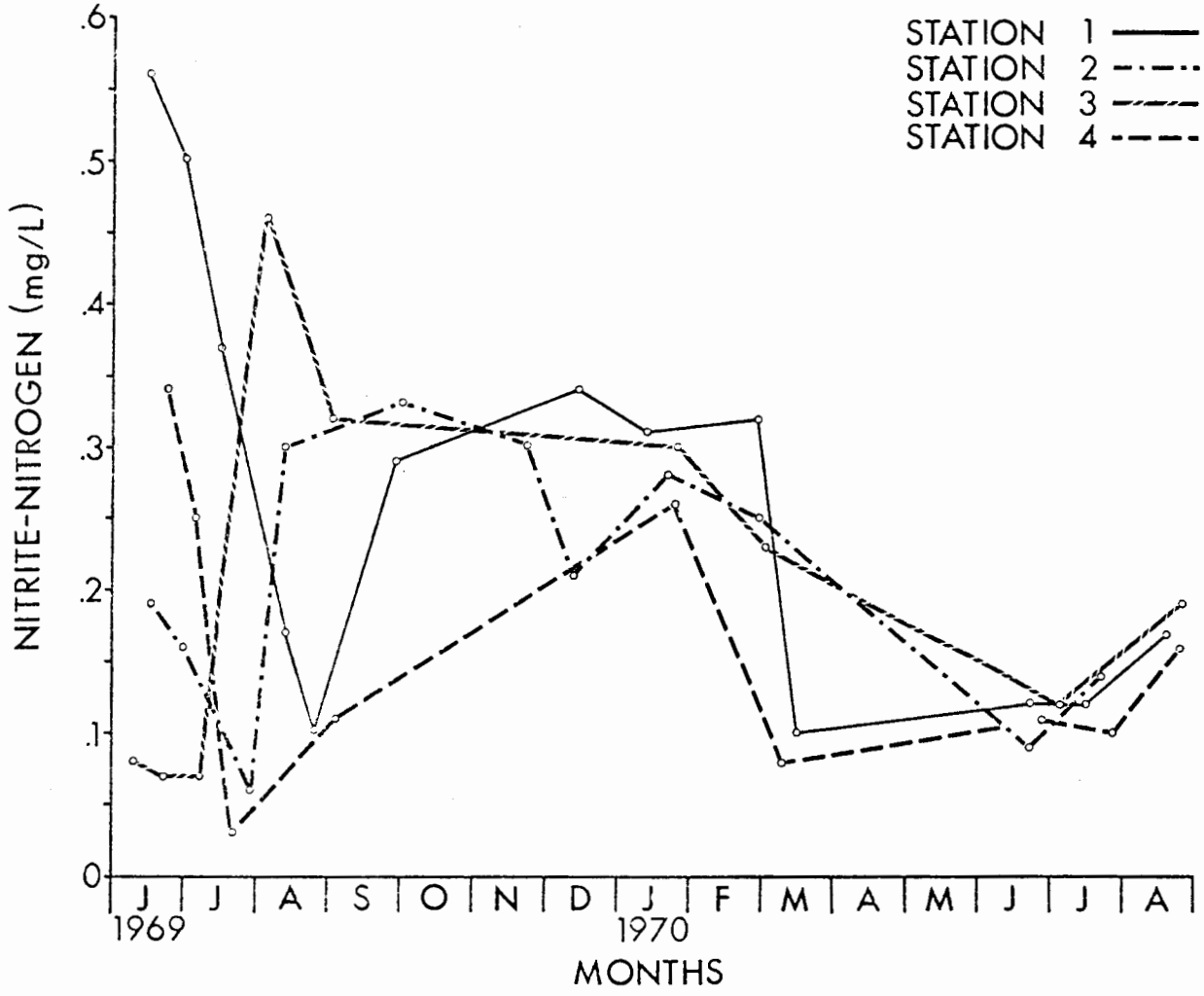


Figure 30. Seasonal variation of nitrite-nitrogen at stations 1-4.

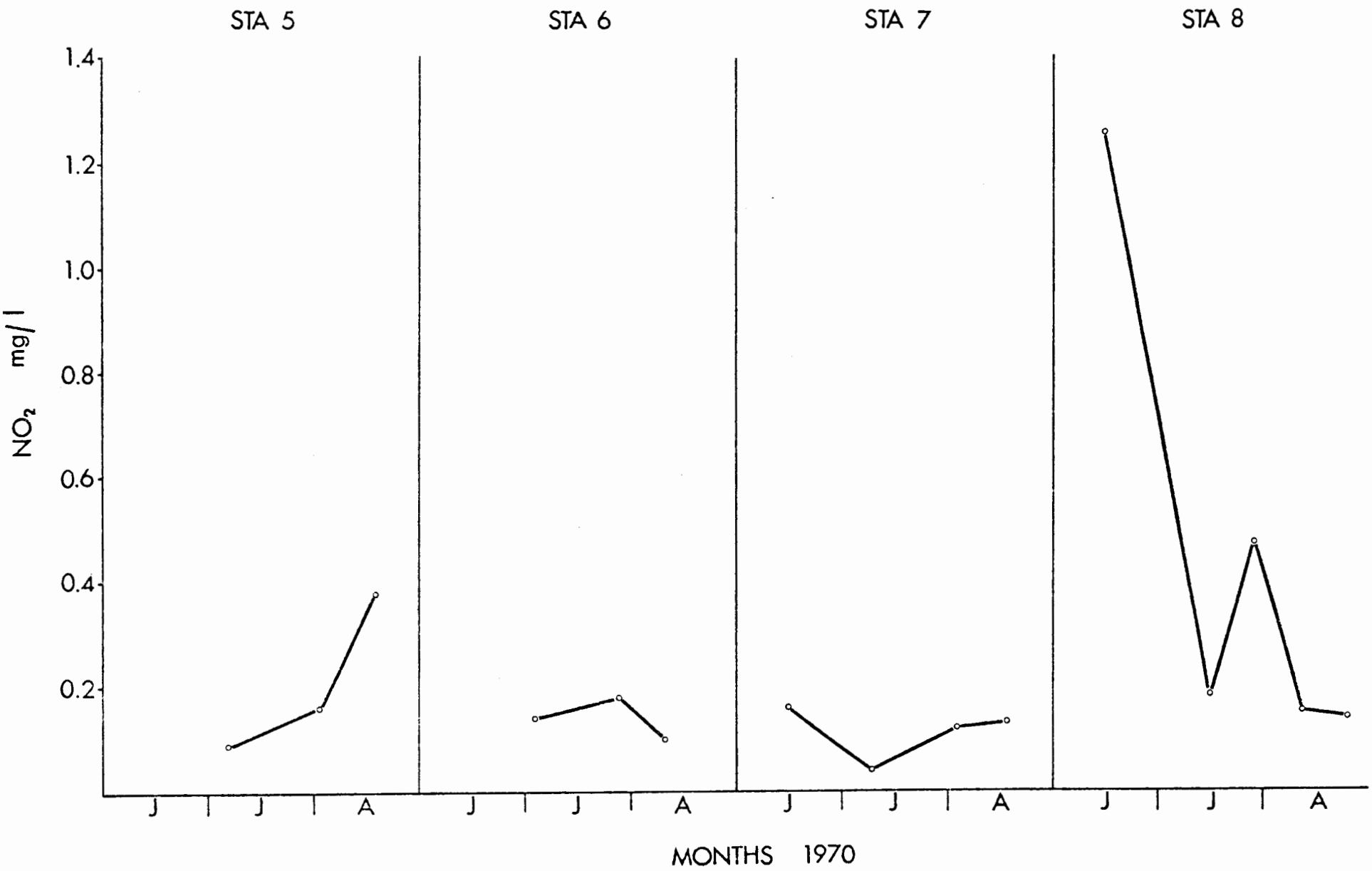


Figure 31. Nitrite-Nitrogen values at stations 5-8.

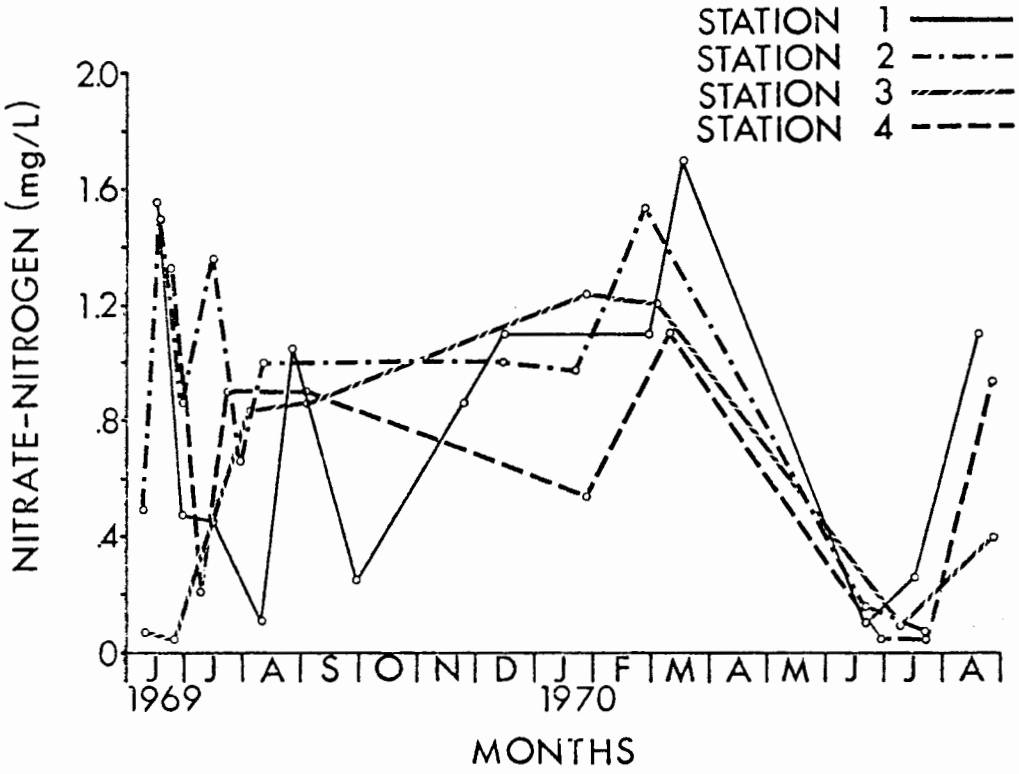
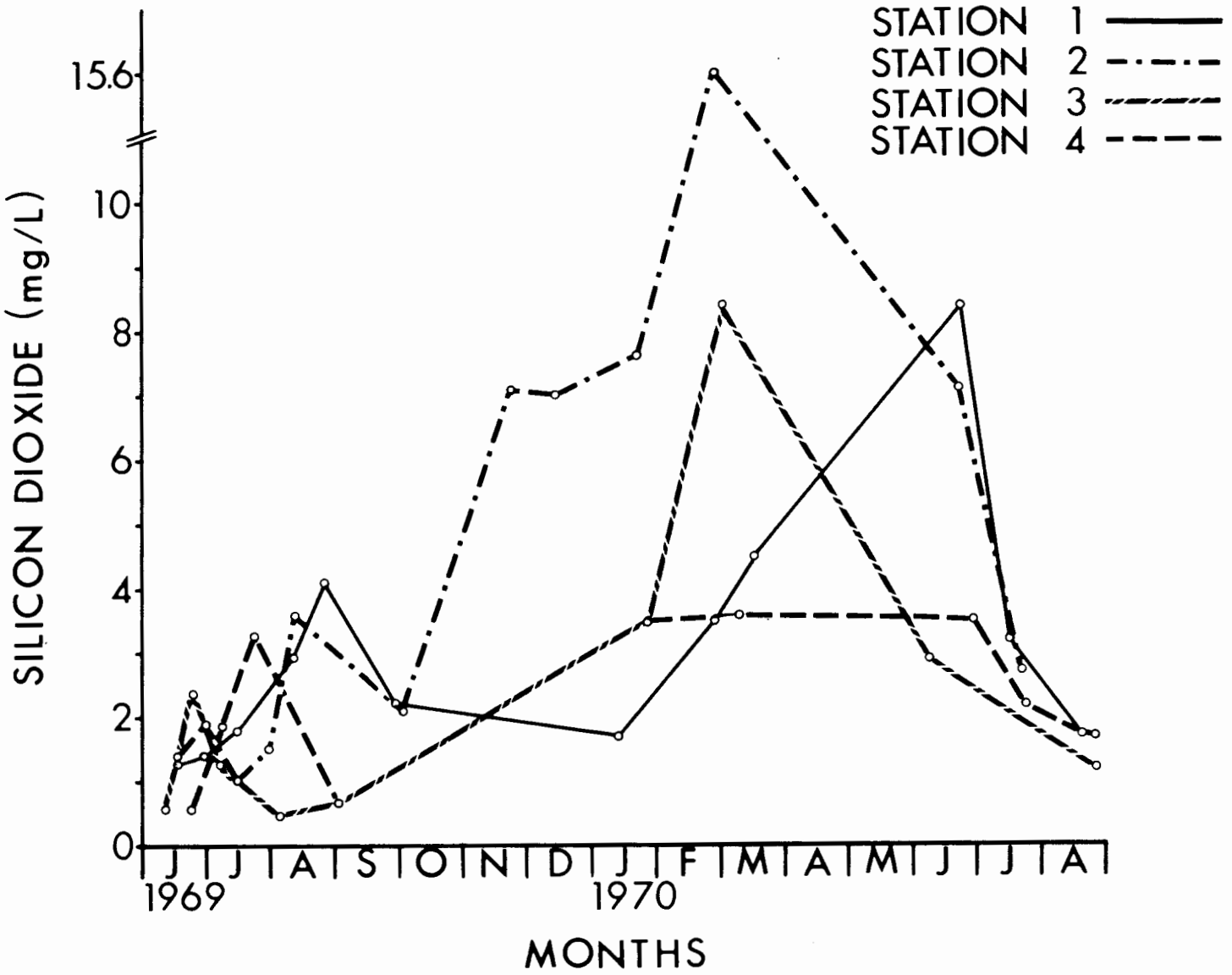


Figure 32. Seasonal variation of nitrite-nitrogen values at stations 1-4.


STATION 1
STATION 2
STATION 3
STATION 4
SILICON DIOXIDE (mg/L)
15.6
10
8
6
4
2
0
J J A S O N D J F M A M J J A
1969
1970
MONTHS

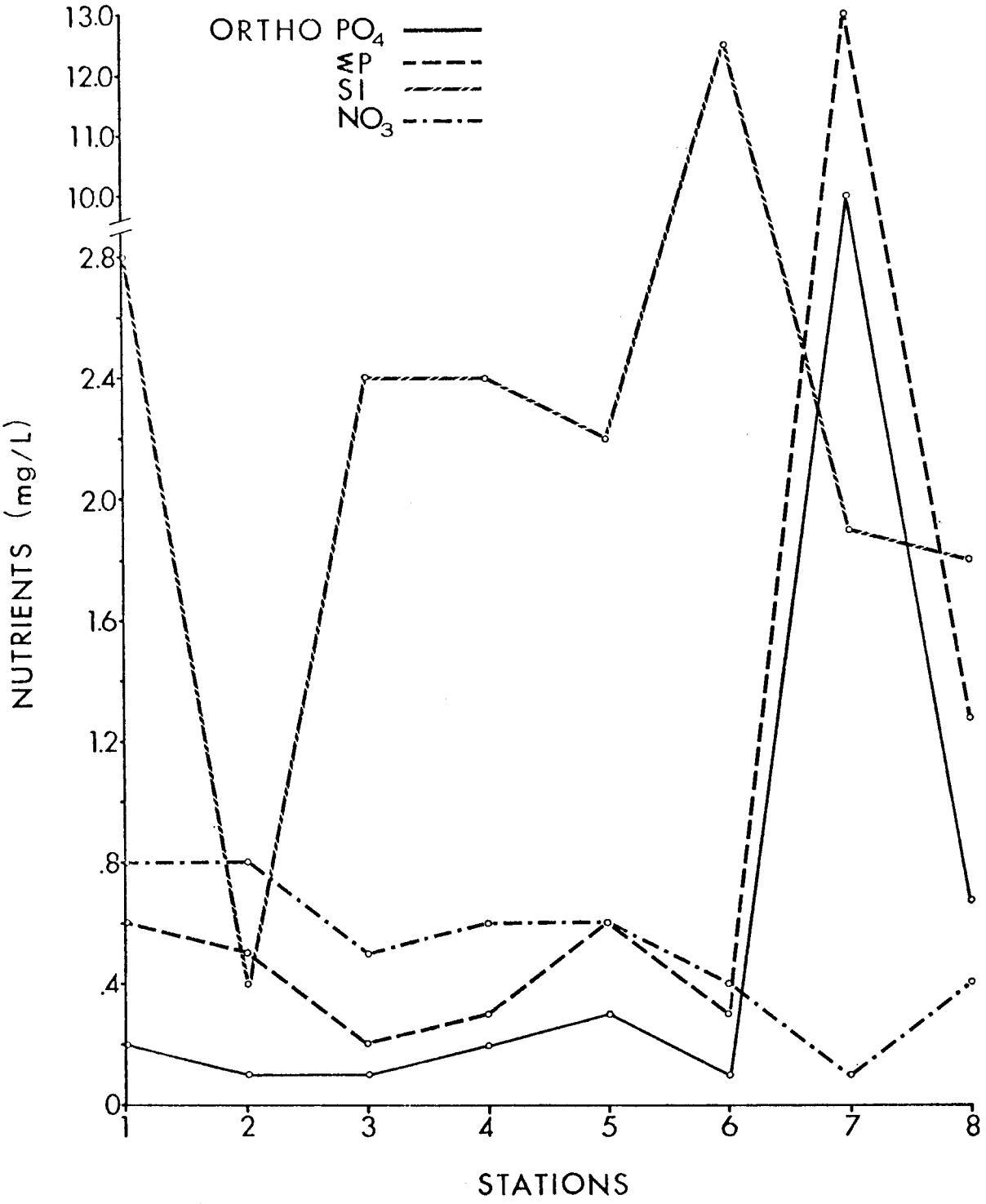


Figure 34. Mean values of nutrients at stations 1-8.

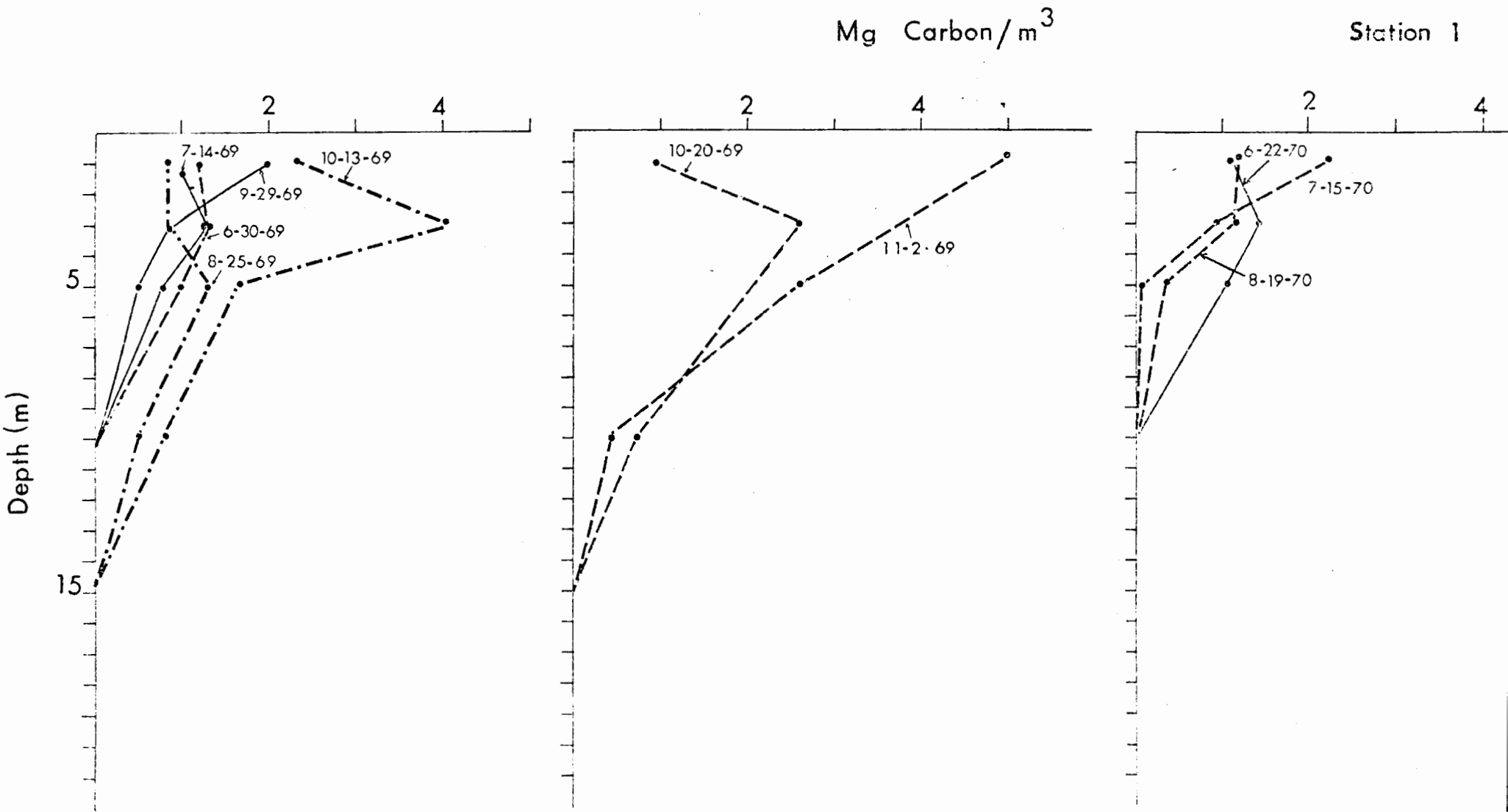
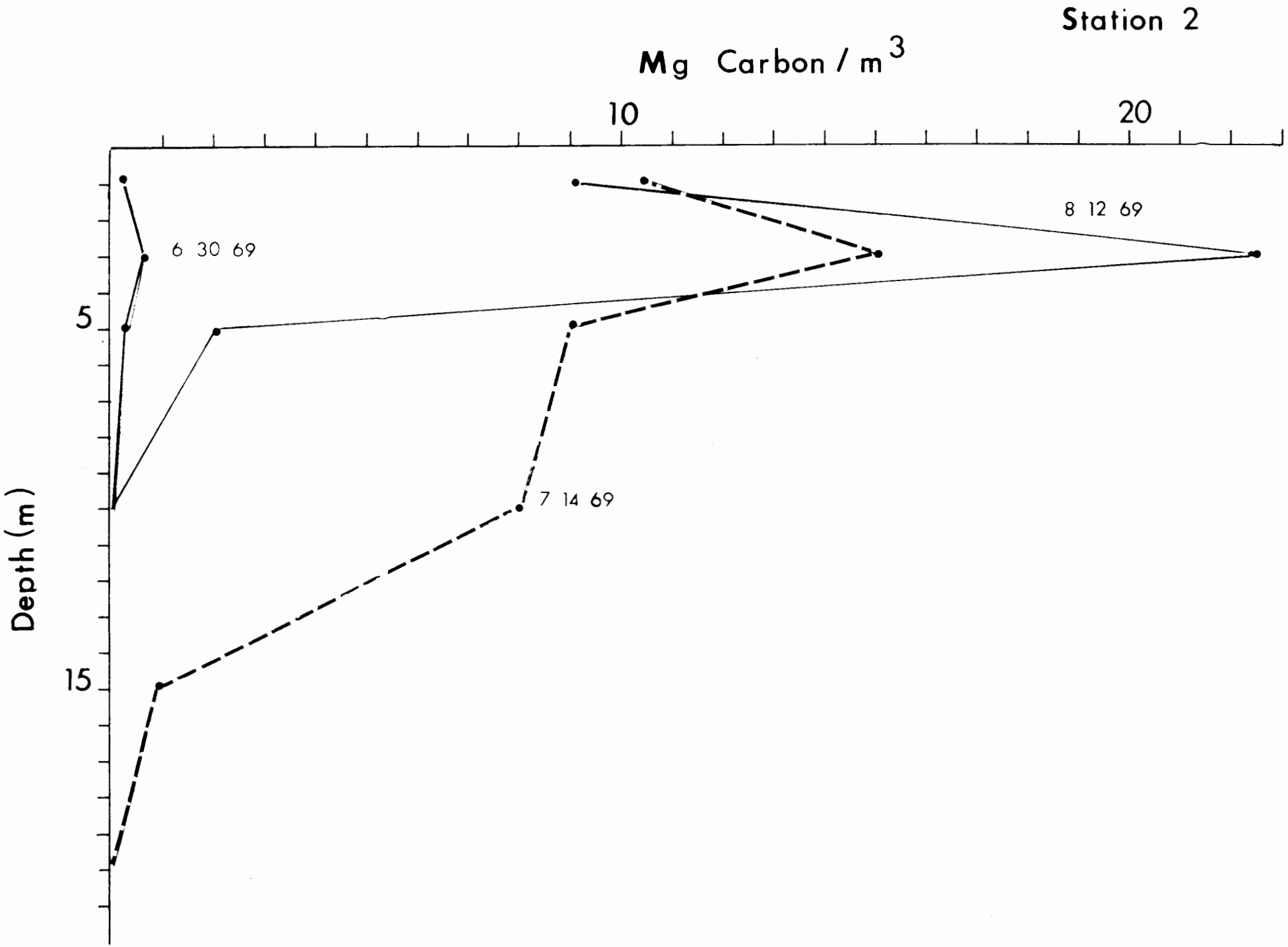


Figure 35. In situ primary productivity at station 1.


Station 2
Mg Carbon / m 3
10
20
8 12 69
6 30 69
7 14 69
5
15
Depth (m)

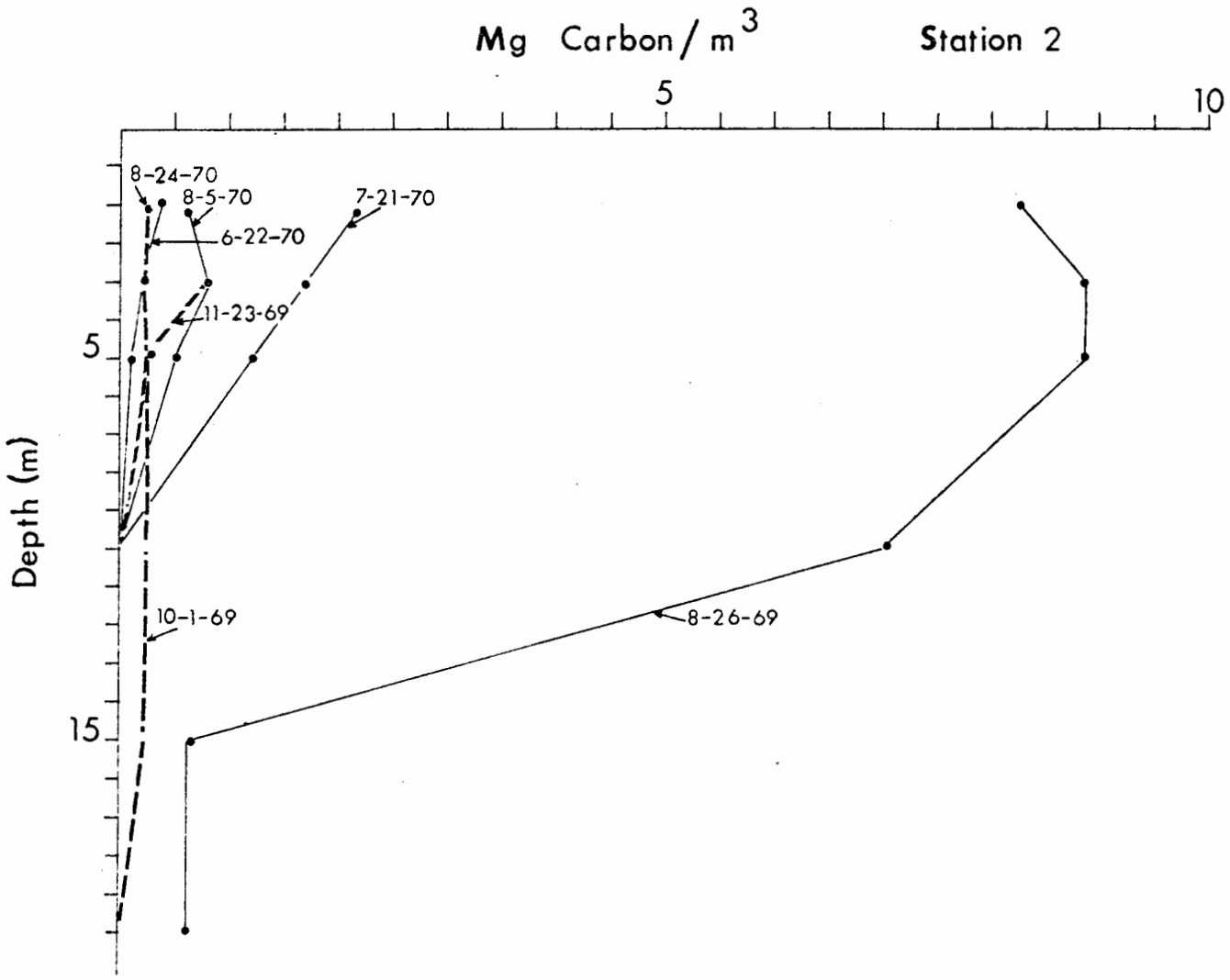


Figure 37. In situ primary productivity at station 2 - 1970

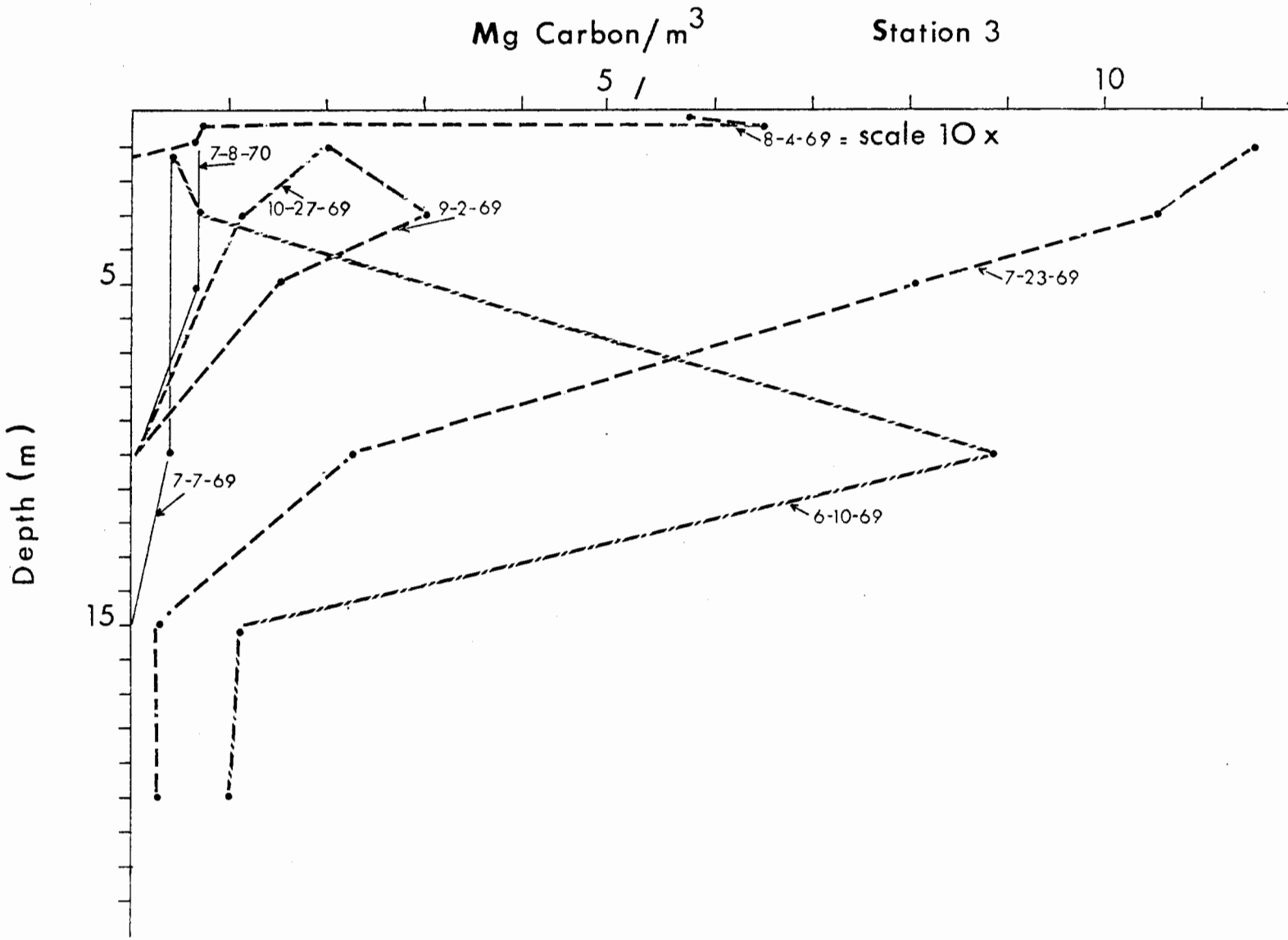


Figure 38. In situ primary productivity at station 3.

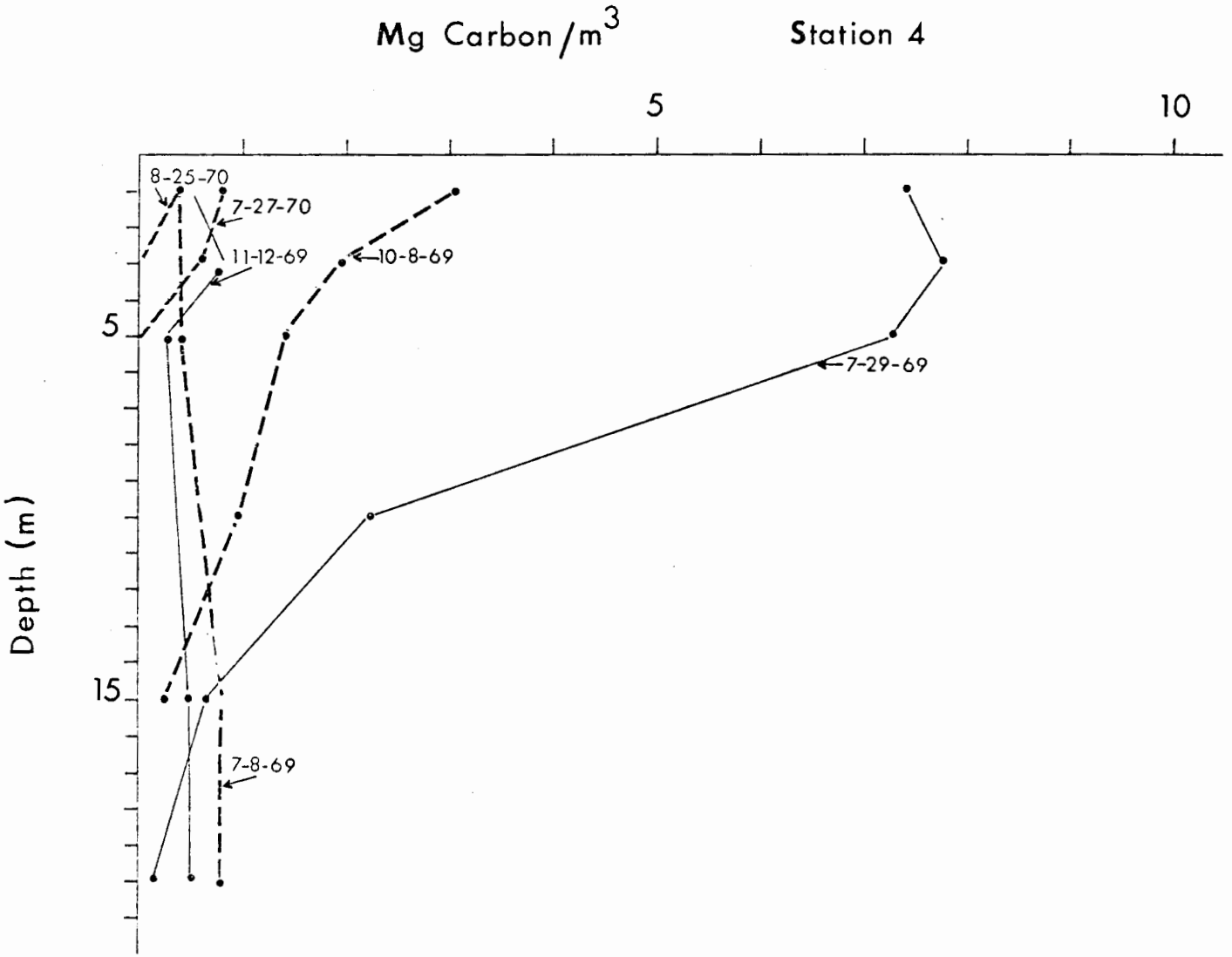
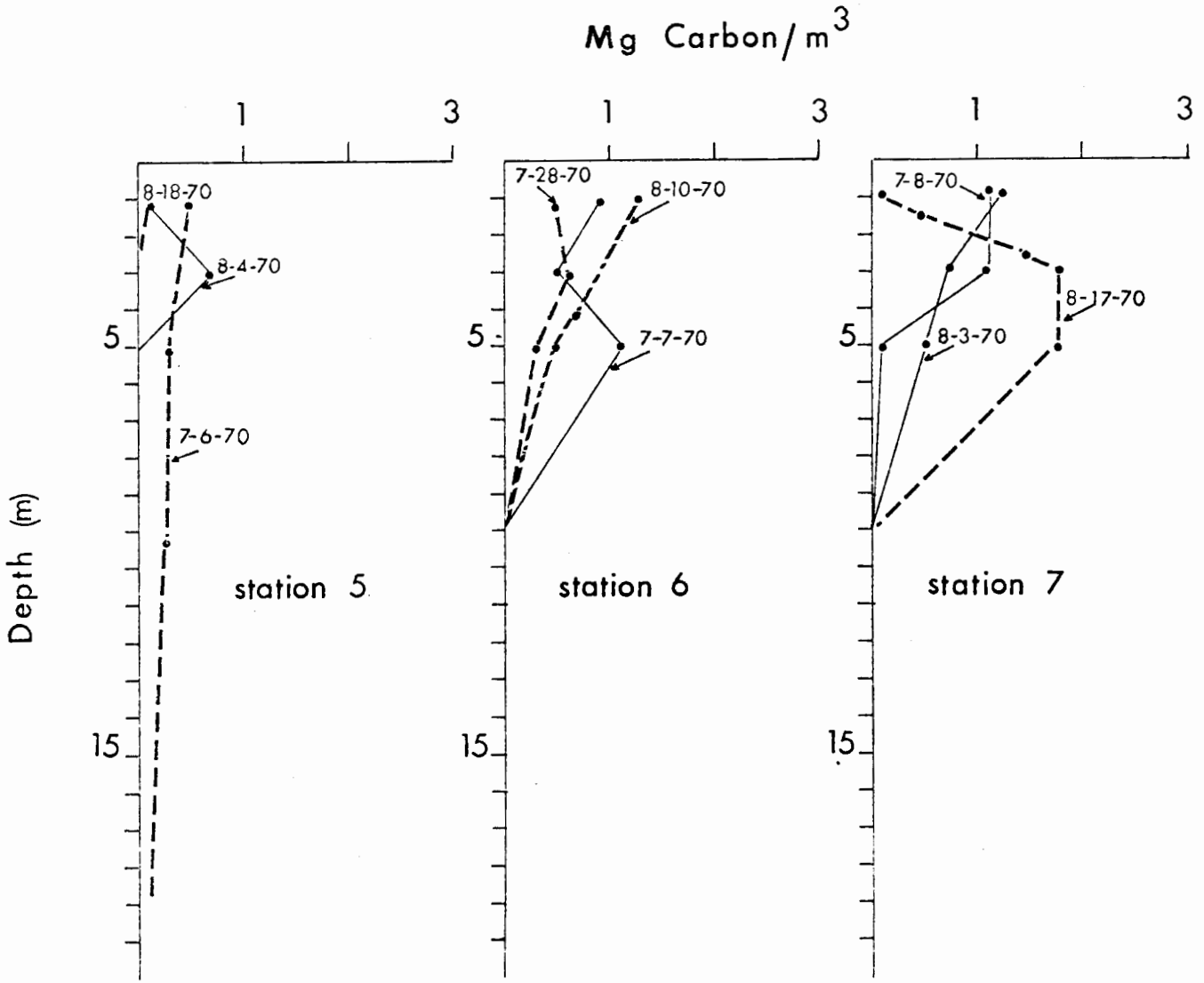


Figure 39. In situ primary productivity at station 4.



Figures 40-42. In situ primary productivity at stations 5, 6 and 7.

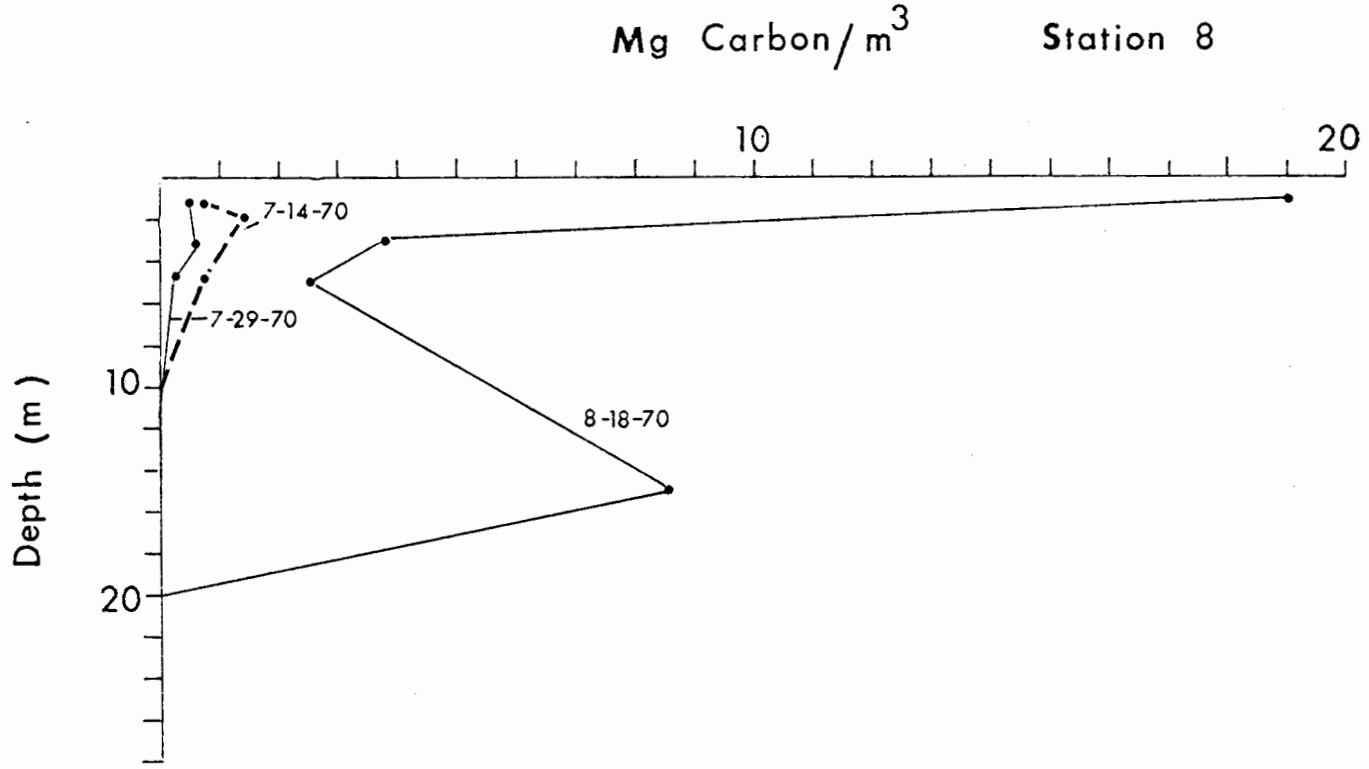


Figure 43. In situ primary productivity at station 8.

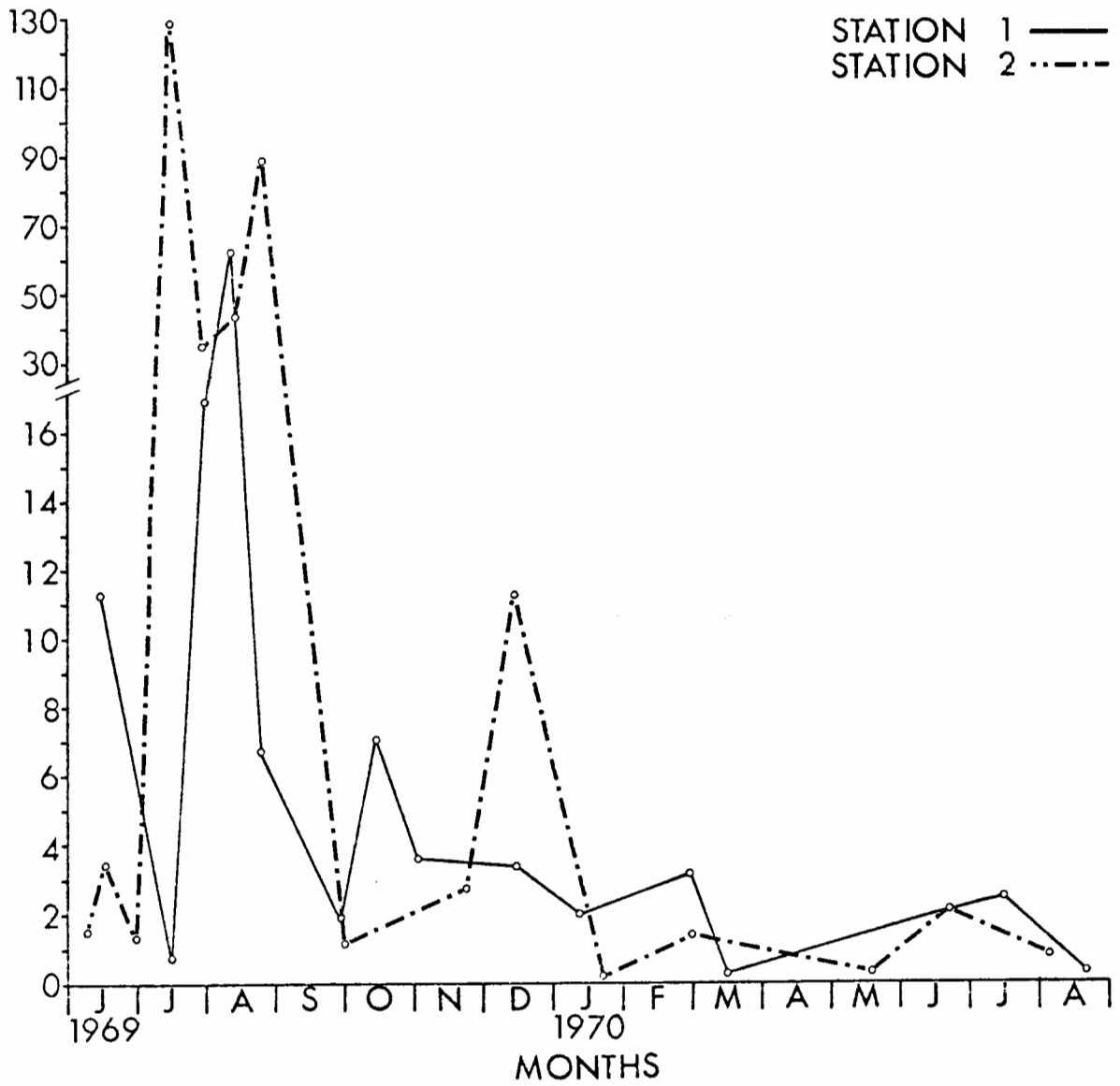


Figure 22. Primary productivity of unenriched laboratory cultures from stations 1 and 2.

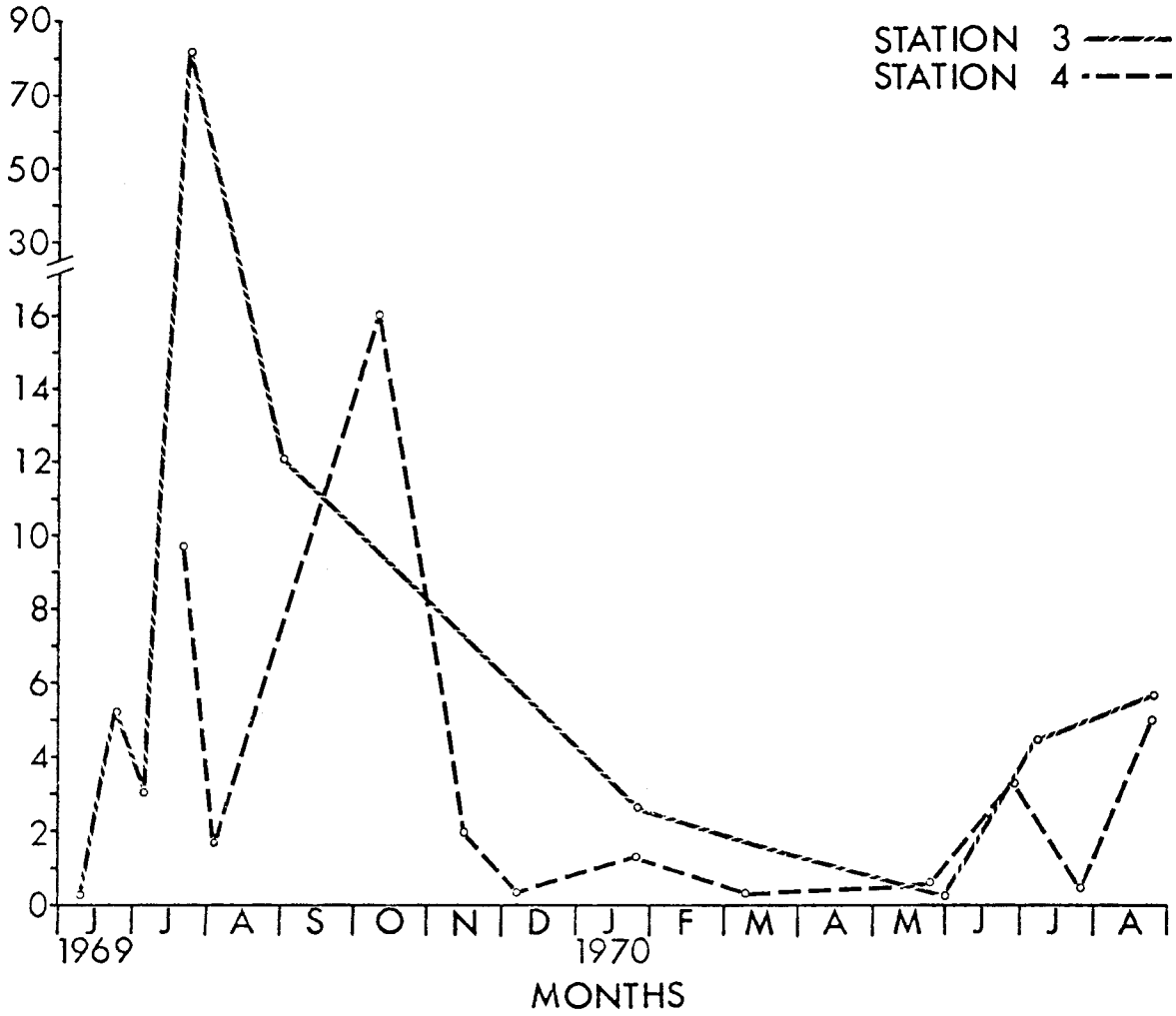


Figure 45. Primary productivity of unenriched laboratory cultures from stations 3 and 4.

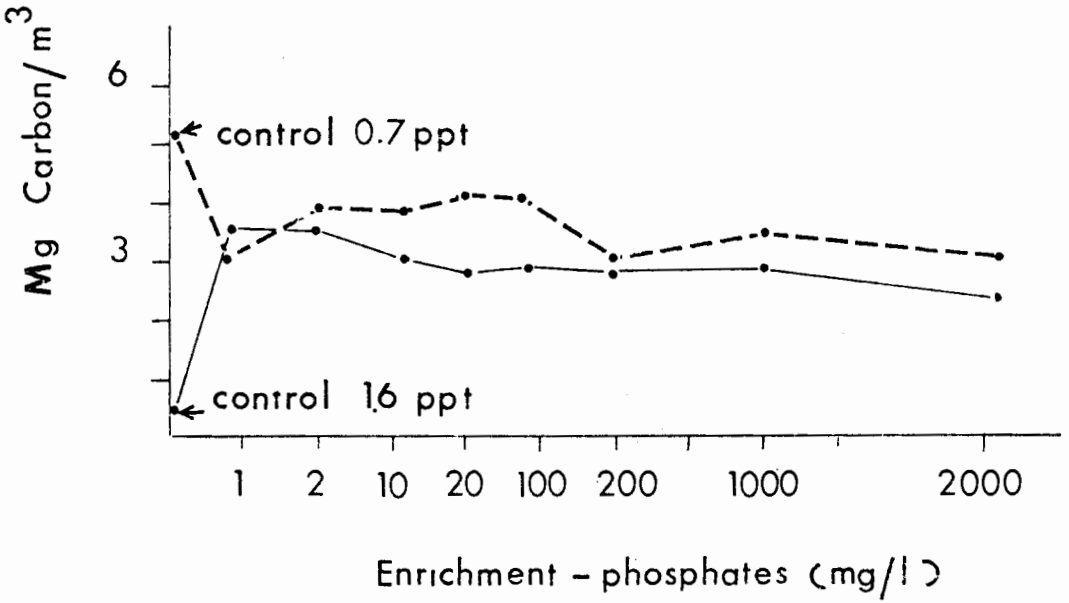


Figure 46. Typical carbon-14 nutrient enrichment experiments - orthophosphates.

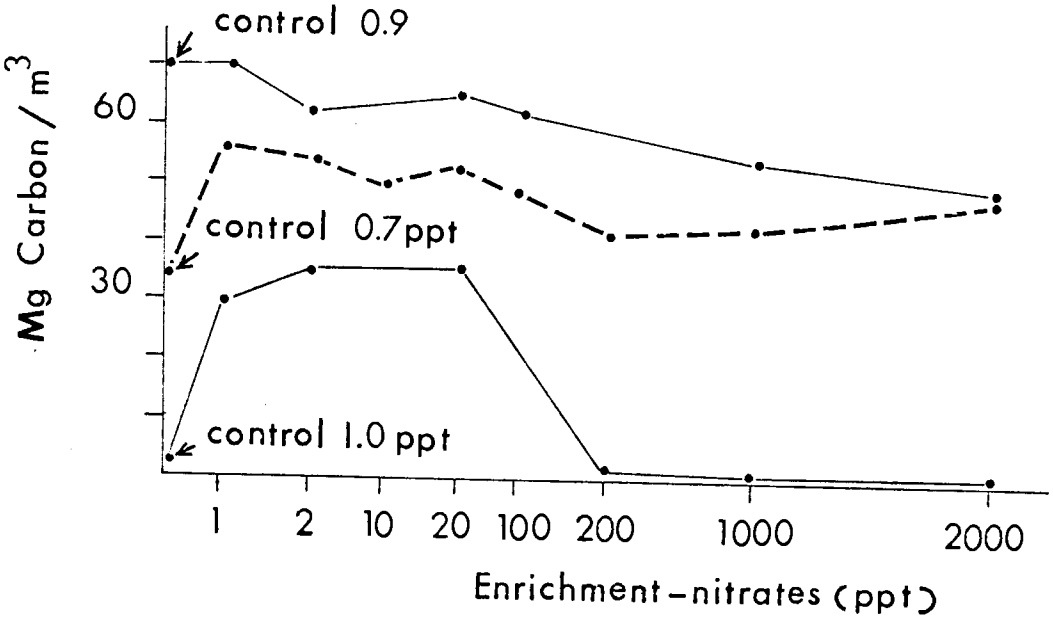


Figure 47. Typical carbon-14 nutrient enrichment experiments - nitrates.

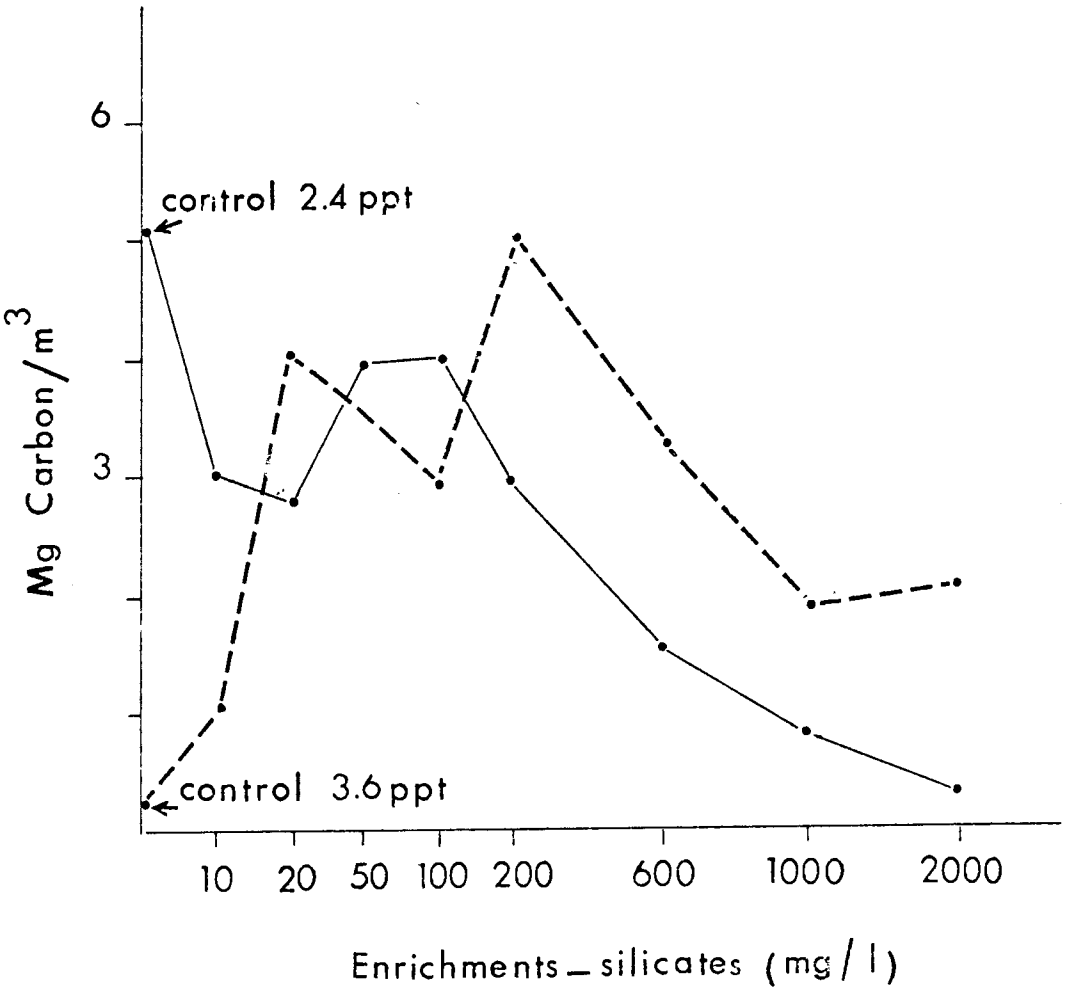


Figure 48. Typical carbon-14 nutrient enrichment experiments - silicates.

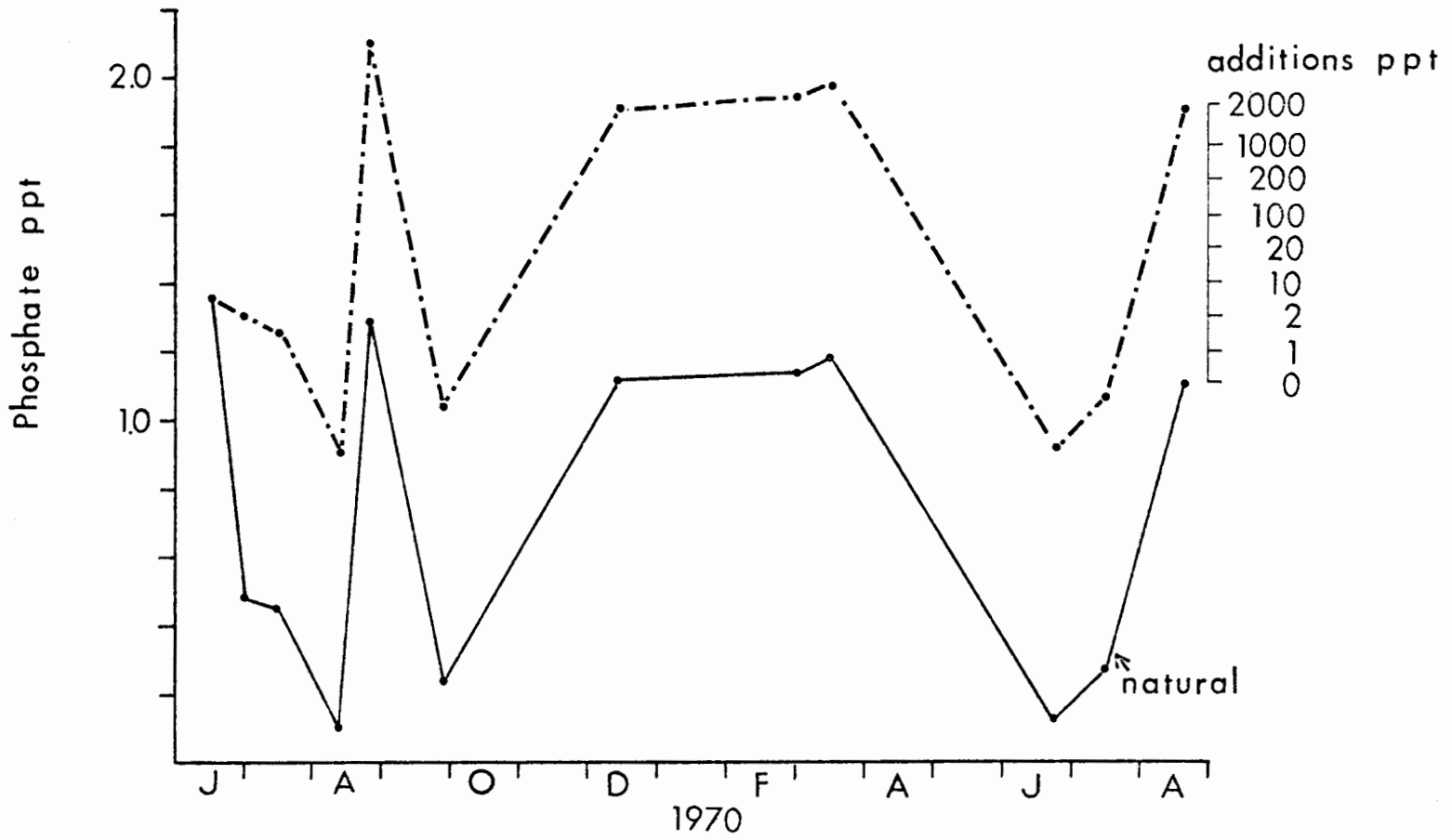


Figure 49. Summary of nitrate enrichment experiments for station 1.

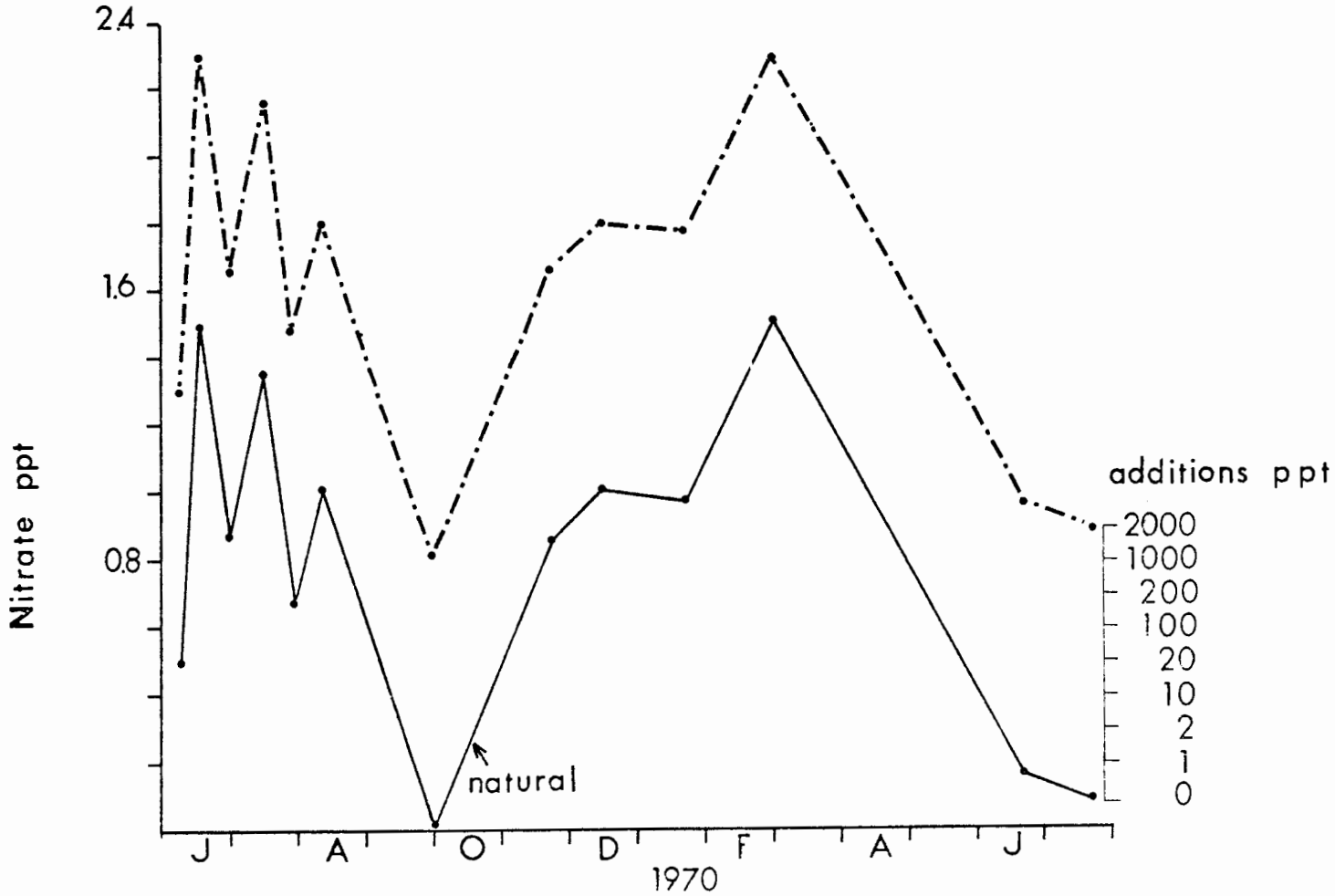


Figure 50. Summary of nitrate enrichment experiments for station 2.

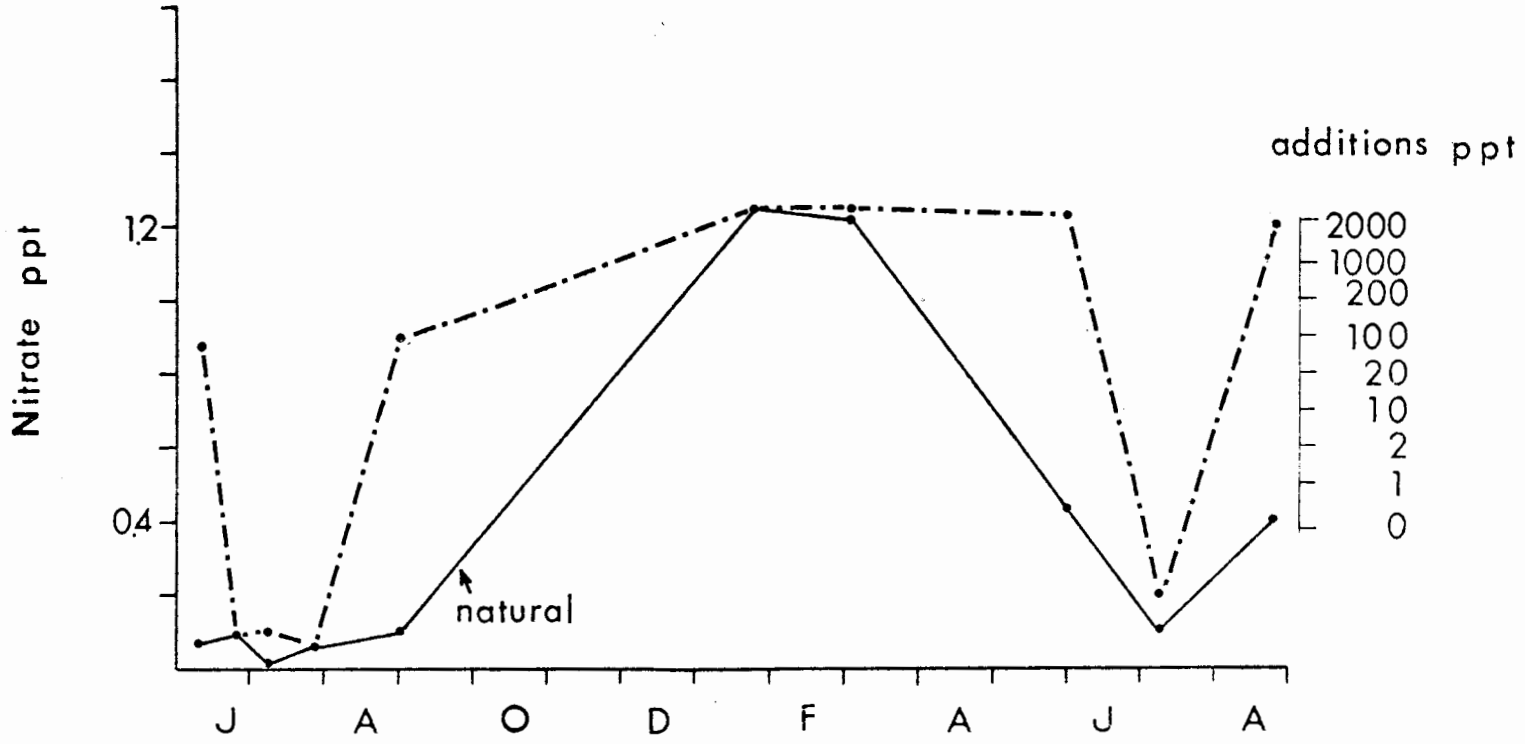


Figure 51. Summary of nitrate enrichment experiments for station 3.

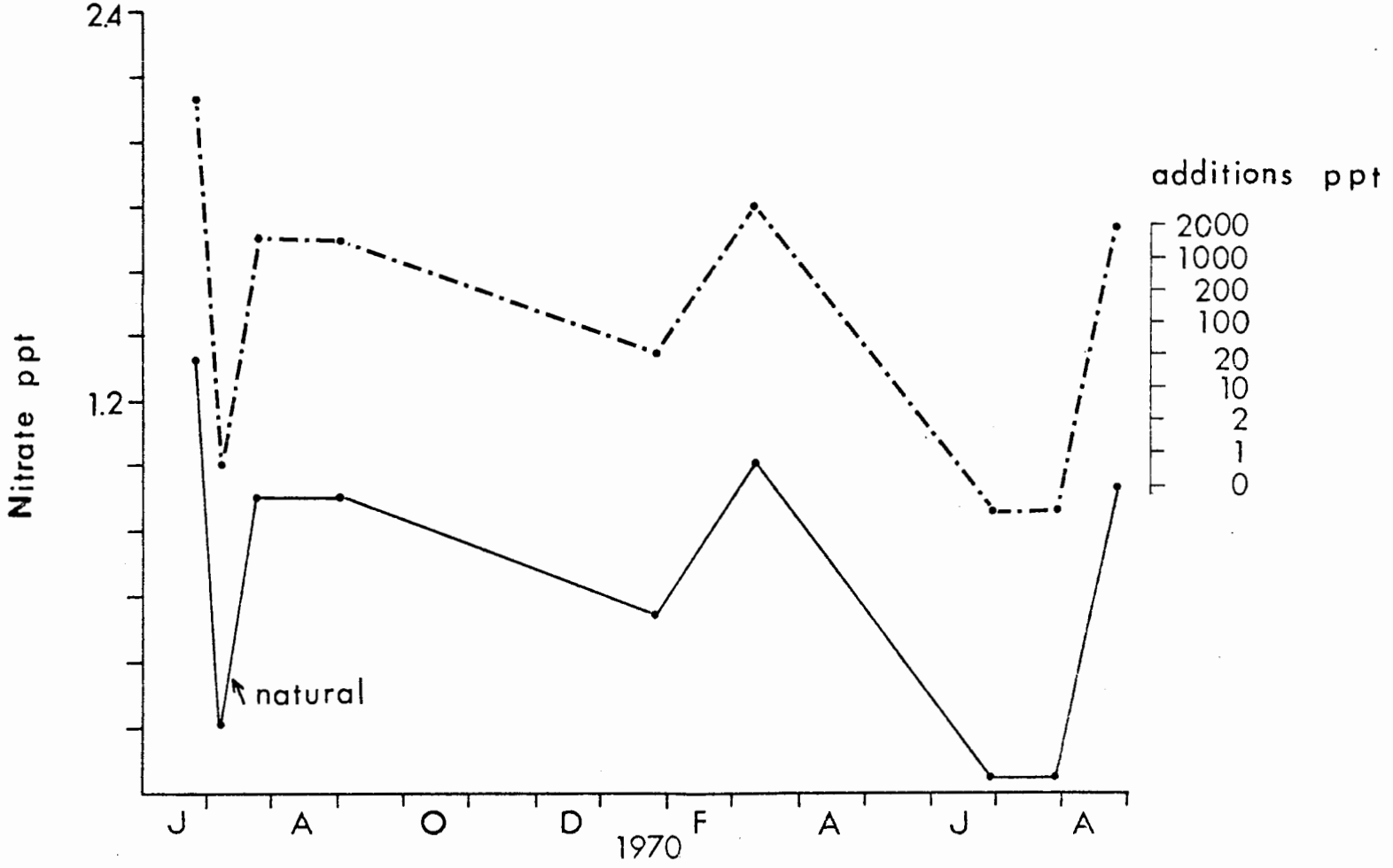


Figure 52. Summary of nitrate enrichment experiments for station 4.

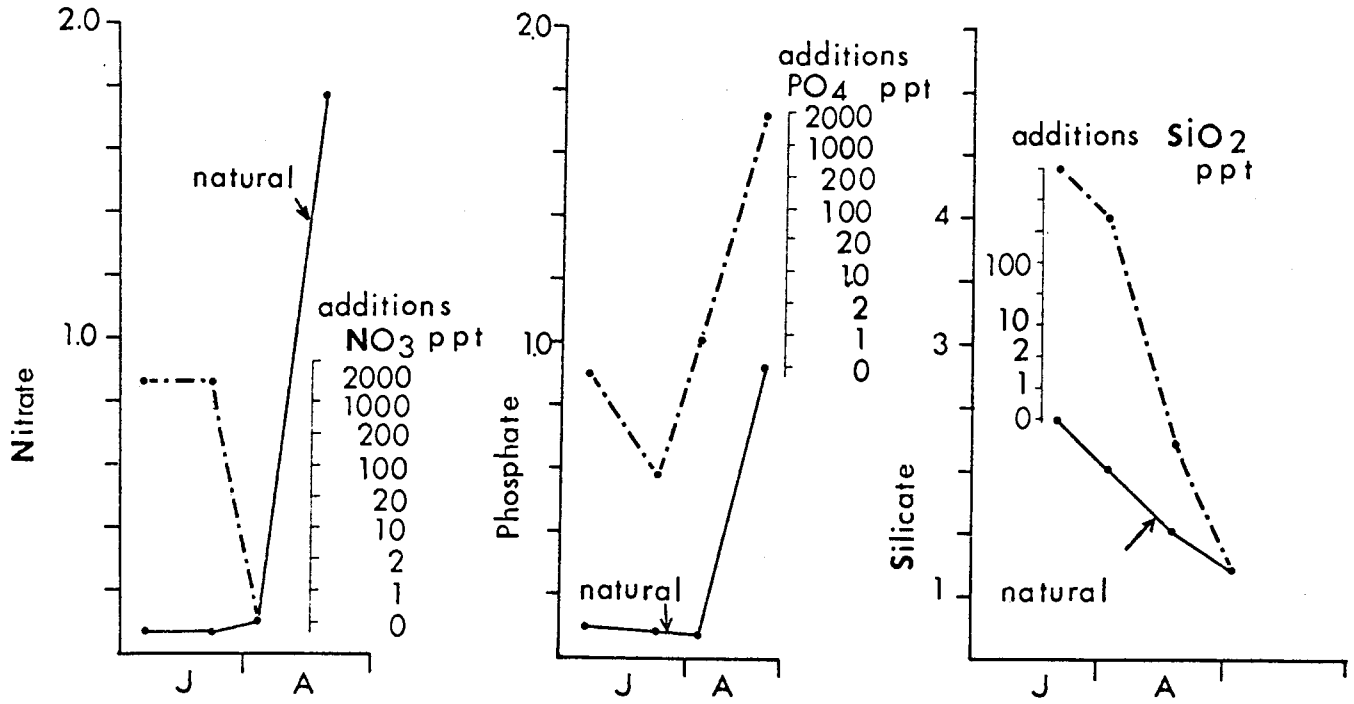


Figure 53. Summary of nitrate, phosphate and silicate enrichment experiments for station 5.

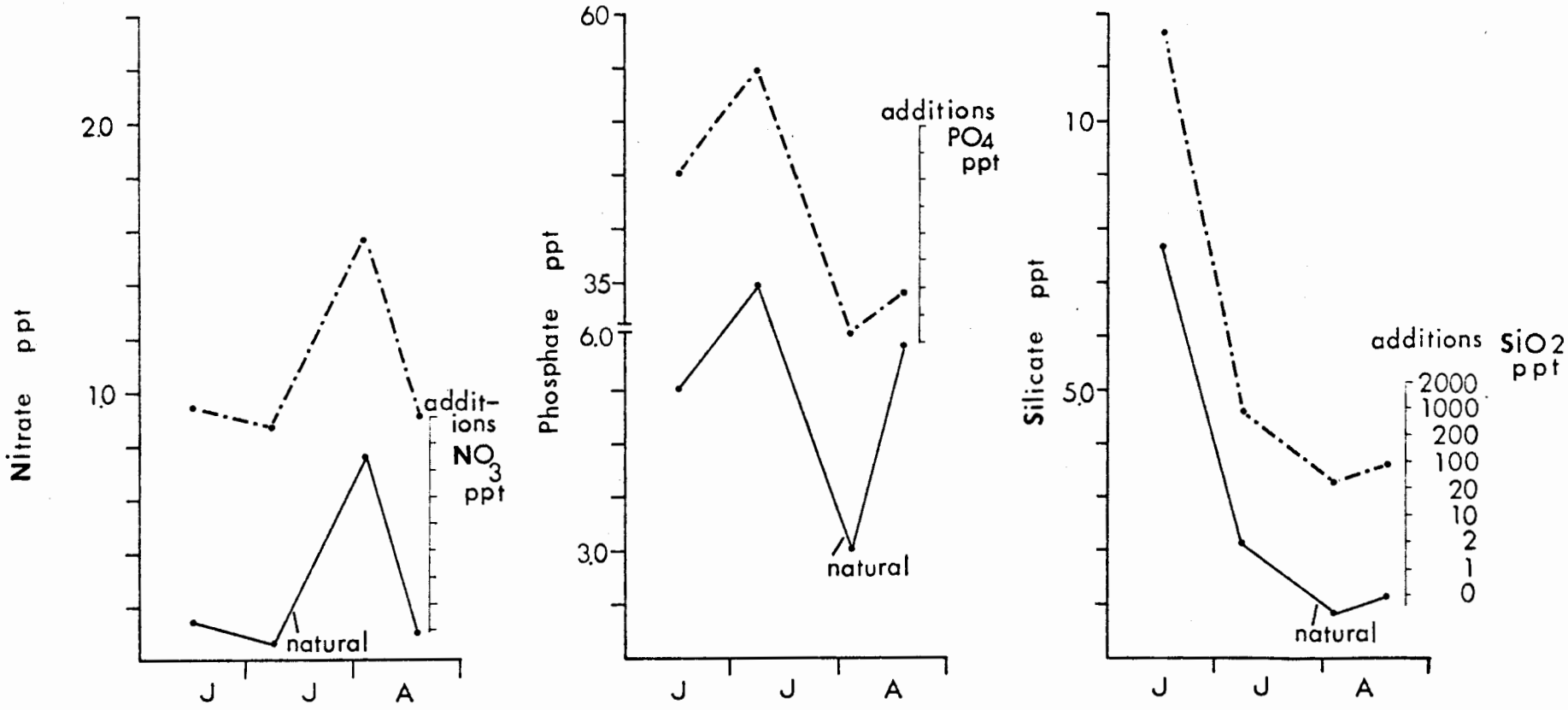


Figure 55. Summary of nitrate, phosphate and silicate enrichment experiments for station 7.

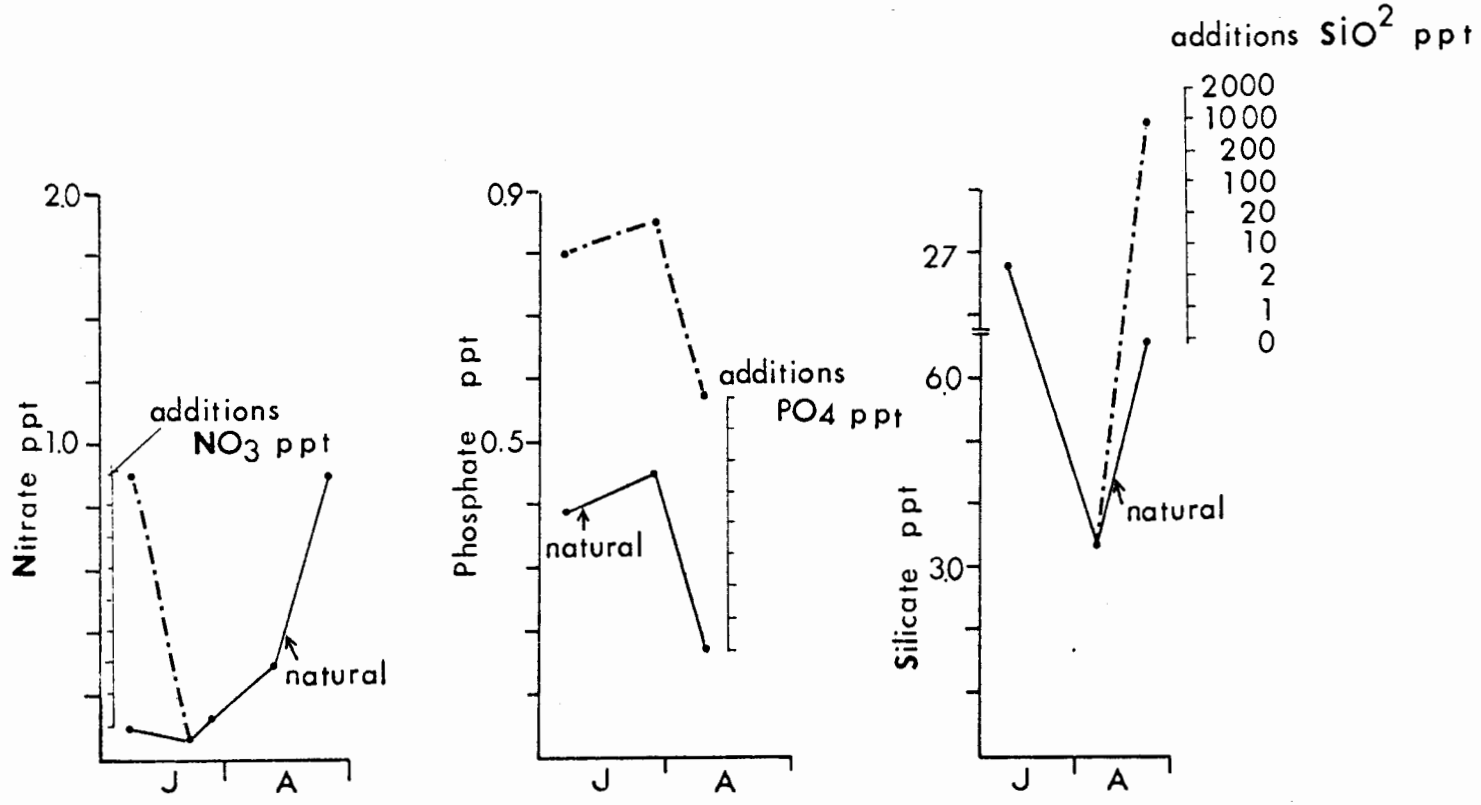


Figure 54. Summary of nitrate, phosphate and silicate enrichment experiments for station 6.

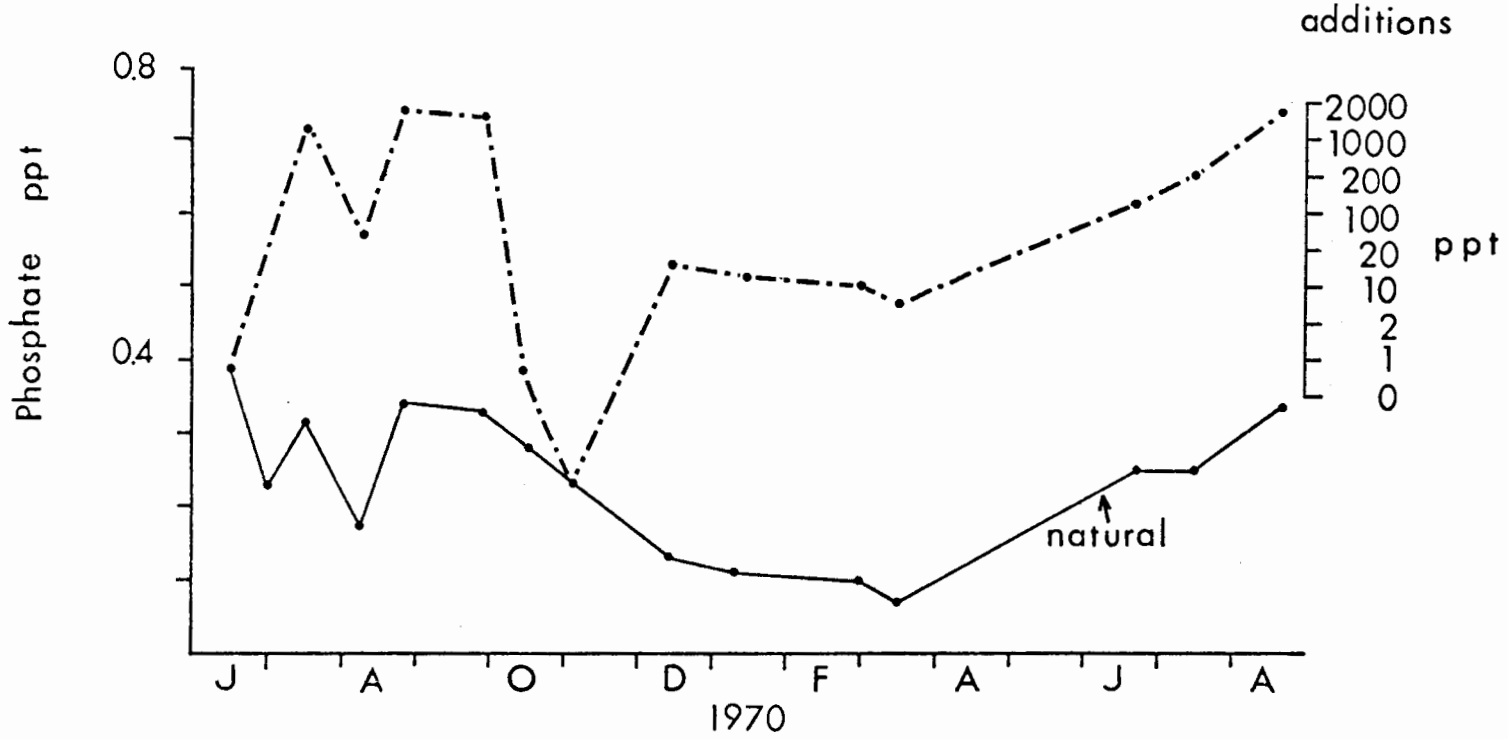


Figure 57. Summary of phosphate enrichment experiments for station 1.

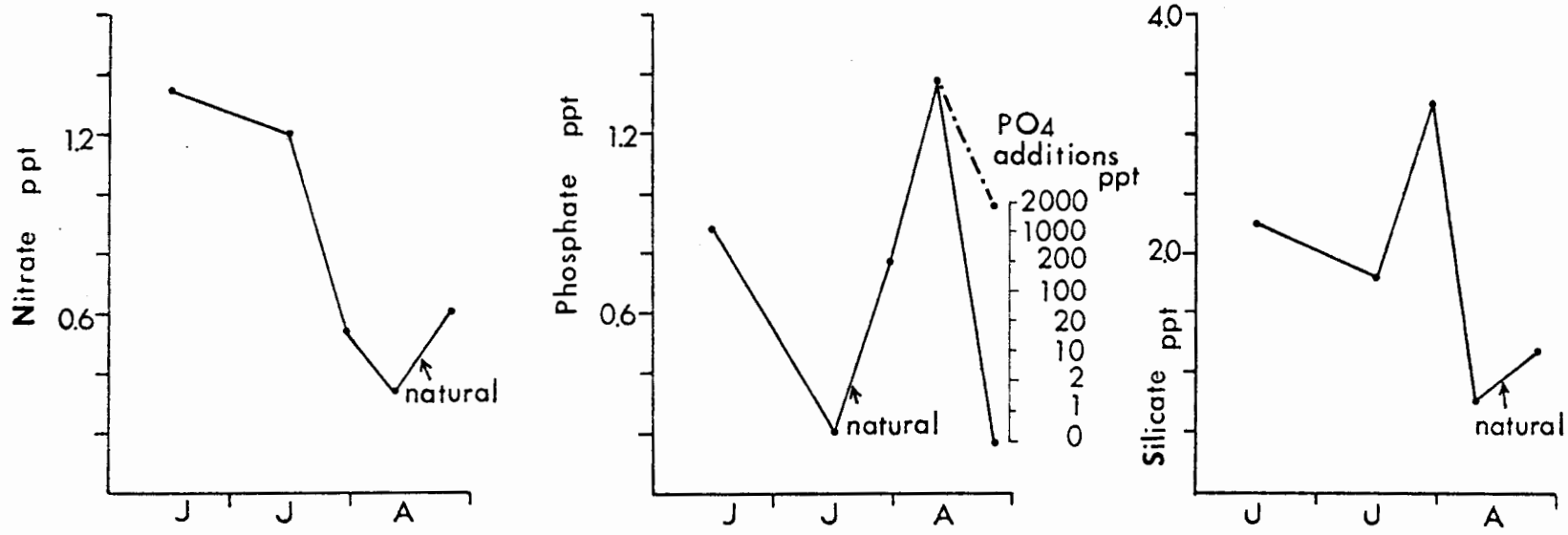


Figure 56. Summary of nitrate, phosphate and silicate enrichment experiments for station 8.

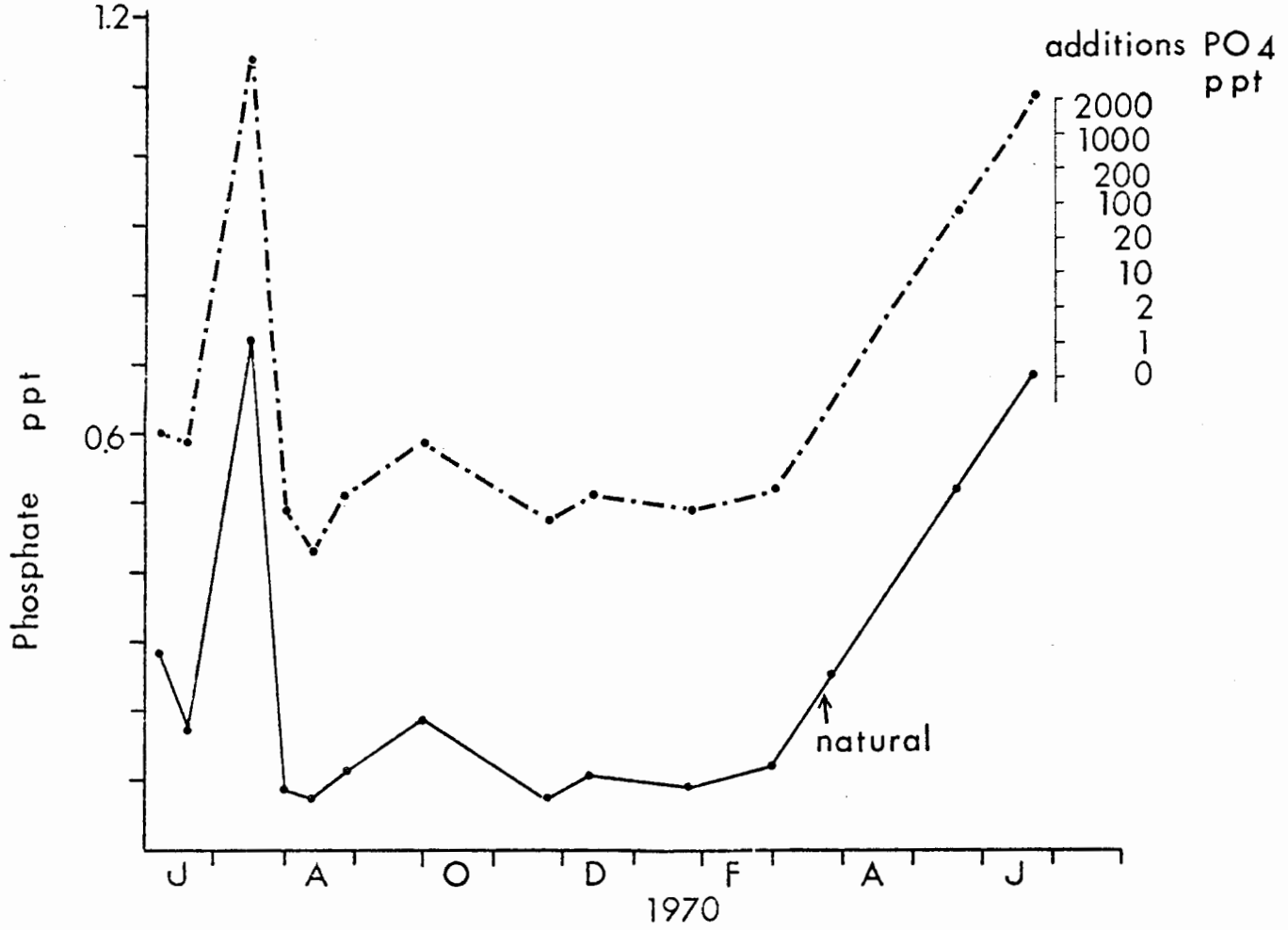


Figure 58. Summary of phosphate enrichment experiments for station 2.

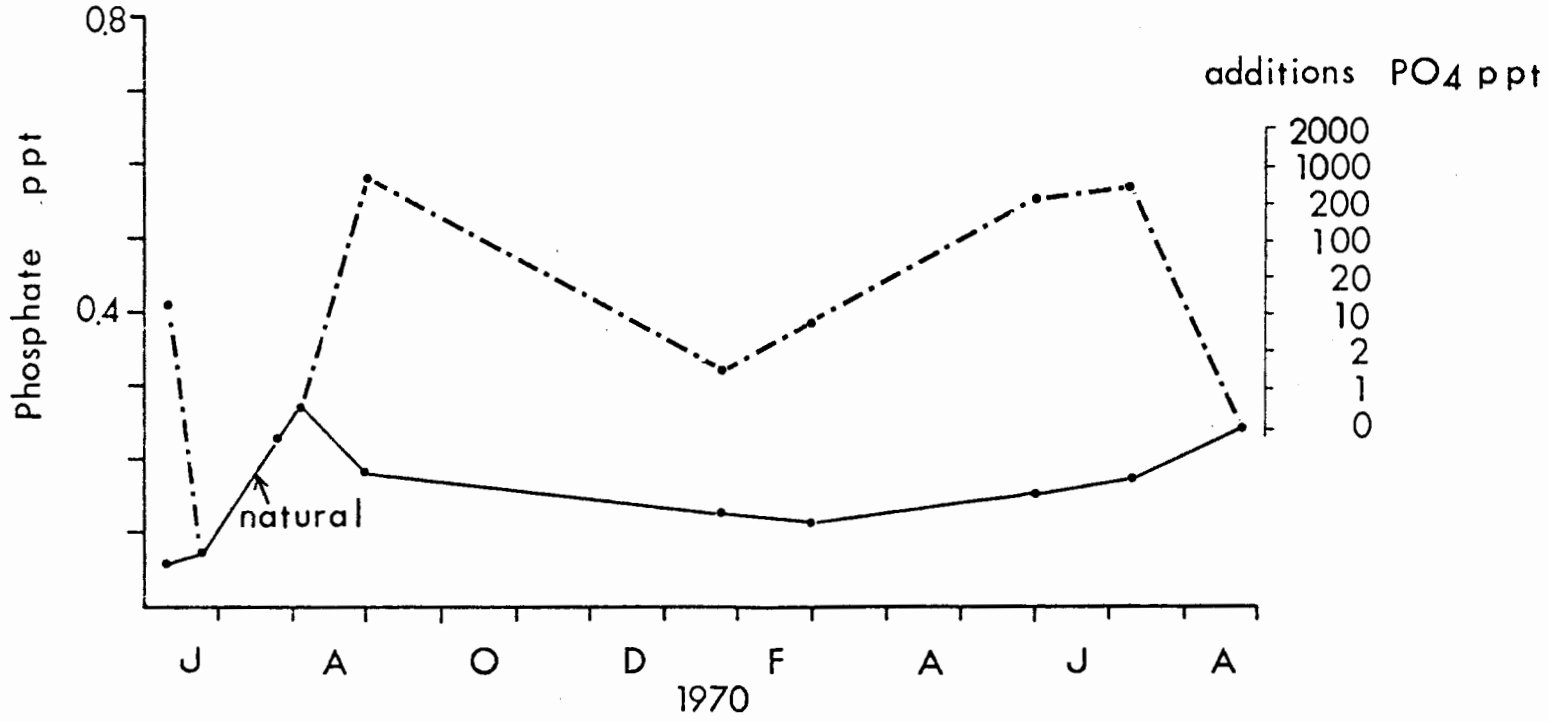


Figure 59. Summary of phosphate enrichment experiments for station 3.

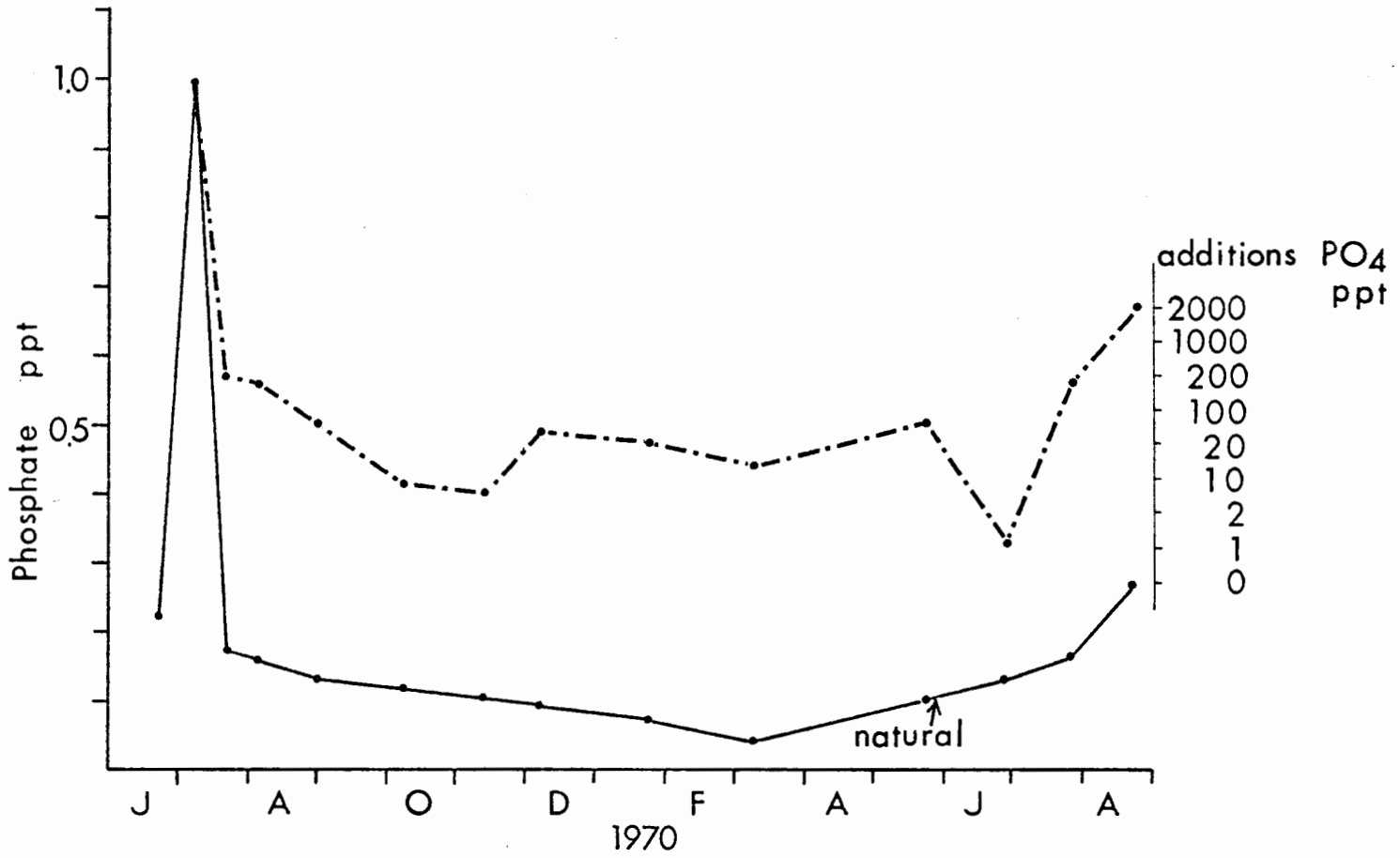


Figure 60. Summary of phosphate enrichment experiments for station 4.

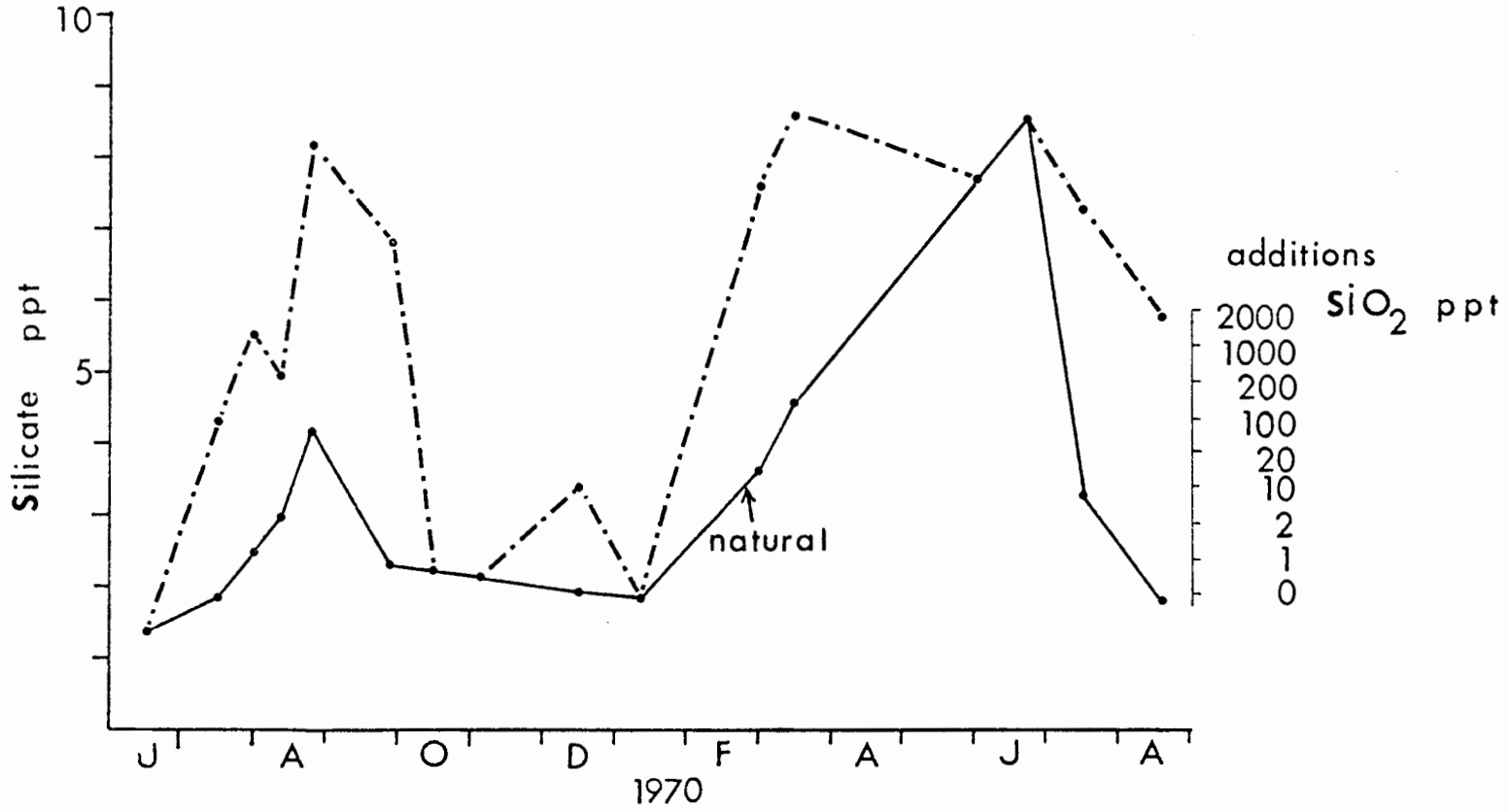


Figure 61. Summary of silicate enrichment experiments for station 1.

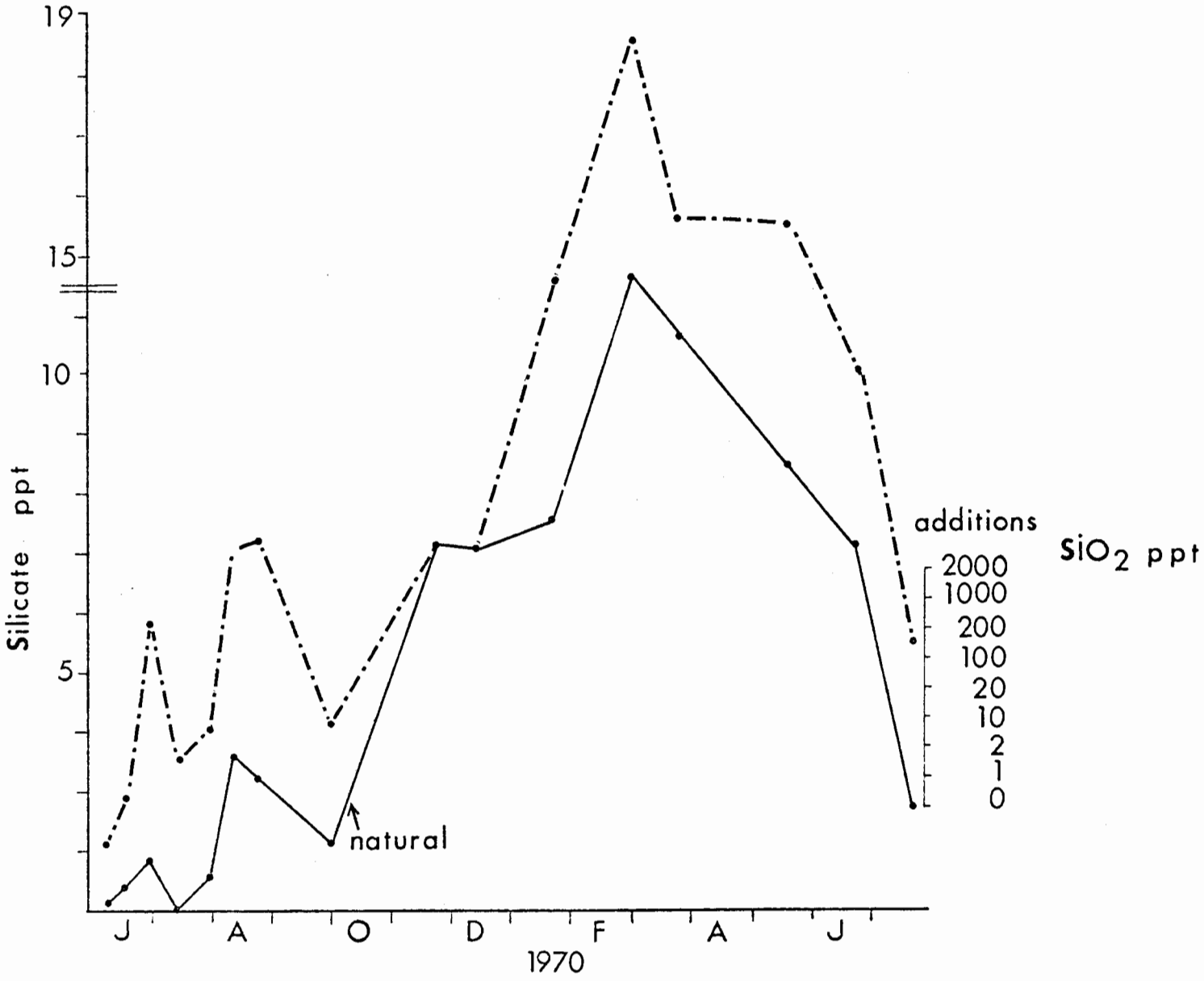


Figure 62. Summary of silicate enrichment experiments for station 2.

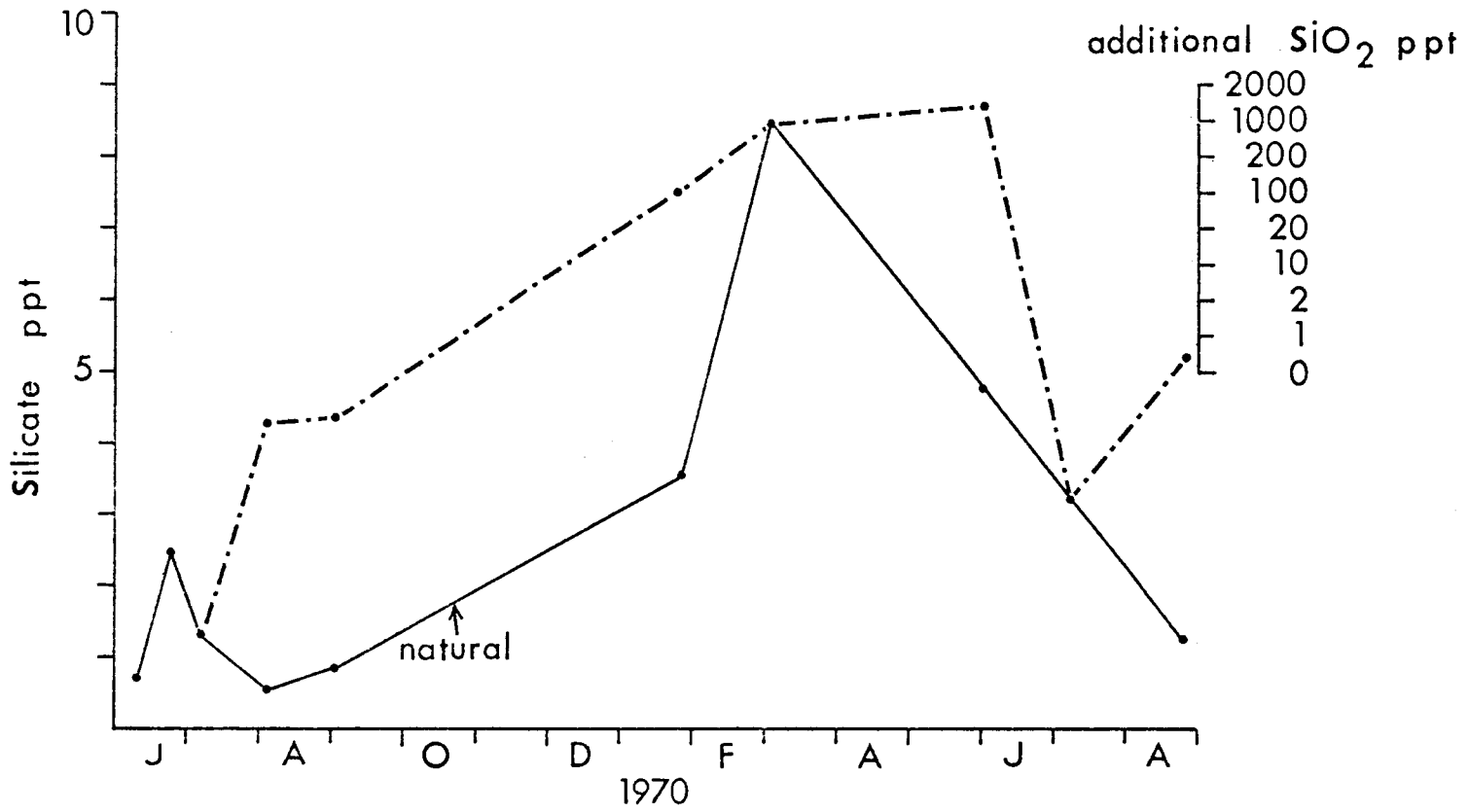


Figure 63. Summary of silicate enrichment experiments for station 3.

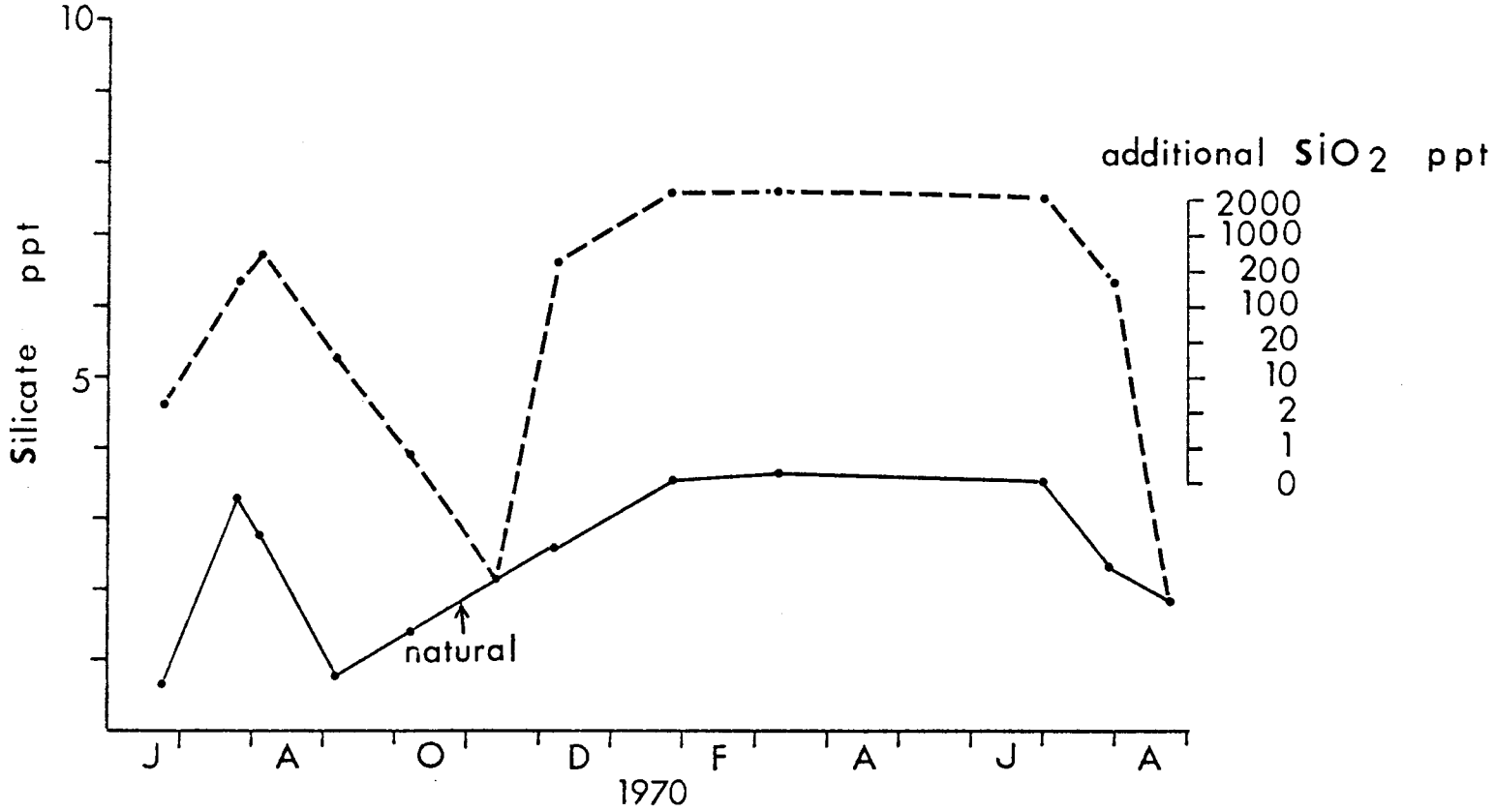


Figure 64. Summary of silicate enrichment experiments for station 4.

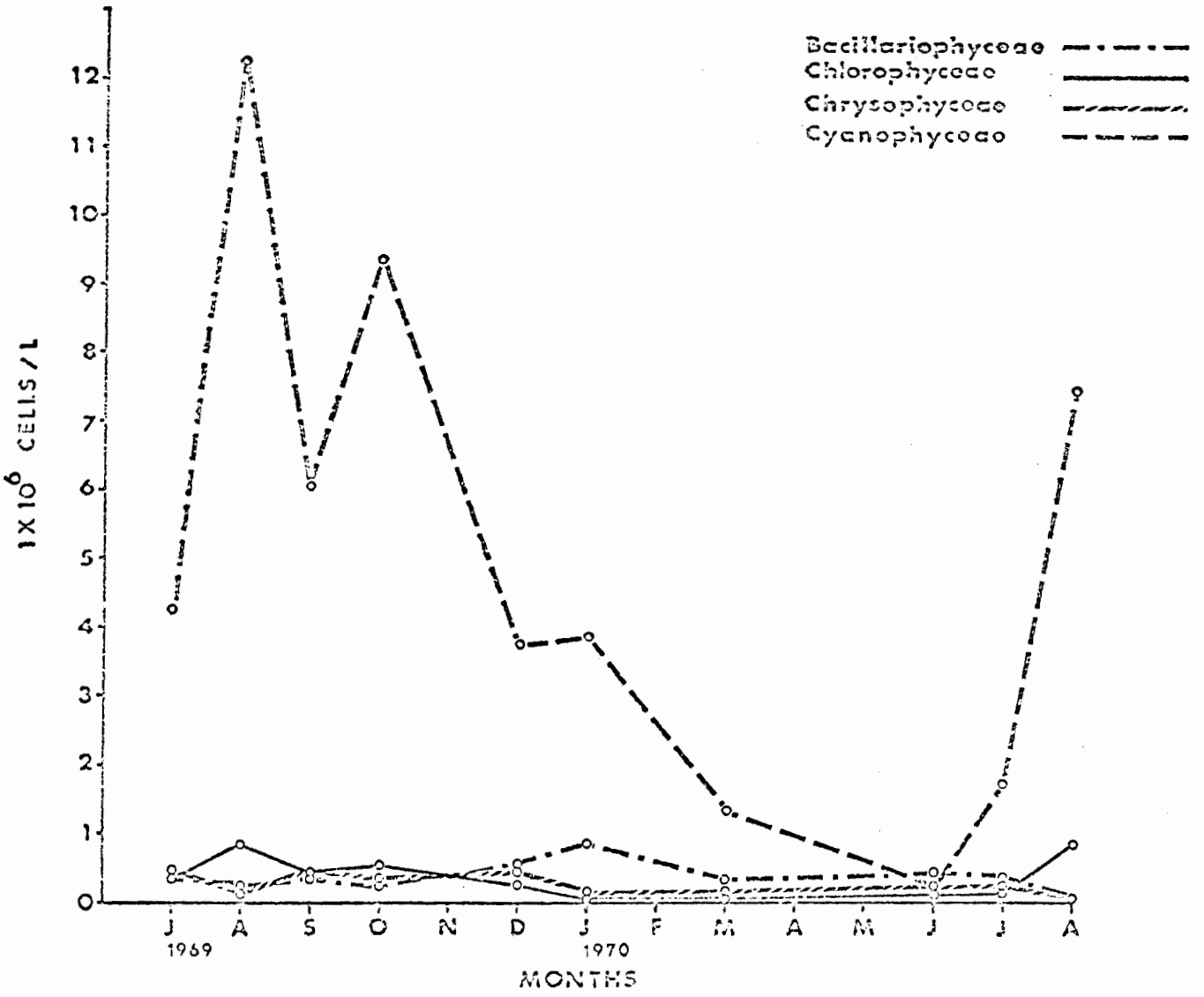


Figure 65. Monthly variation in numbers of cells per class at station 3.

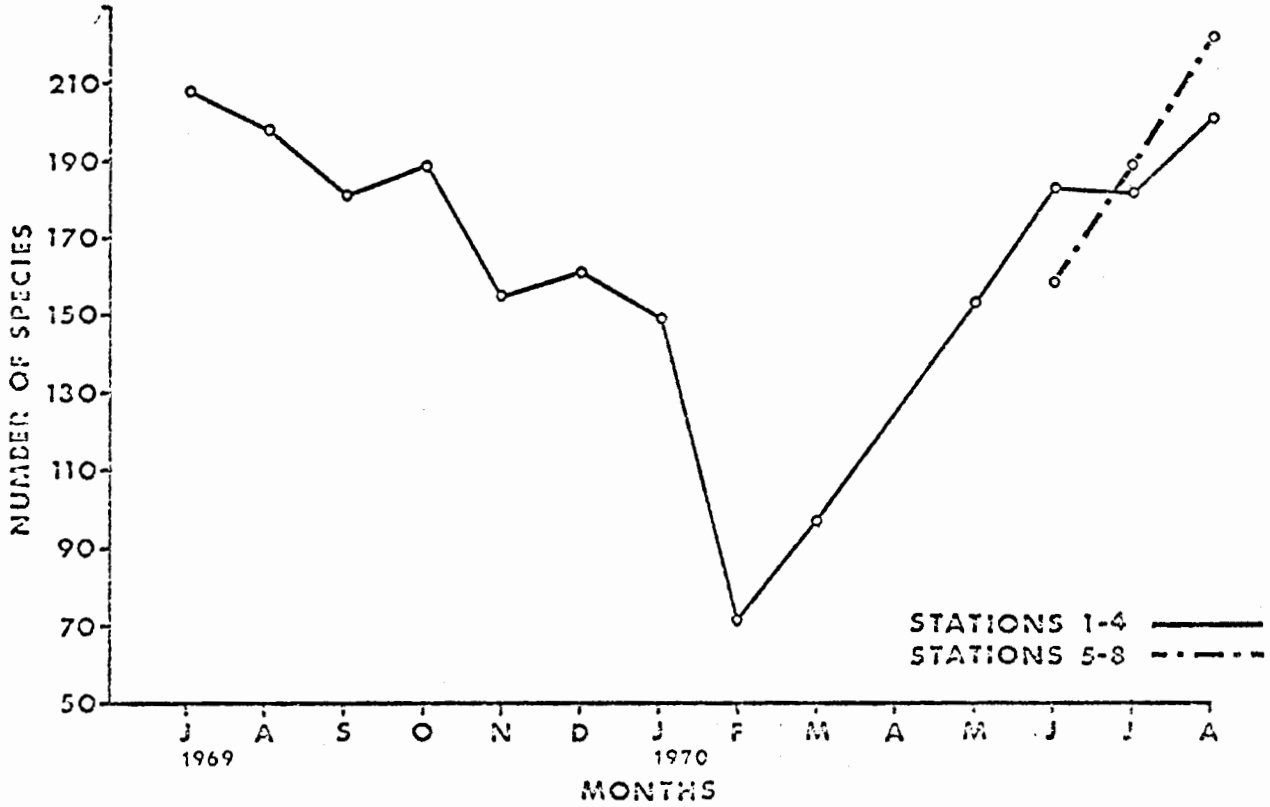


Figure 66. Monthly variation in numbers of species at all stations.

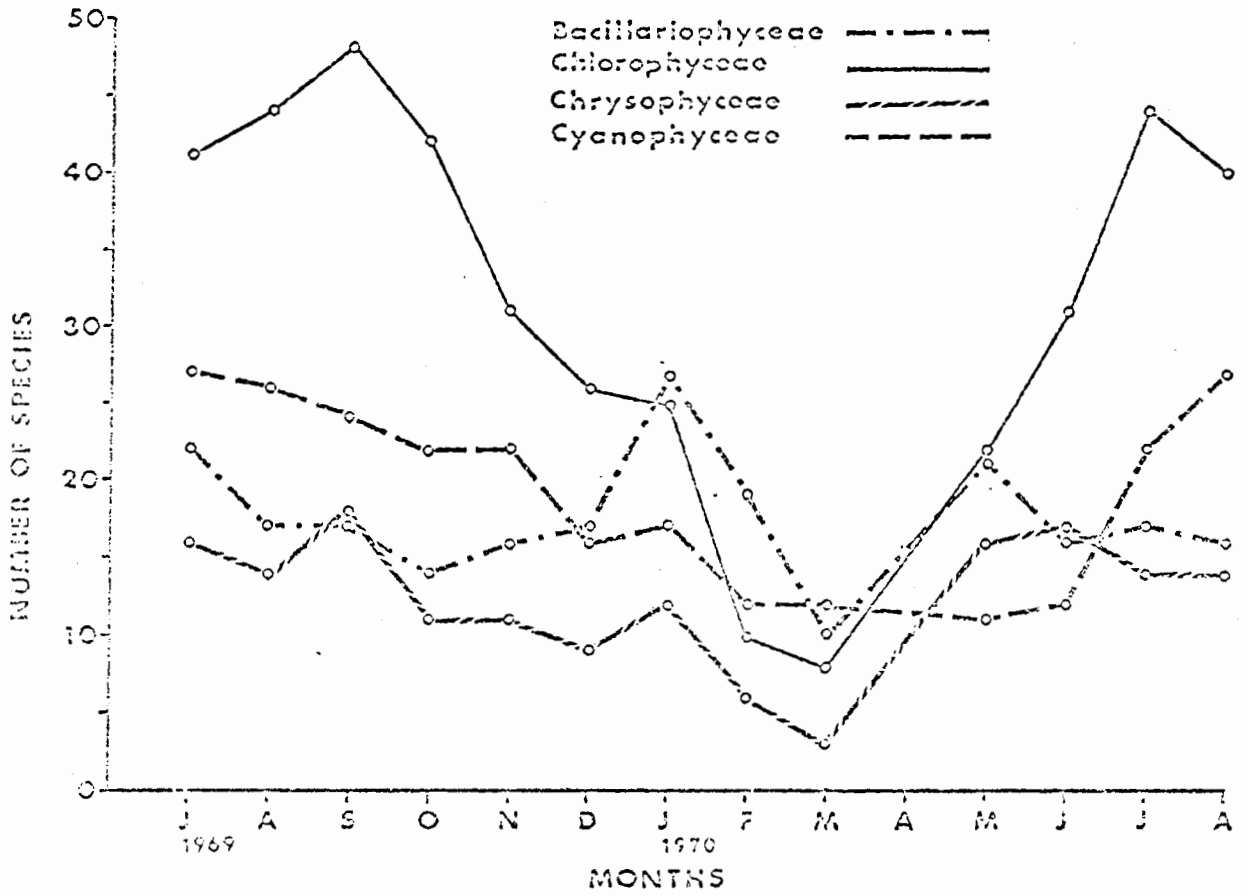


Figure 67. Seasonal variation in numbers of species per class at station 1.

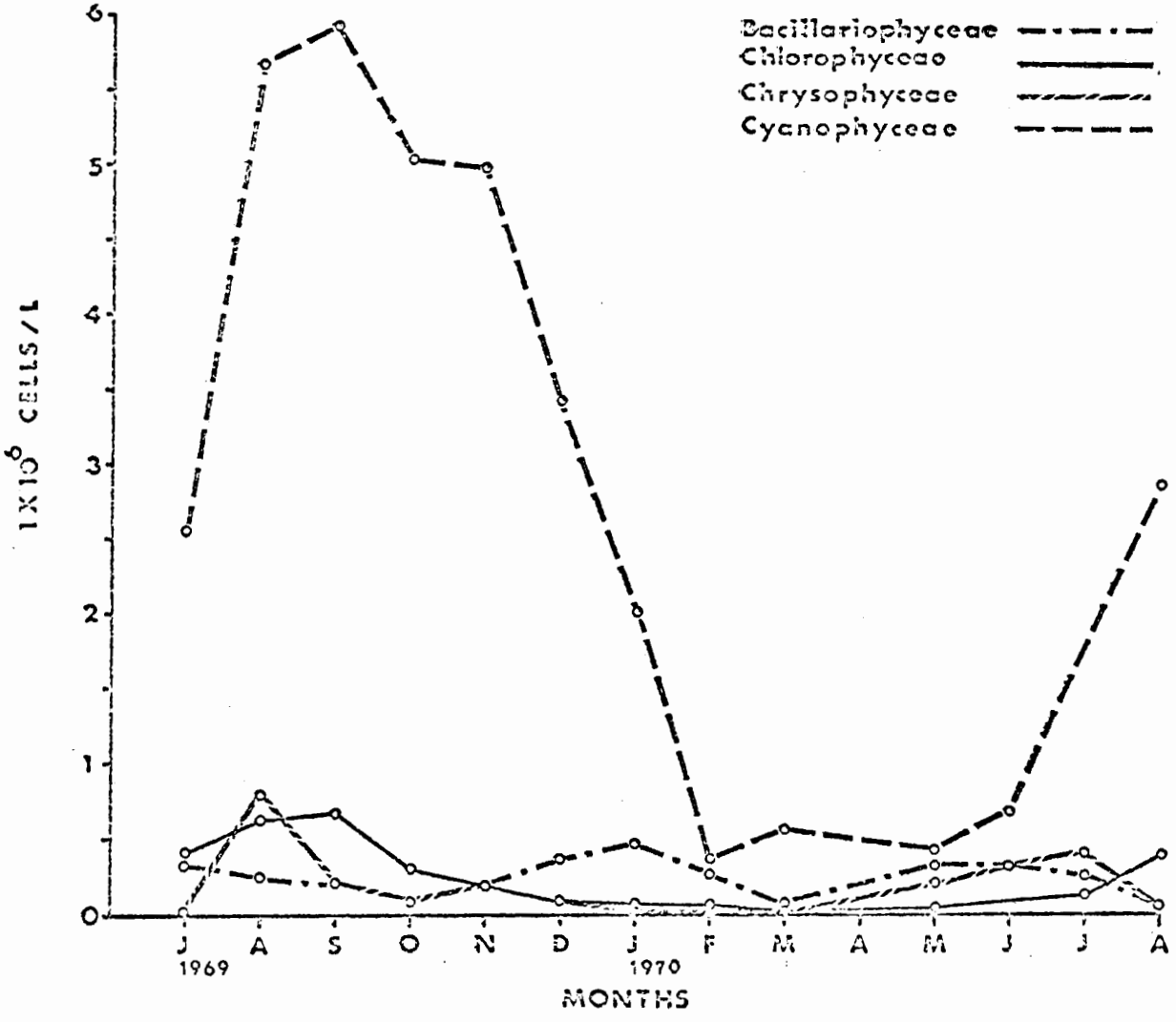


Figure 68. Monthly variation in numbers of cells per class at station 1.

Figure 69. Seasonal variation in numbers of cells at stations 1-4.

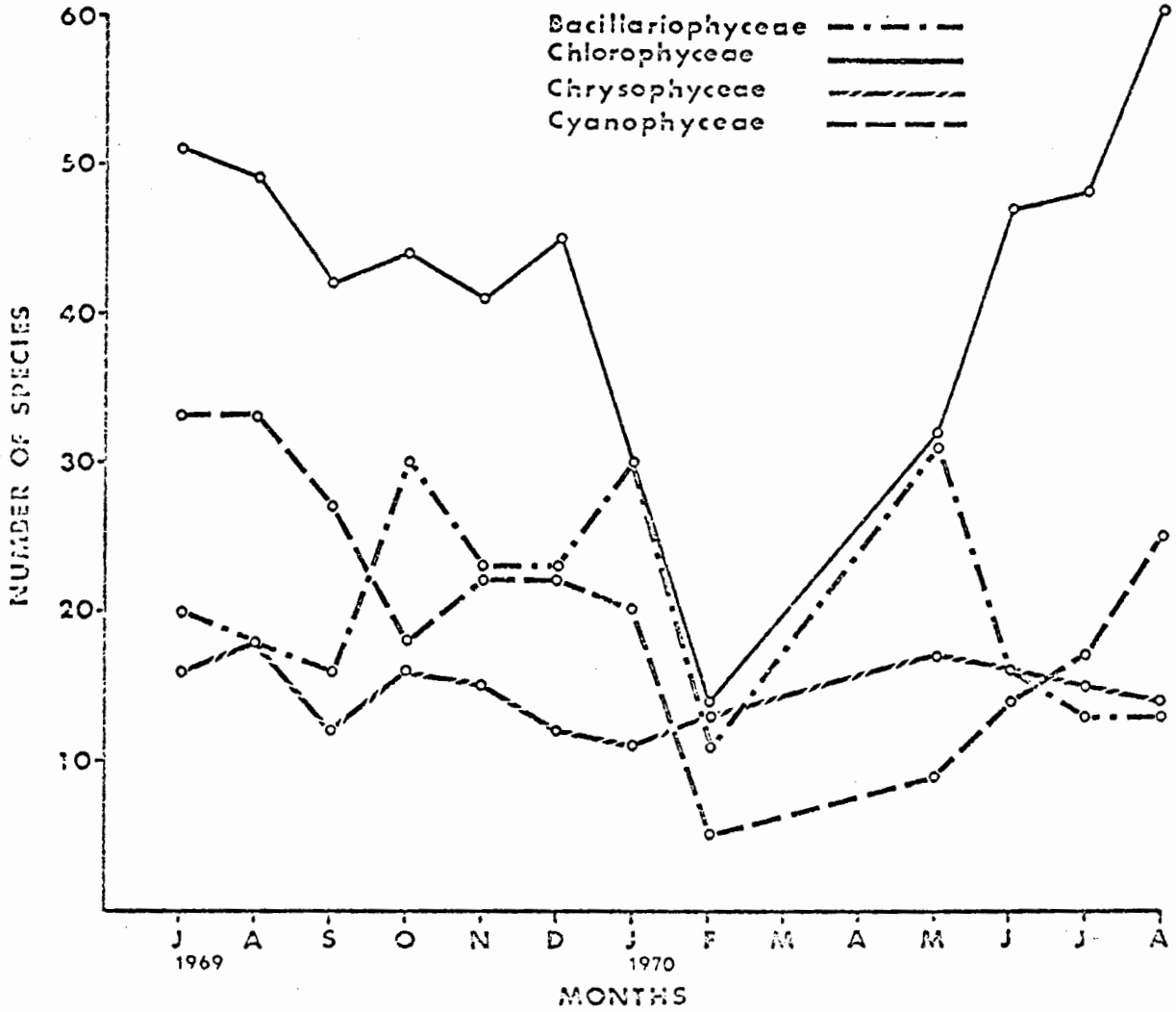


Figure 70. Seasonal variation in numbers of species per class at station 2.

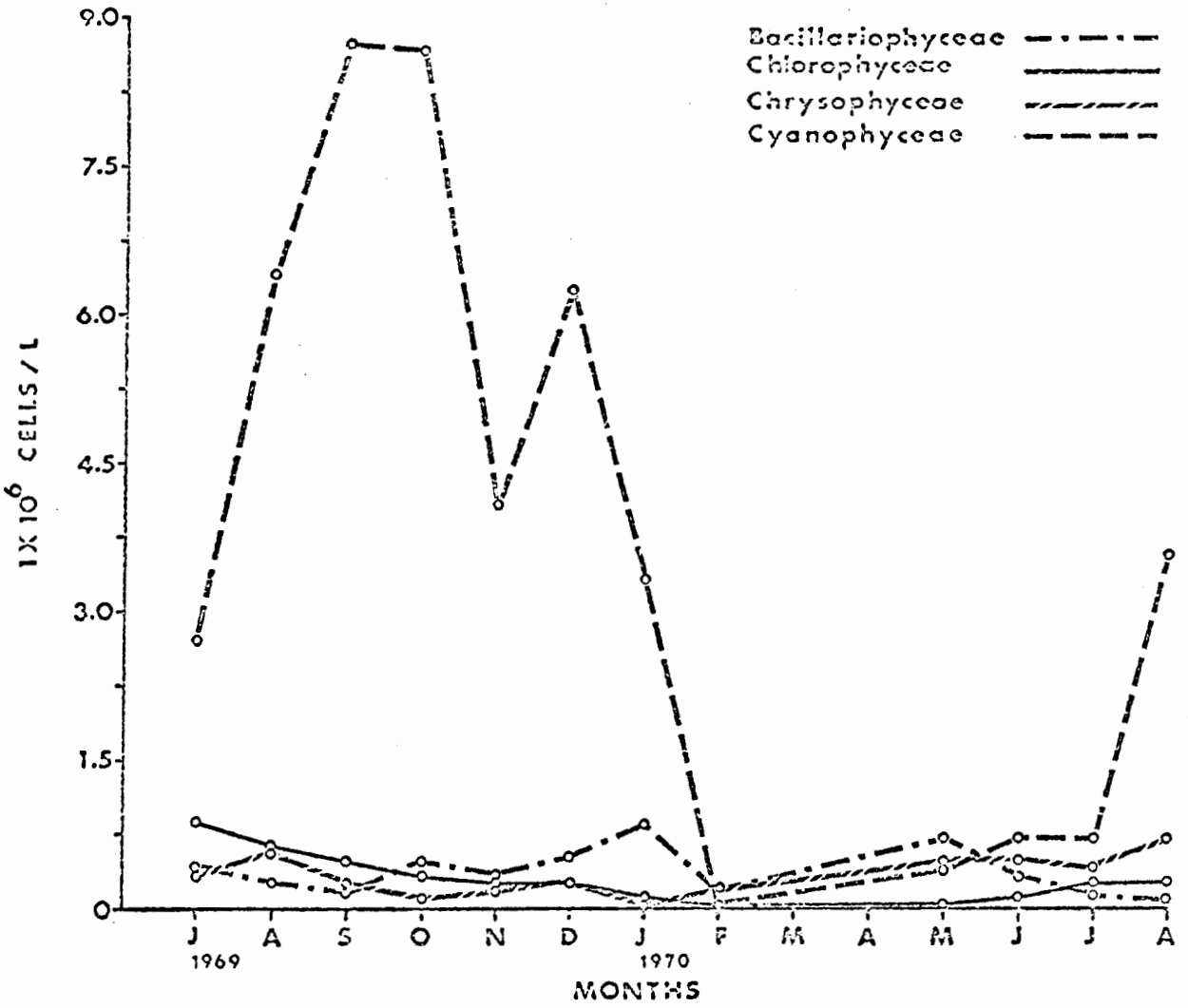


Figure 71. Monthly variation in numbers of cells per class at station 2.

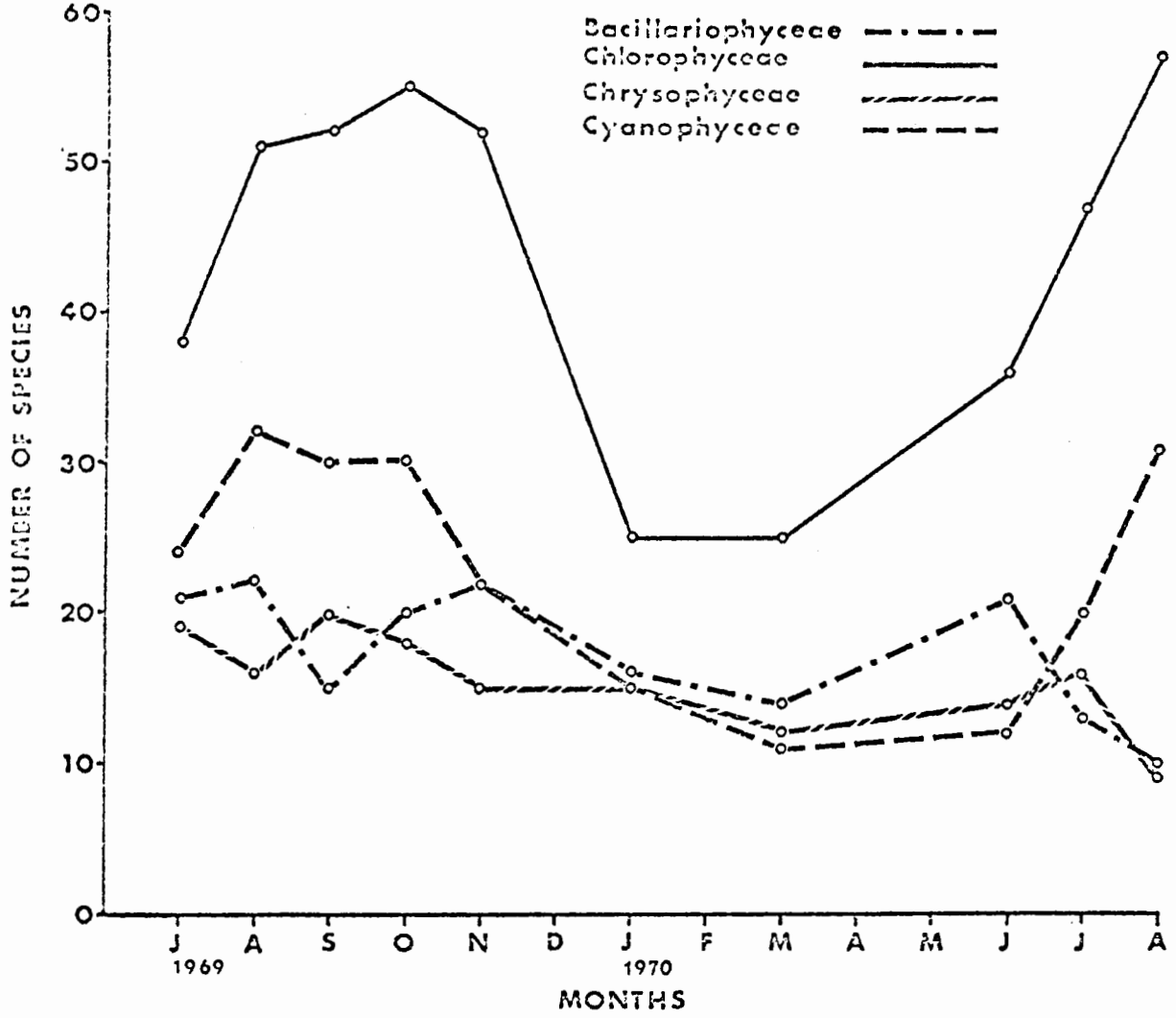


Figure 72. Seasonal variation in numbers of species per class at station 3.

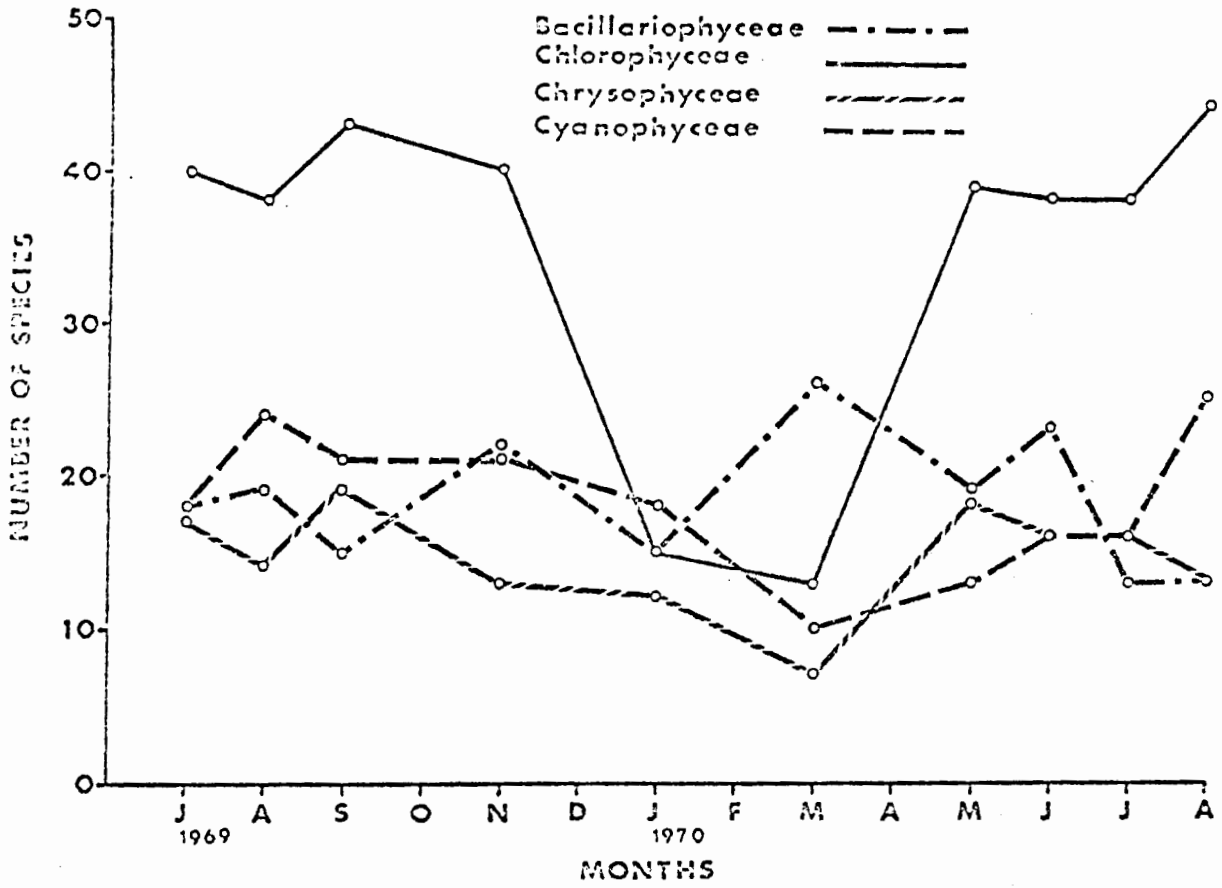


Figure 73. Seasonal variation in numbers of species per class at station 4.

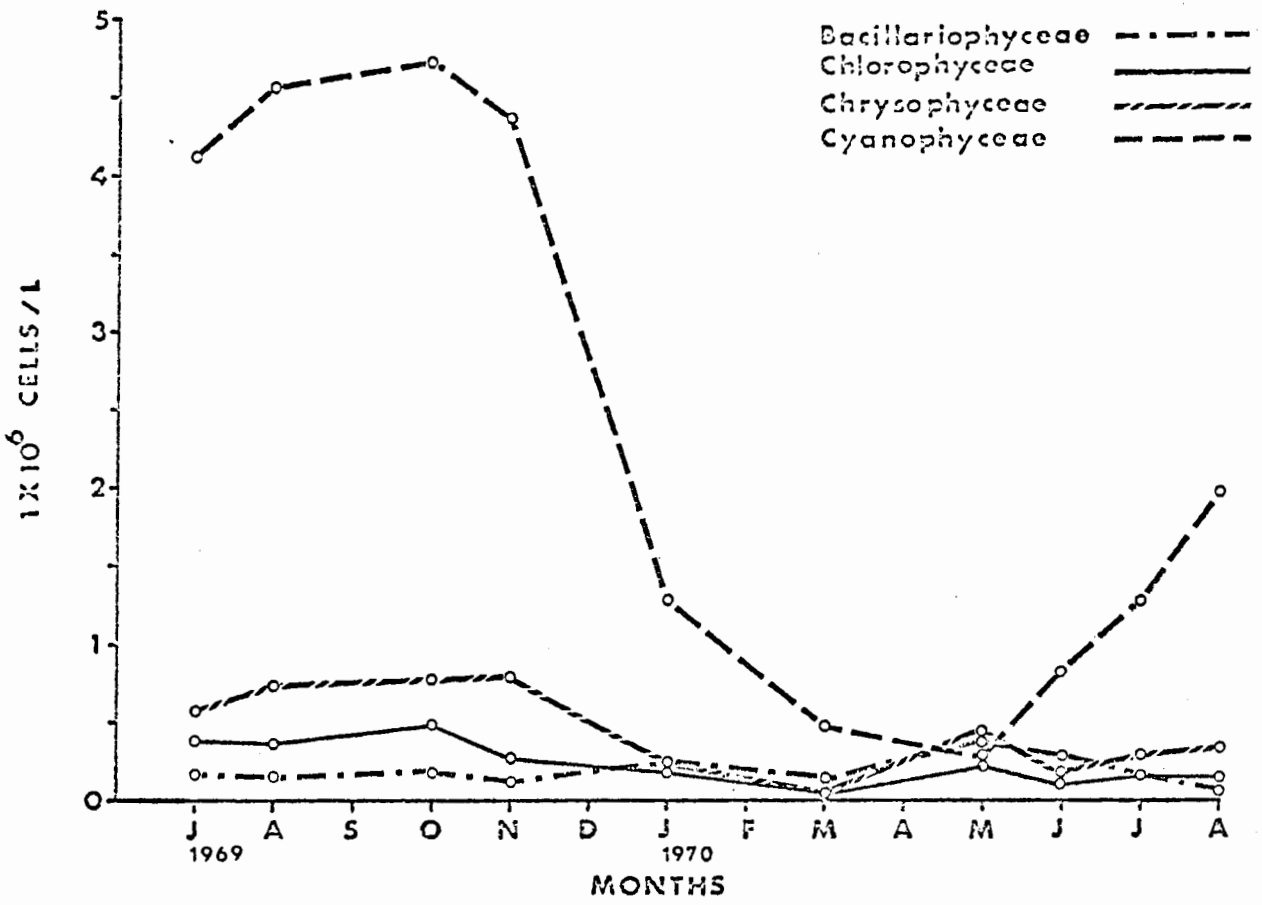


Figure 74. Monthly variation in numbers of cells per class at station 4.

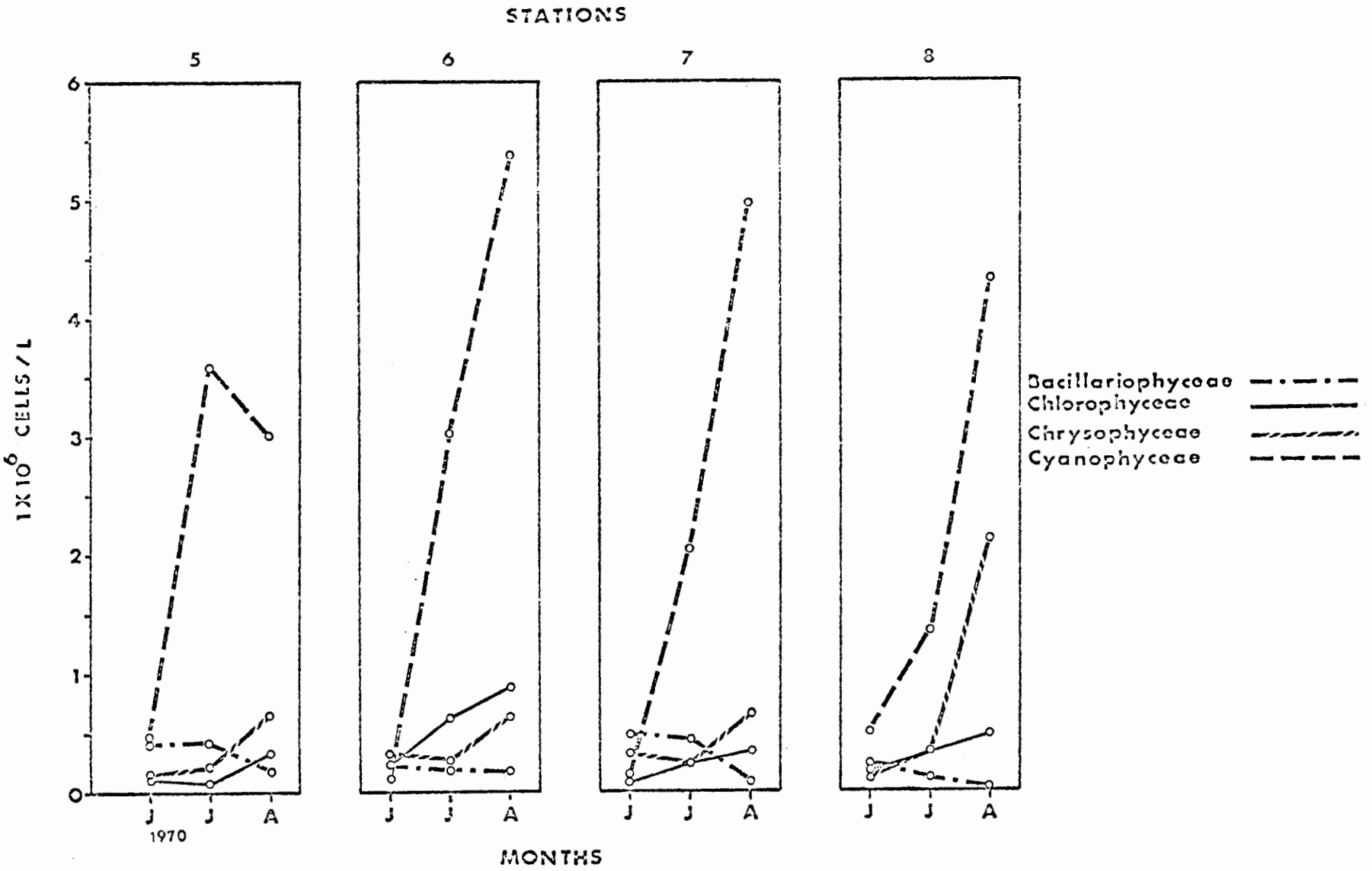


Figure 75. Monthly variation in numbers of cells per class at stations 5-8.

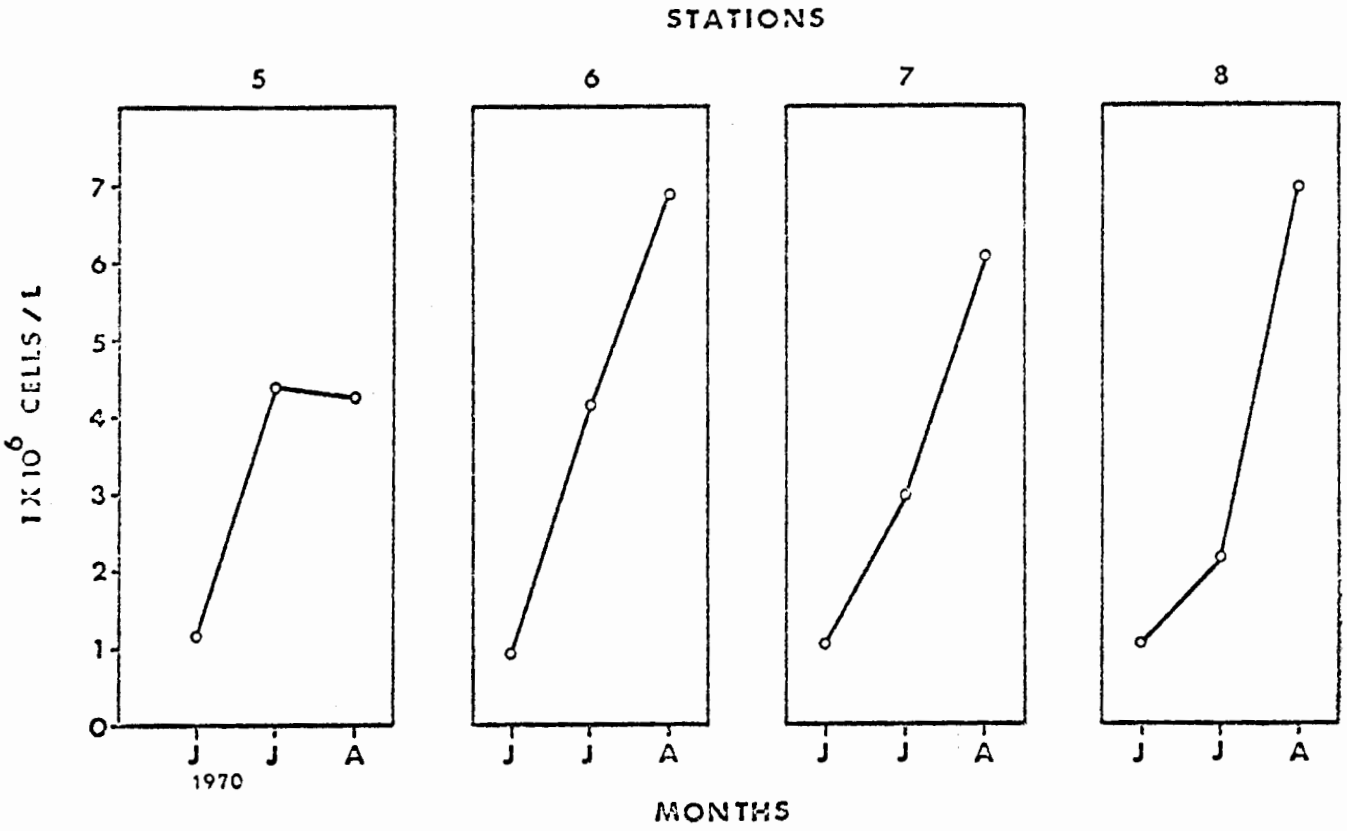


Figure 76. Seasonal variation in number of cells at stations 5-8.

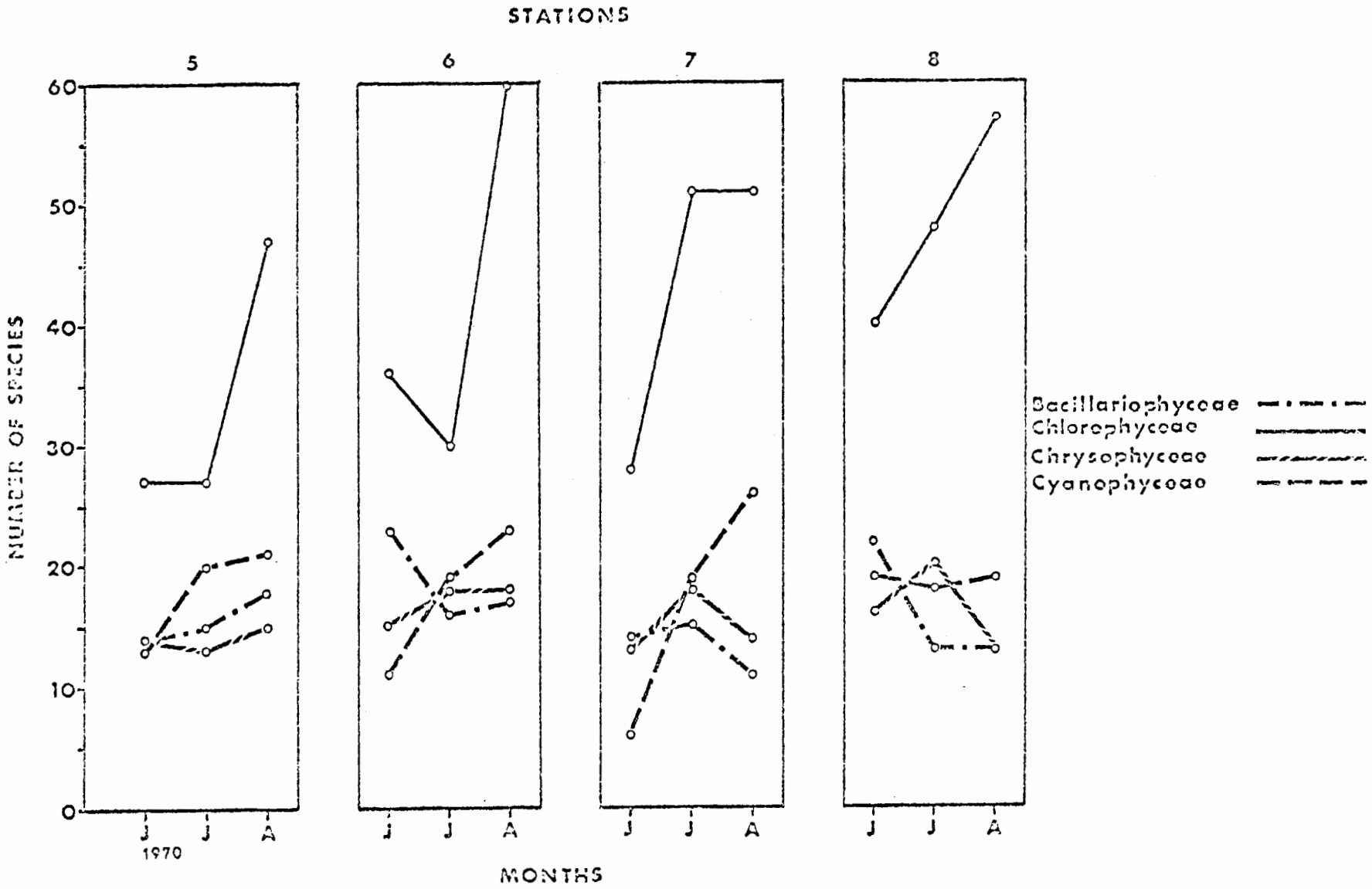


Figure 77. Seasonal variation in number of species per class at stations 5-8.