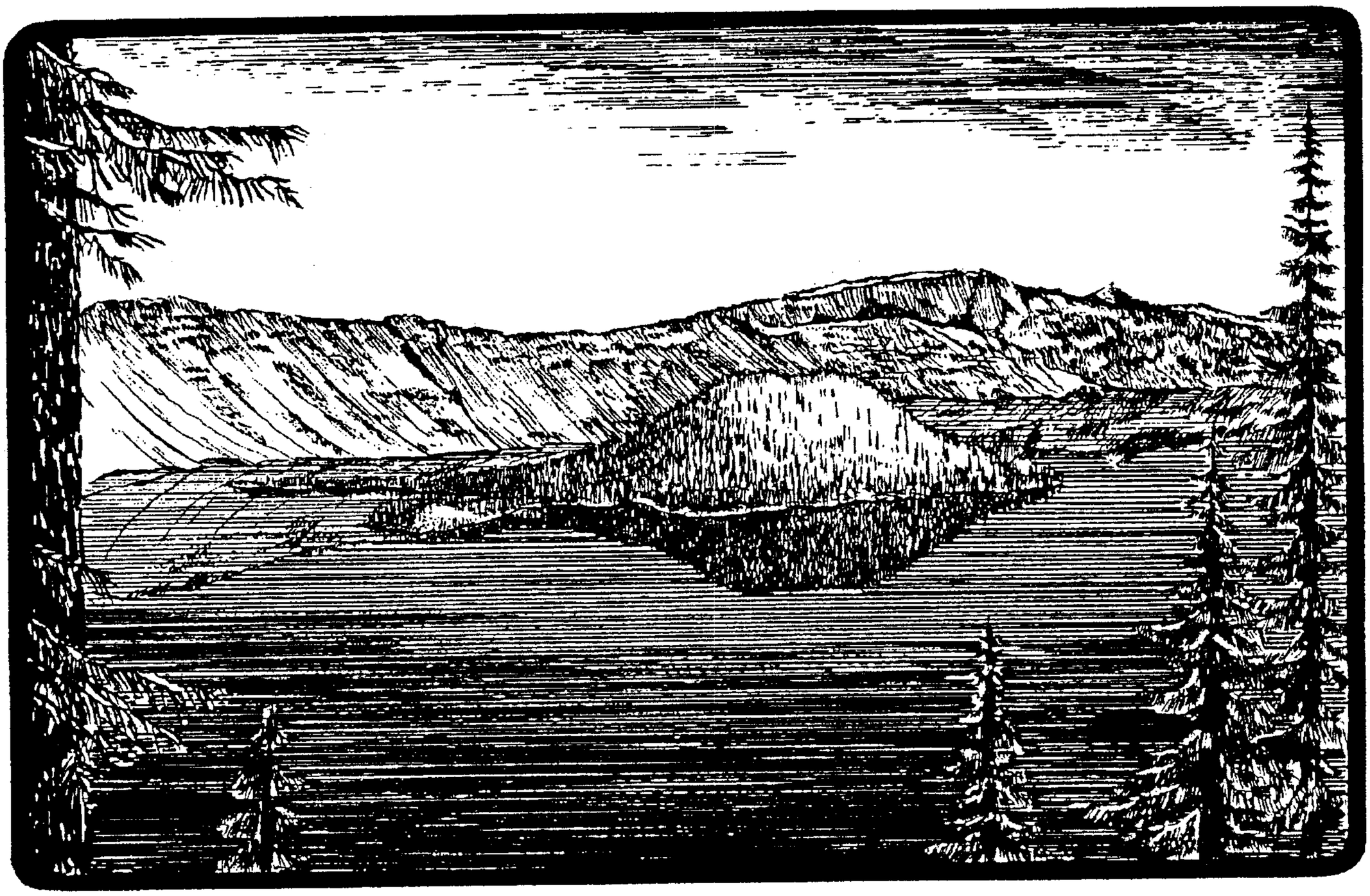
# Crater Lake Limnological Studies 2002 Annual Report

Technical Report NPS/CCSOFRESC/NRTR-2003/07



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# CRATER LAKE LIMNOLOGICAL STUDIES
# 2002 ANNUAL REPORT


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Technical Report NPS/CCSOFRESC/NRTR-2003/07

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The 10-year study documented many of the components and processes important to lake clarity and the lake system as a whole. Long-term change could not be fully evaluated because very little historical data were available to compare with the detailed data base assembled during the 10-year study. This situation underscored the need for a long-term monitoring program to evaluate future change against the benchmark set in the 10-year study. Implementation of the proposed long-term monitoring program at Crater Lake required additional funding. Such funding was available starting in the 1994 field season. The sampling program in 1994 followed the protocols established during the 10-year study, except that the complete suite of nutrient and trace element samples were collected only in August. Water samples from inflowing springs on the caldera walls were collected to continue monitoring for any signs of changing levels of nitrate after the rim sewage facility was disconnected in 1990 and to assess any possible contamination from construction activities at Rim Village.

The purposes of this annual report are to: 1) define the working objectives of the 2002 program; 2) report on the findings from the 2002 field season; 3) compare current limnological data with past lake conditions; and 4) describe the 2003 monitoring program.

## Study Area

The lake covers the floor of the Mt. Mazama caldera that formed about 7,700 years ago (Bacon et al., 2002). The lake, at a maximum depth of 592 m, has a surface area of 53.4 $km^2$, and a mean depth of 325 m (Byrne 1965, Phillips 1968, Bacon et al., 2002). Steep caldera walls surround the lake, resulting in a ratio of lake area to watershed area (flat map) of about 3.6. A secondary intracaldera volcanic cone forms Wizard Island, the largest of two islands in the caldera (Fig. 1). Surface inflow is restricted to intracaldera springs and small streams. There is no surface outlet.

## Project Objectives

The program can be summarized in two broad objectives. First, baseline data will be collected to characterize the limnological conditions of the lake from 1982/1983 to 2002. Second, lake structure and organization will be defined in order to develop reliable relationships among physical, chemical, and biological components of the ecosystem.

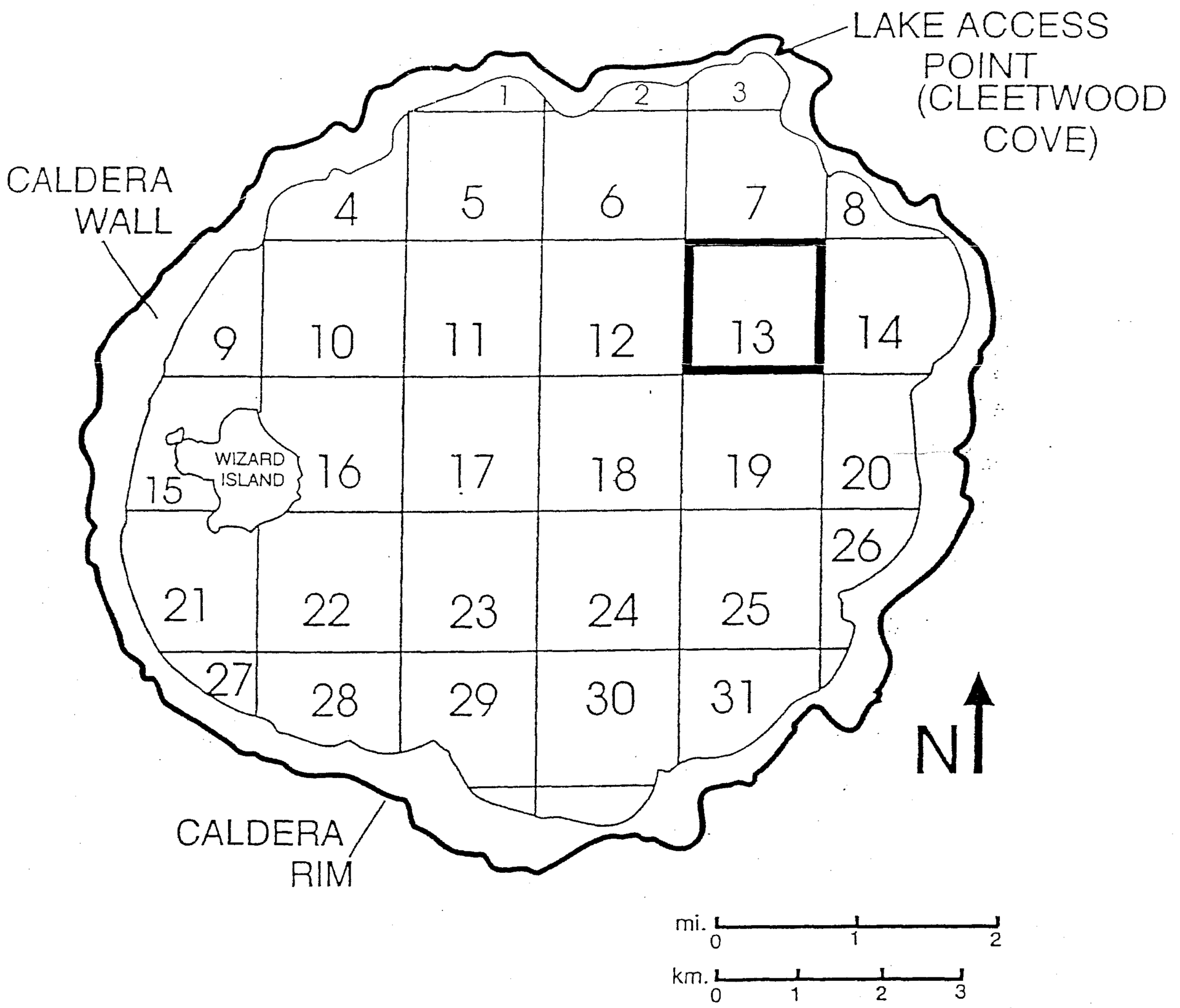



Figure 1. Crater Lake station grid system established by Hoffman (1969).

Although the two broad objectives are useful for general discussion and program direction, project selection requires the initial development of conceptual models as shown in Figures 2 and 3. The first model illustrates the general components and the broad relationships between components within the ecosystem, such as the interrelationships among climatological, terrestrial, anthropogenic perturbations, and lake characteristics. The second model is on within-lake aspects of the ecosystem, which are only part of the caldera ecosystem shown in Figure 2.

## Baseline Monitoring

*Methods (2002)*

Samples for trend analyses were restricted to Station (grid) 13 (Fig. 1), the deepest portion of the lake basin. Components of the baseline monitoring program were determined as shown in Table 1. Trend samples were collected once each month from May, July, August, and September to a depth of 550 m. Water samples were collected using 4-liter Van Dorn style bottles to 550 m. Analyses and methods performed, respectively, in the park chemistry laboratory were total alkalinity (potentiometrically), pH (Altex meter), specific conductance (YSI conductivity bridge), and dissolved oxygen (Winkler method - azide modification with PAO titrant). Additional pH and conductivity measurements, and analyses of nutrient samples (May and August for orthophosphorus and total phosphorus, and May, July, August and September for Kjeldahl nitrate, and amonia) were performed by the Cooperative Chemical Analytical Laboratory (CCAL), Oregon State University. Water temperature was recorded using a Sea-Bird CTD. Secchi disk readings were taken using a standard black and white 20-cm disk. A beam transmissometer (SeaTech) was used to assess light transmission and spatial distributions of particles in the lake. A spectroradiometer (Licor) was used to characterize the spectral characteristics of incident light to a depth of 180 m. Except for the depth of 1% of the incident solar radiation (expressed as PAR), these spectral data will be reported later. Chlorophyll samples were collected and filtered at the park. Total chlorophyll was determined later using a Turner fluorometer. John Salinas prepared the chlorophyll standards. The depth distribution of chlorophyll was also determined "insitu" using a wetlabs fluorometer. Phytoplankton samples (1 liter) were collected only in August, preserved in Lugol's solution, and processed using the inverted scope method (data reported later because a new taxonomist is

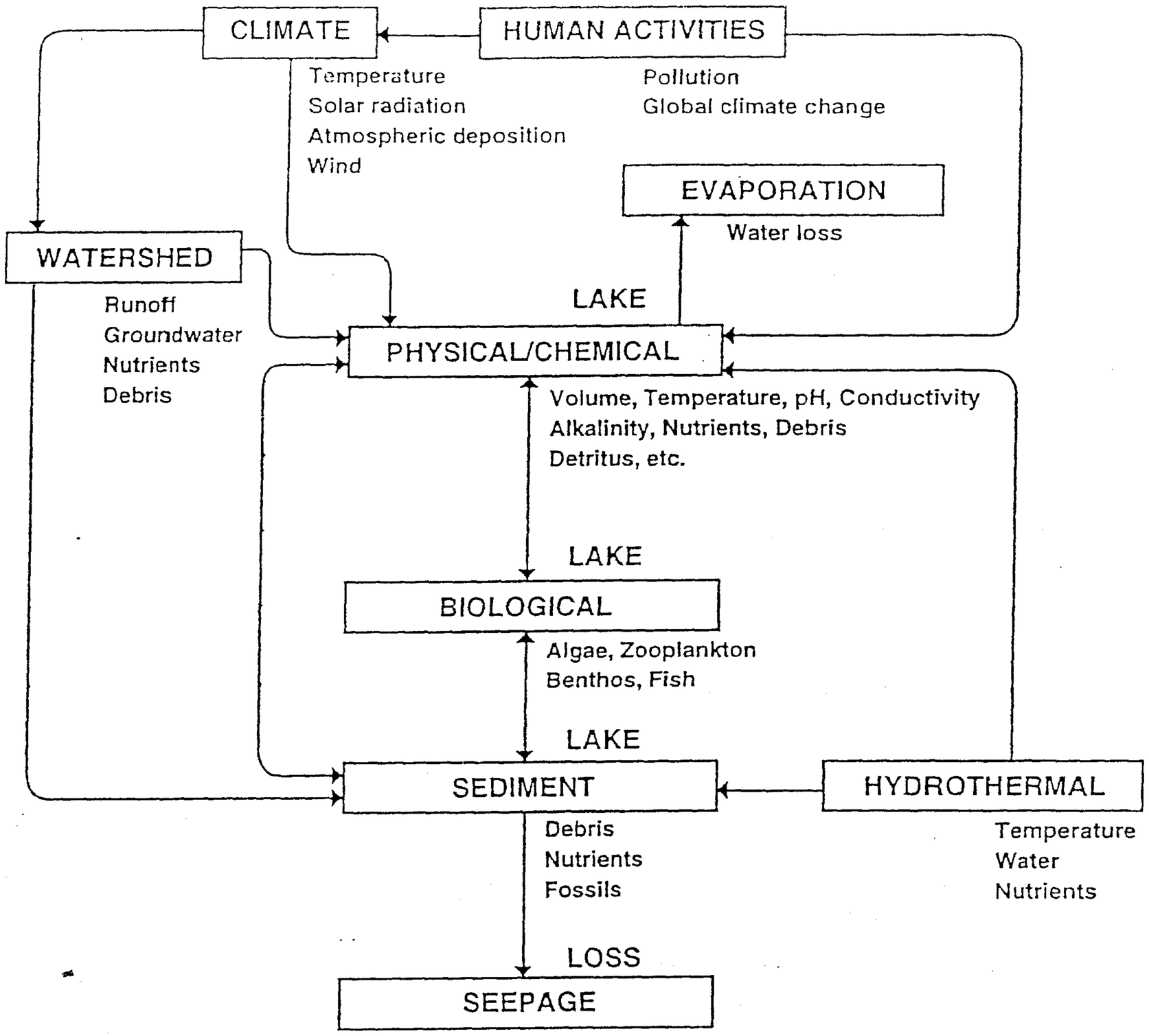



Figure 2. Conceptual model of the Crater Lake ecosystem.

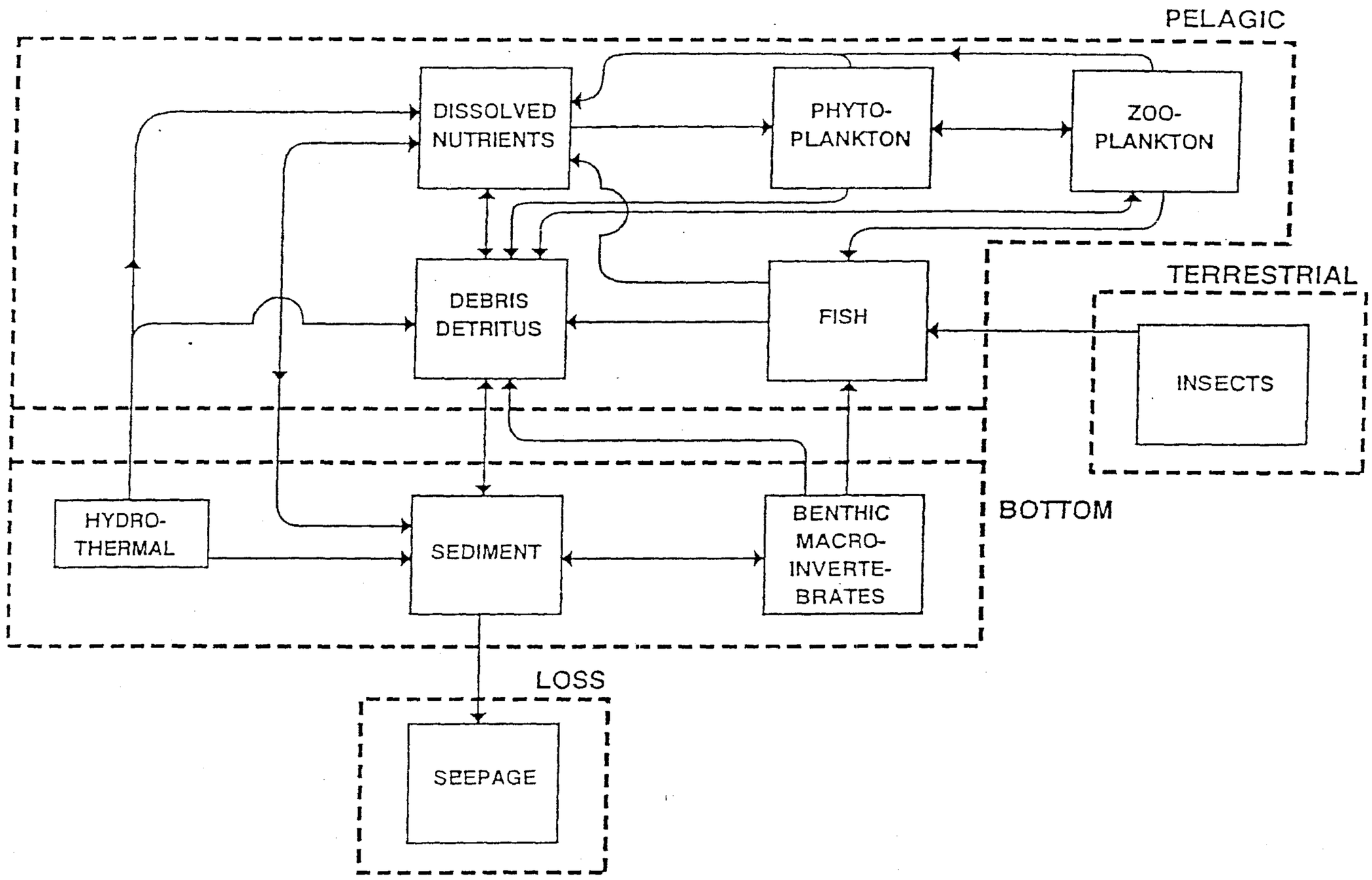



Figure 3. Details of the lake aspects of the conceptual model shown in Figure 2.

Table 1. Components of the Crater Lake Baseline Limnological Monitoring Program, 2002.

1. Lake

   A. Temperature
      Conductivity, temperature, and depth probe (CTD)

   B. Optical

      1. Secchi disk (20 cm)
      2. Transmissometer (to 550 m)
      3. Spectroradiometer (to 180 m)

   C. Chemical
      Determine pH, total alkalinity, specific conductance, dissolved oxygen, total phosphorus, orthophosphate-P, nitrate-N, total Kjeldahl-N, ammonia-N, silica, and trace elements at all or selected depths from the following depth sequence: 0, 5, 10, 20, 60, 100, 200, 300, 400, 500, and 550 m.

   D. Biological

      1. Total chlorophyll
         Estimate the *in vitro* total chlorophyll at the following depth sequence:
            5 m intervals from 0 to 10 m
            10 m intervals from 10 to 40 m
            20 m intervals from 40 to 200 m
            25 m intervals from 200 to 300 m
         Estimate the insitu chlorophyll using a wetlabs fluorometer.

      2. Primary production (carbon-14 light/dark bottle)
         Estimate primary production at the chlorophyll sampling depths to 180 m.

      3. Phytoplankton
         Determine species, densities, and biovolumes at all chlorophyll sampling depths (August only).

      4. Zooplankton
         Determine species, densities, and biomasses. Samples taken with a vertical haul .5 m diameter number 25 (64 μm) closing net.

      5. Fish
         Determine species, abundance, biomass, distribution, age, sex, growth and food habits. Fish samples collected with gill nets and by angling. Distribution and abundance of fish using an echosounder.

2. Springs

   Physical and chemical water quality
      Record temperature and take samples for pH, conductivity, alkalinity, nutrients, and trace elements.

analyzing the samples). Primary production estimates were made using the carbon-14 light/dark bottle method. The primary production samples were filtered at the park. Primary production and chlorophyll samples were examined for picoplankton. Each sample was split in half. One half was filtered using a 0.45 μm filter. The other halves were filtered through 2.0 μm filters, followed by filtration through 0.22 μm filters. The picoplankton results will be reported later. The filters were placed into scintillation cocktail vials and transported to the Radiation Center, Oregon State University, where the samples were processed.

Zooplankton samples were sampled using a 0.50 m closing net with a 64 μm mesh. Day vertical tows to 200 m were taken during trend weeks in May, July, August, and September. The data will be reported later because a new taxonomist is analyzing the samples.

Fish were collected with horizontal gillnets. Each fish was identified to species, measured for length, weighed, sexed. Scales and stomach samples were collected from kokanee salmon for later analysis. Distribution and abundance of fish were determined using an echosounder. These data will be reported later.

Water samples from caldera springs and streamlets were taken during each trend week. In addition to temperature, unfiltered samples were processed for pH, conductivity, and alkalinity. Filtered (prewashed filters) samples were shipped to the CCAL for nutrient analyses.

The results section will include data from the 2002 field season and data collected from 1982 - 2001. However, in some cases the 2002 data have not been analyzed, whereas in other cases we have not had a chance to analyze data collected prior to 2002. These missing analyses will be reported in the future.

*Results and Interpretations*

Secchi disk readings in 2002 (typically 3 readings per person per observation session), taken under acceptable environmental conditions, i.e., calm or slightly rippled lake surface at midday and under clear skies (or skies with a few high clouds or high haze), ranged from 28.5 to 36.9 m (Table 2).

Secchi disk readings taken between 1982 and 2001 were generally in the mid-high 20s and low 30s each year from June through September. The highest (deepest) readings usually occurred in late June and July and the lowest in August (data not shown). Nonetheless, there were some differences in the temporal patterns during the past 20 years (Fig. 4). For example, in 1997 some readings exceeded 40 meters, whereas some readings in 1995 were less than 20 m in depth. Secchi disk readings in 2002 were consistent with those in 1982-2001 (Fig. 4).

Table 2. Crater Lake Secchi Disk (20-cm) Readings at Station 13, 2002.

| Date | Initial Time | Observer | Number of Readings | Average Reading (m) | Weather Conditions & Comments |
|---|---|---|---|---|---|
| 5-16 | 11:08 | Buktenica | 3 | 31.7 | high thin clouds 0.5" ripple |
| | | Girdner | 3 | 33.3 | |
| | | Salinas | 3 | 30.5 | |
| | | | Average | 31.8 | |
| 7-16 | 11:30 | Buktenica | 3 | 35.9 | 5% puffy clouds, Heavy smoke entered caldera 7/15 & cleared, moderate smoke in caldera today. Flat calm. |
| | | Girdner | 3 | 36.1 | |
| | | | Average | 36.0 | |
| 8-12 | 13:55 | Girdner | 3 | 28.5 | Clear. Tour boat wakes at times. |
| 9-10 | 12:25 | Buktenica | 3 | 36.8 | 100% clear. Calm, slight ripple at times. |
| | | Girdner | 3 | 37.0 | |
| | | | Average | 36.9 | |

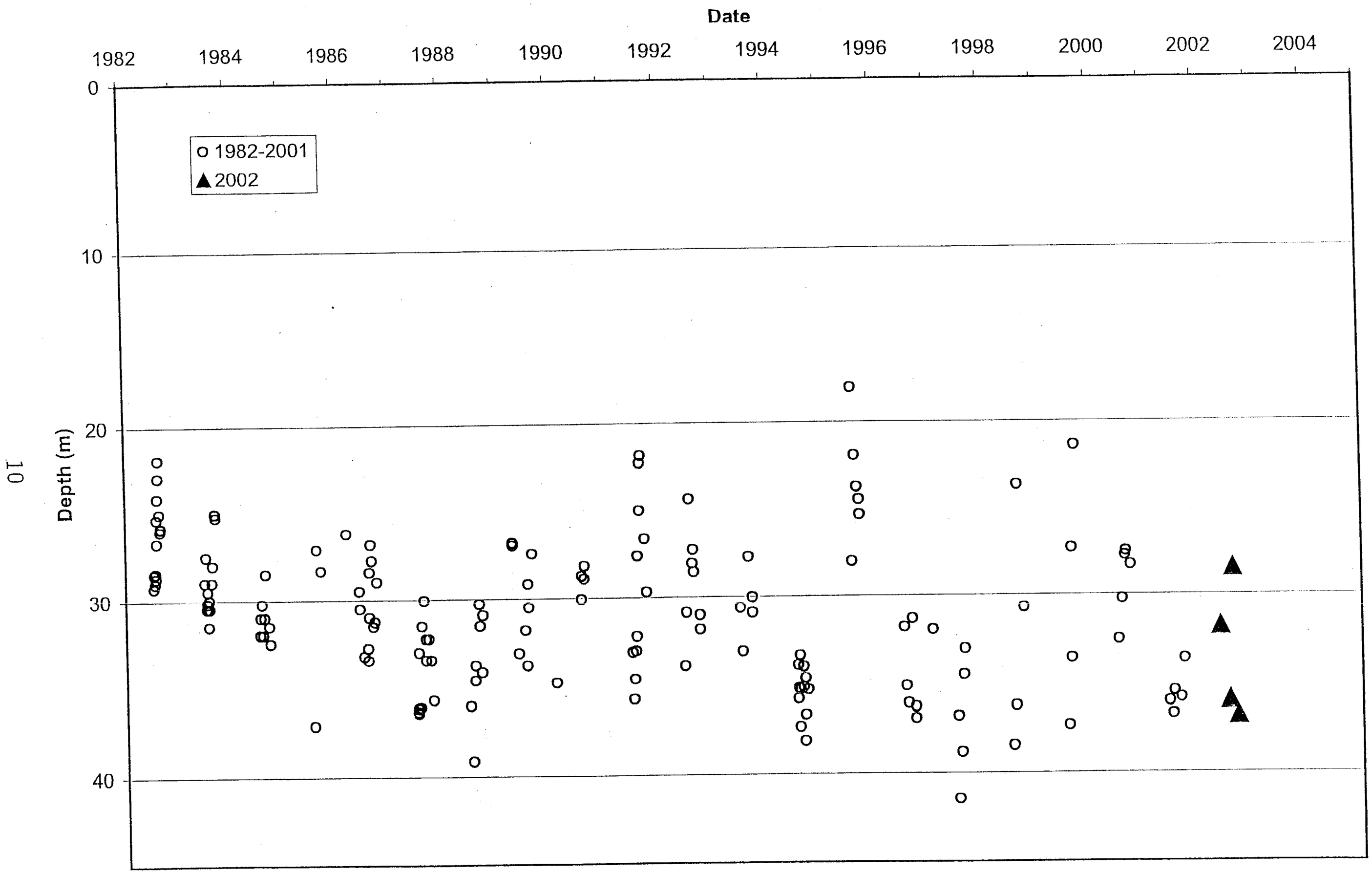



Figure 4. Secchi disk measurements in Crater Lake from 1968 to 2002.

Light

Light transmission (%) in 2002 was slightly depressed in the upper 150 m of the water column in May, July, August, and September (Figs. 5 - 8). Below 300 m, the percent light transmission was near 90% during the field season.

The depth of 1% of the incident solar radiation was typically between 90 and 110 m from 1996 to 2002. A low reading was recorded during the January field trip in 1997 (Fig. 9).

Water Quality

Near-surface temperature in 2002 was about 4°C in May (Fig. 5), 16°C in July (Fig. 6), about 15°C in August (Fig. 7), and 14°C in September (Fig. 8). The lake was thermally stratified in July, August, and September (Figs. 6 - 8).

Lake pH generally was highest (7.7 - 7.9) in the upper 100 m of the water column. Below 100 m, pH decreased slightly with increasing depth (Table 3).

Conductivity ranged from about 112 to 116 µmhos/cm (Table 3). In general, conductivity was highest in the lower strata of the water column. Total alkalinity ranged from about 26 to 28 mg/l (as $CaCO_3$) (Table 3).

Dissolved oxygen (DO) concentrations typically were lowest in the upper strata of the water column during thermal stratification (Table 3). DO concentrations generally were highest at the mid-depths and then decreased in concentration with increased lake depth. In May, before thermal stratification, DO concentrations were fairly uniform in the water column except for a slightly depressed value at 550 m. Nonetheless, the water column was well oxygenated throughout the sampling season.

Total phosphorus ranged from 14 to 20 µg/L (Table 4). Orthophosphate-P ranged from 9 to 14 µg/L. Total phosphorus was variable in concentration within the water column whereas orthophosphate-P was highest in concentration in the deep lake.

Concentrations of ammonia-N ranged from 0 to 4 µg/L (Table 5). Total Kjeldahl-N was highest in concentration (30 - 50 µg/L) from 0 - 100 m in August, whereas it was fairly uniform at 20 µg/L from 0 to 550 m in May (Table 5). Nitrate-N was highest in concentration from 300 to 550 m (Table 5).

Water samples for cation and anion analyses were collected from near the lake surface to a depth of 550 m in August (Table 6). Sodium ranged from 9.9 - 10.6 mg/L, potassium was

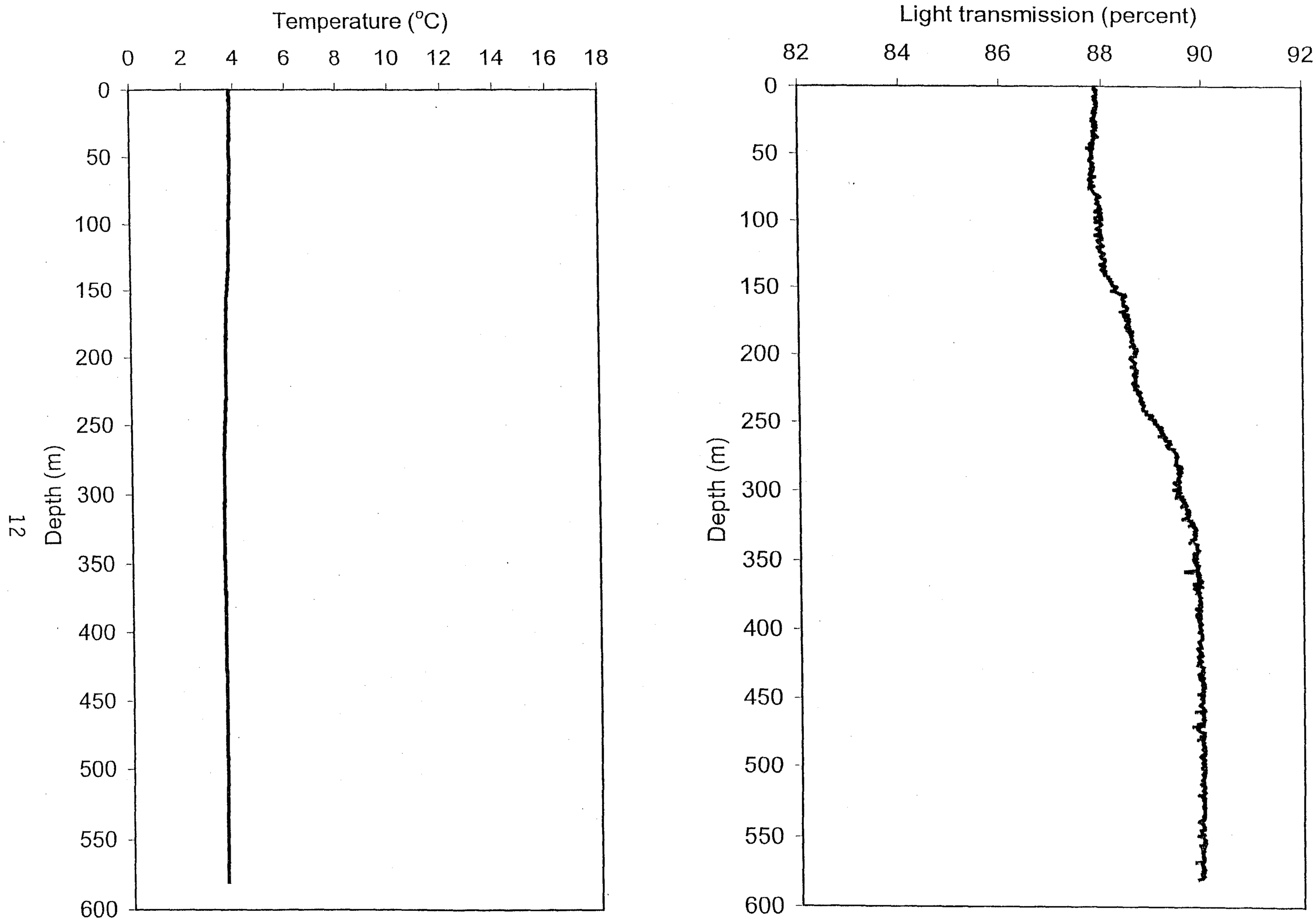



Figure 5. Temperature (°C) and light transmission (%) from the lake surface to near the lake bottom, May 15. 2002 at Station 13.

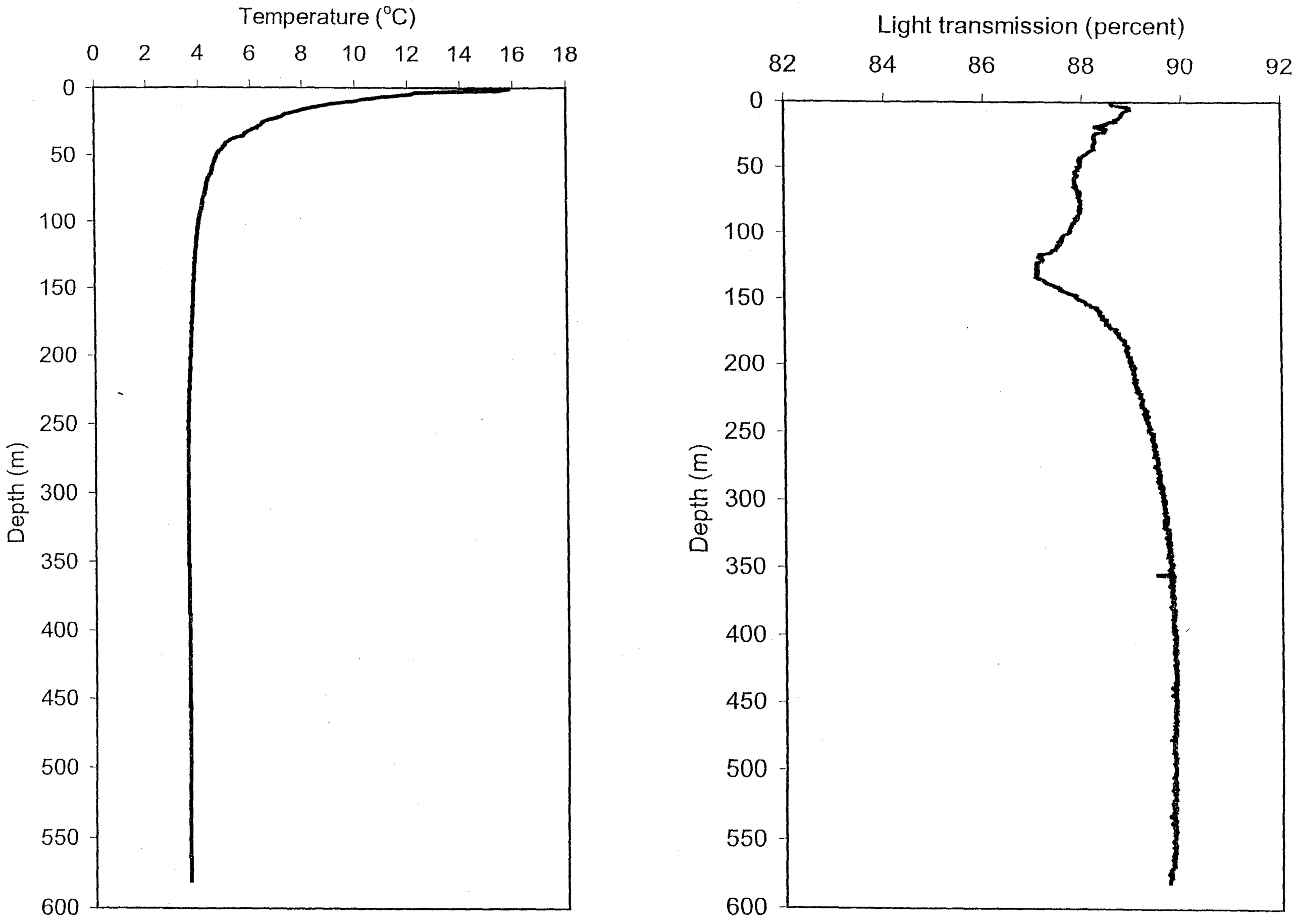



Figure 6. Temperature (°C) and light transmission (%) from the lake surface to near the lake bottom, July 15, 2002 at Station 13.

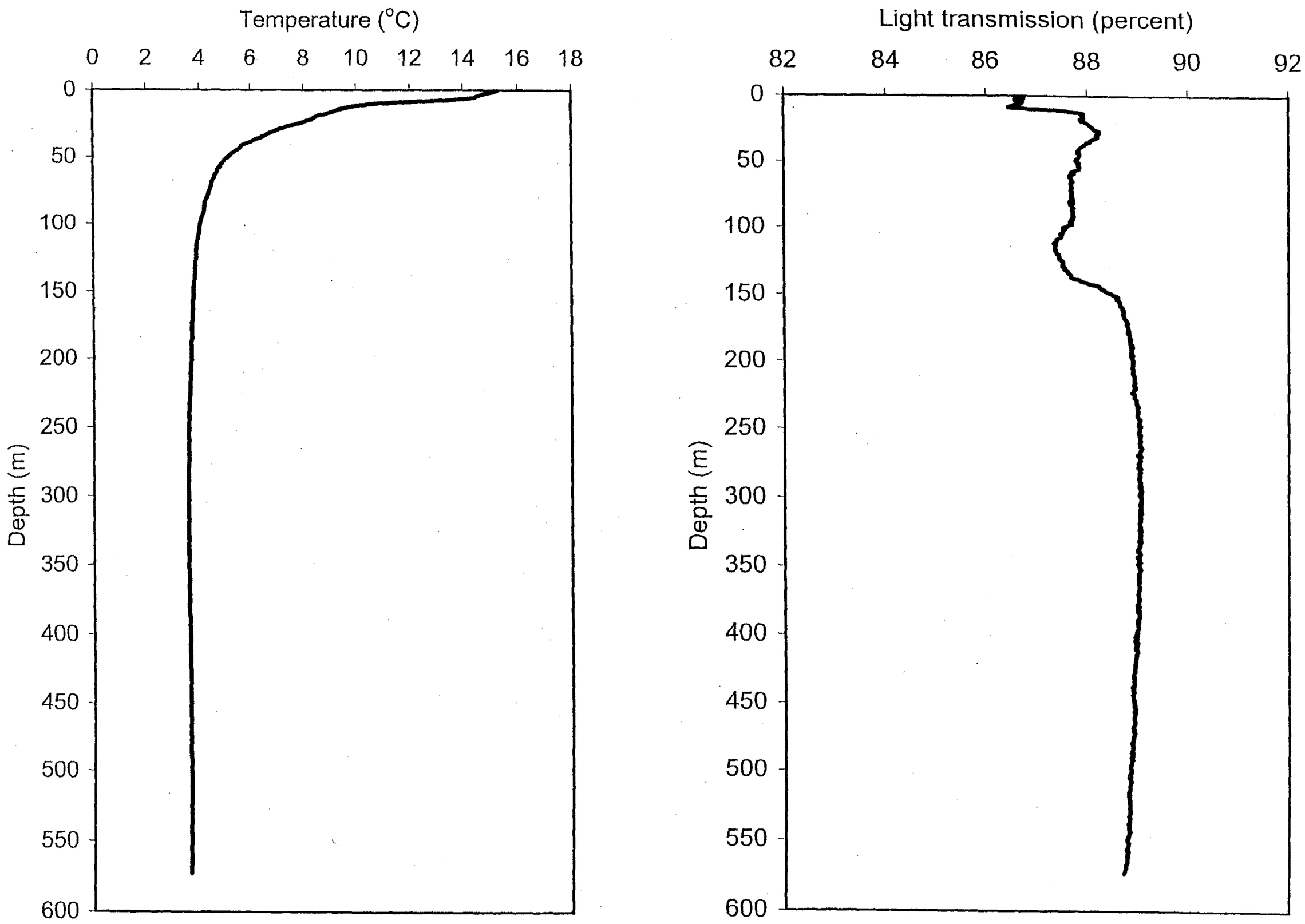
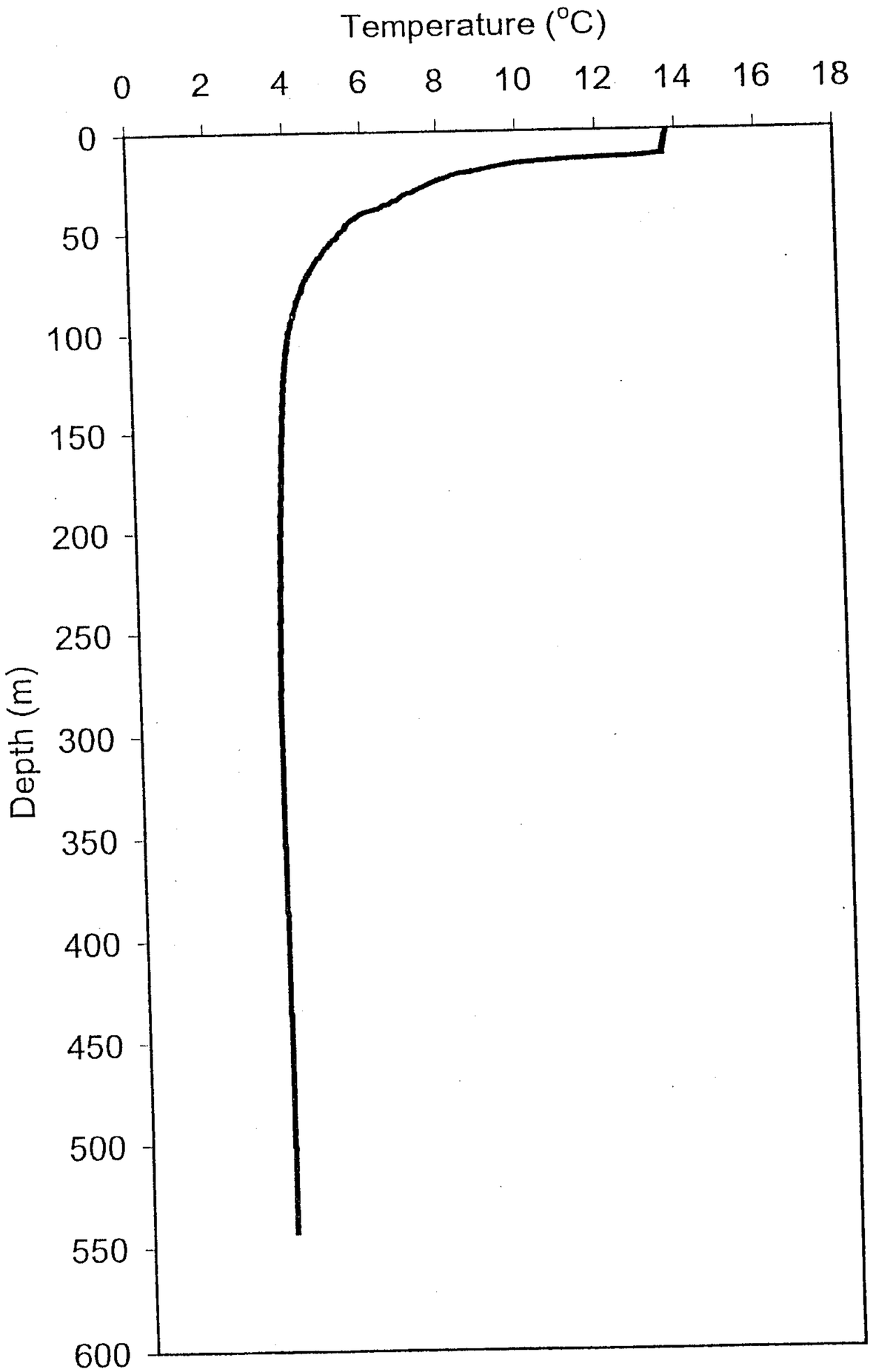



Figure 7. Temperature (°C) and light transmission (%) from the lake surface to near the lake bottom, August 12, 2002 at Station 13.



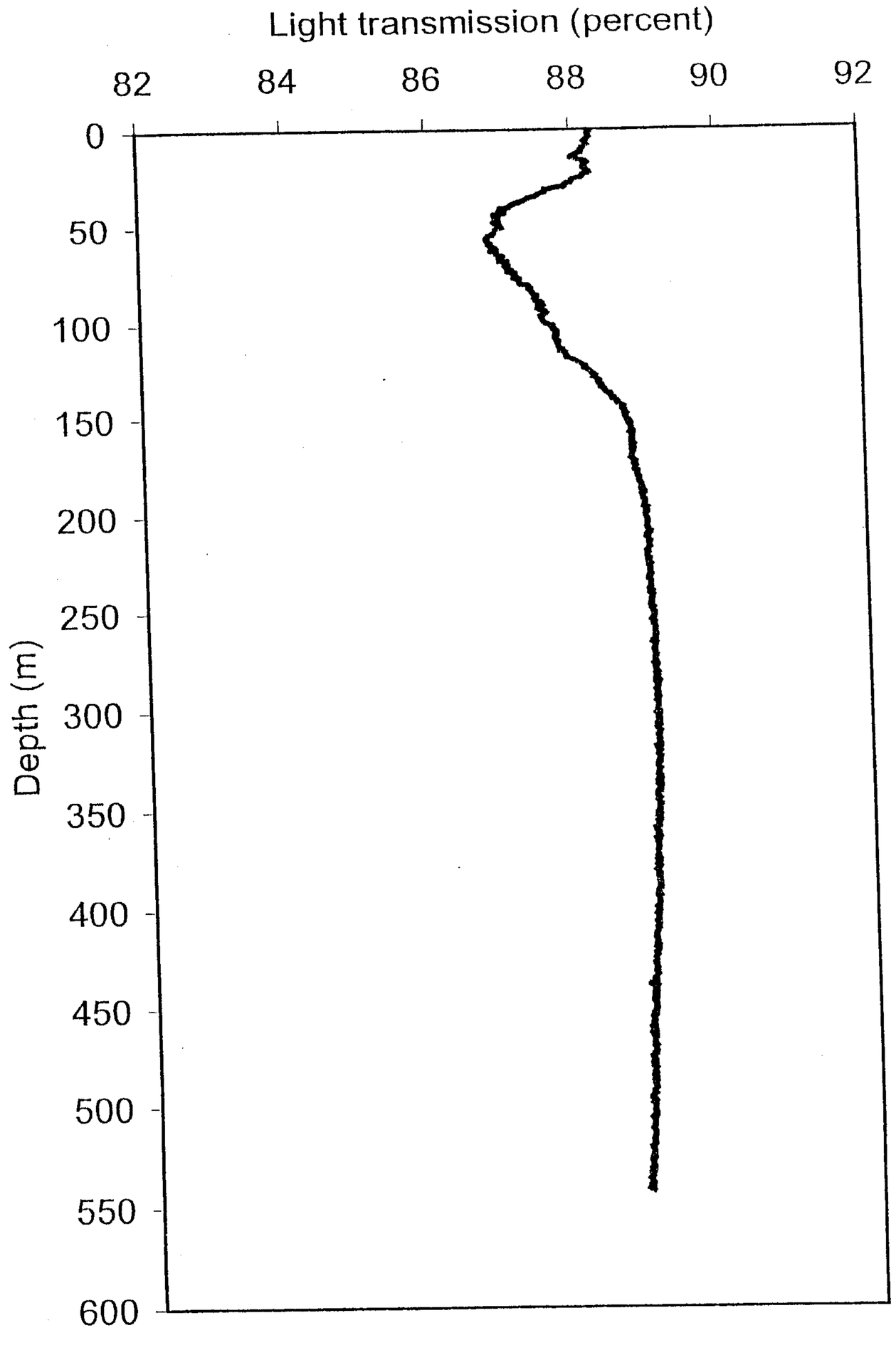




Figure 8. Temperature (°C) and light transmission (%) from the lake surface to near the lake bottom, September 10, 2002 at Station 13.

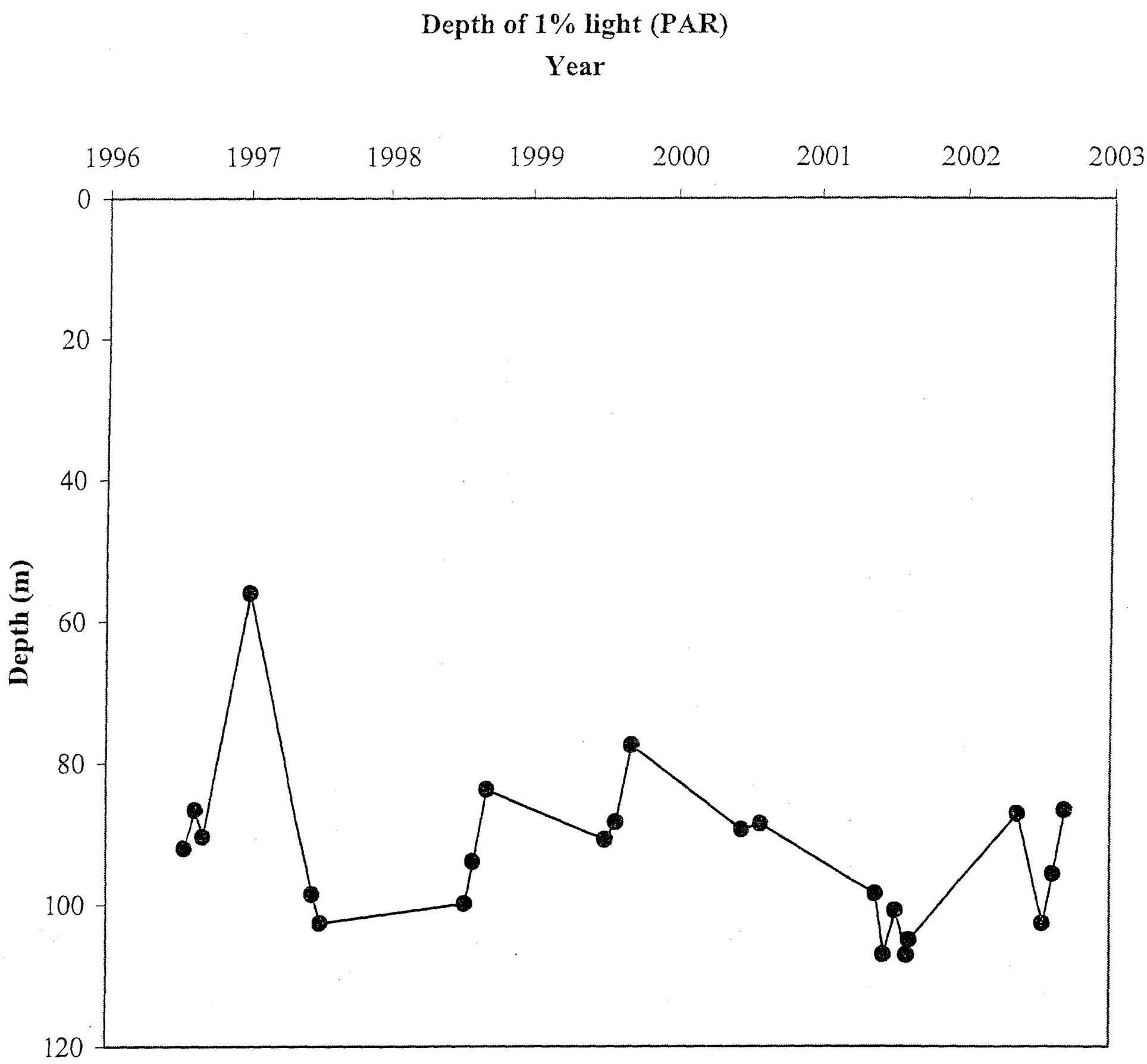



Figure 9. Depth of 1% of the incident solar radiation (expressed as PAR) from 1996 to 2002.

Table 3. Crater Lake Water Chemistry, 2002.

| Sample Date | Depth | pH | Conductivity | Alkalinity mg/l | Dissolved Oxygen mg/l |
|---|---|---|---|---|---|
| 5-15 | 0 | 7.7 | 111.9 | 28.4 | 9.86 |
| | 5 | 7.7 | 111.8 | 26.1 | 9.88 |
| | 10 | 7.7 | 111.9 | 26.1 | 9.94 |
| | 20 | 7.7 | 112.0 | 26.6 | 9.90 |
| | 60 | 7.7 | 112.1 | 26.2 | 9.94 |
| | 100 | 7.7 | 111.8 | 26.2 | 9.90 |
| | 200 | 7.7 | 112.2 | 26.2 | 9.84 |
| | 300 | 7.6 | 112.4 | 26.2 | 9.48 |
| | 400 | 7.5 | 113.7 | 26.5 | 9.30 |
| | 500 | 7.5 | 113.8 | 27.2 | 9.62 |
| | 550 | 7.5 | 115.2 | 26.8 | 9.03 |
| 7-16 | 0 | 7.8 | 112.7 | 25.9 | - |
| | 5 | 7.8 | 112.5 | 25.9 | 8.55 |
| | 10 | 7.8 | 112.5 | 26.1 | 9.15 |
| | 20 | 7.8 | 112.0 | 25.8 | 9.80 |
| | 60 | 7.8 | 112.1 | 25.9 | 10.62 |
| | 100 | 7.8 | 112.2 | 26.1 | 10.38 |
| | 200 | 7.7 | 112.5 | 26.9 | 9.84 |
| | 300 | 7.7 | 113.2 | 26.0 | 9.70 |
| | 400 | 7.7 | 112.6 | 26.0 | 10.04 |
| | 500 | 7.7 | 113.0 | 26.5 | 9.46 |
| | 550 | 7.6 | 113.8 | 26.5 | 9.58 |
| 8-13 | 0 | 7.5 | 113.6 | 26.3 | 8.04 |
| | 5 | 7.8 | 112.5 | 25.9 | 8.41 |
| | 10 | 7.8 | 111.9 | 26.7 | 9.53 |
| | 20 | 7.7 | 112.0 | 26.4 | 10.15 |
| | 60 | 7.8 | 112.3 | 26.9 | 10.83 |
| | 100 | 7.7 | 112.3 | 26.7 | 10.56 |
| | 200 | 7.7 | 112.4 | 26.7 | 10.17 |
| | 300 | 7.6 | 112.6 | 26.7 | 9.94 |
| | 400 | 7.5 | 114.4 | 27.2 | 9.82 |
| | 500 | 7.4 | 115.1 | 27.4 | 9.61 |
| | 550 | 7.5 | 115.6 | 27.4 | 9.59 |
| 9-10 | 0 | 7.8 | 114.0 | 26.8 | 8.24 |
| | 5 | 7.8 | 112.9 | 27.0 | 8.28 |
| | 10 | 7.8 | 113.1 | 26.6 | 8.31 |
| | 20 | 7.8 | 113.1 | 26.4 | 10.19 |
| | 60 | 7.9 | 111.9 | 26.3 | 11.00 |
| | 100 | 7.7 | 111.7 | 26.4 | 10.52 |
| | 200 | 7.7 | 112.1 | 26.8 | 10.15 |
| | 300 | 7.6 | 113.2 | 26.8 | 9.98 |
| | 400 | 7.5 | 114.4 | 26.9 | 9.73 |
| | 500 | 7.5 | 115.6 | 27.5 | 9.63 |
| | 550 | 7.5 | 115.5 | 27.4 | 9.49 |

Table 4. Crater Lake Total Phosphorus and Orthophosphate-P Profiles, 2002. Concentration Expressed as µg/L.

| Depth (m) | Orthophosphate | | Total Phosphorus | |
|---|---|---|---|---|
| | 5/15 | 8/13 | 5/15 | 8/13 |
| 0 | 9 | 10 | 16 | 20 |
| 5 | 9 | 10 | 17 | 16 |
| 10 | 9 | 10 | 15 | 15 |
| 20 | 10 | 10 | 18 | 14 |
| 60 | 9 | 9 | 17 | 15 |
| 100 | 9 | 10 | 16 | 18 |
| 200 | 9 | 11 | 17 | 15 |
| 300 | 11 | 12 | 16 | 18 |
| 400 | 11 | 13 | 19 | 19 |
| 500 | 11 | 14 | 19 | 18 |
| 550 | 12 | 14 | 20 | 18 |

Table 5. Crater Lake Kjeldahl-N, Nitrate-N, and Ammonia-N Profiles for Selected Depths, 2002. Concentration Expressed as µg/L. Zero Values Indicate Below Detection Limits.

| Depth (m) | Total Kjeldahl-N | | Nitrate-N | | | | Ammonia-N | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 5/15 | 8/13 | 5/15 | 7/16 | 8/13 | 9/10 | 5/15 | 7/16 | 8/13 | 9/10 |
| 0 | 20 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 20 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 10 | 20 | 40 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 4 |
| 20 | 20 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 60 | 20 | 30 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 100 | 20 | 50 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 200 | 20 | 20 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 300 | 0 | 20 | 3 | 9 | 8 | 6 | 0 | 0 | 0 | 0 |
| 400 | 20 | 20 | 7 | 0 | 11 | 10 | 0 | 0 | 0 | 0 |
| 500 | 20 | 20 | 8 | 8 | 13 | 11 | 0 | 0 | 0 | 0 |
| 550 | 20 | 20 | 11 | 10 | 14 | 12 | 0 | 0 | 0 | 0 |

Table 6. Crater Lake Concentrations of Selected Cations and Anions in August 2002. Concentration Expressed as mg/L.

| Depth (m) | Na | K | Ca | Mg | SO4 | Cl | SiO2 |
|---|---|---|---|---|---|---|---|
| 0 | 10.1 | 1.8 | 6.9 | 3.0 | 3.4 | 10.3 | 8.4 |
| 5 | 9.9 | 1.8 | 6.9 | 3.0 | 3.4 | 10.3 | 8.4 |
| 10 | 10.0 | 1.7 | 6.8 | 2.9 | 3.4 | 10.2 | 8.4 |
| 20 | 9.9 | 1.7 | 6.8 | 2.9 | 3.4 | 10.2 | 8.3 |
| 60 | 10.1 | 1.8 | 6.8 | 3.0 | 3.4 | 10.2 | 8.3 |
| 100 | 10.0 | 1.7 | 6.8 | 2.9 | 3.4 | 10.2 | 8.4 |
| 200 | 10.1 | 1.8 | 6.9 | 3.0 | 3.4 | 10.3 | 8.3 |
| 300 | 10.2 | 1.8 | 6.9 | 3.1 | 3.4 | 10.3 | 8.4 |
| 400 | 10.3 | 1.8 | 7.1 | 3.0 | 3.2 | 10.5 | 8.5 |
| 500 | 10.4 | 1.8 | 7.1 | 3.1 | 3.5 | 10.7 | 8.6 |
| 550 | 10.6 | 1.8 | 7.2 | 3.1 | 3.5 | 10.5 | 8.6 |

1.7 - 1.8 mg/L, calcium from 6.8 - 7.2 mg/L, magnesium was 2.9 - 3.1 mg/L, chloride from 10.2 - 10.7 mg/L, silica from 8.3 - 8.6 mg/L, and sulfate-S from 3.2 - 3.5 mg/L.

The maximum near-surface temperature in 2002 was comparable to those from 1982-2001 (Larson 2003). For the other water quality variables, the 2002 values were consistent with those recorded from 1982 - 2000 (Larson 1998, 1999, 2003).

Chlorophyll

In 2002, chlorophyll concentrations integrated to 200 m were 23.4 mg/m$^2$ in May,14.0 mg/m$^2$ in July, 20.7 mg/m$^2$ in August, and 23.6 mg/m$^2$ in September. Maximum concentrations occurred between 140 and 160 m in May, at 140 m in July, 120 - 140 m in August; and at 120 m in September (Figs. 10 - 13). Insitu depth distributions of chlorophyll were similar to the invitro samples, except in May (Figs. 10 - 13). The concentrations per m$^2$ in 2002 were similar to those observed since 1992, but were much less than those observed from 1986 - 91 (Figs. 14 and 15). The depth distributions in 2002 were also similar to those observed in prior years.

Primary Production

In 2002, primary production ranged from about 20 - 60 mg C/m$^2$/hr (Fig. 16). Primary production generally ranged between about 40 to 60 mg C/m$^2$/hr from 1987 to 1990, whereas it typically averages about 30 mg C/m$^2$/hr during 1996 - 2001 (Fig. 16). (Note: analytical problems in the laboratory resulted in frequent abnormal results for samples collected between 1991 and 1995. Dr. Thomas Berman provided a solution to the problem in 1995. He recommended that we increase the concentration of the fuming acid to which we expose the filters after filtration).

Zooplankton

The zooplankton assemblage in 2002 consisted of one crustacean taxon (*Bosmina longirostris*) and nine rotifer taxa (*Synchaeta oblonga, Polyarthra dolichoptera, Philodina acuticornis, Keratella quadrata, Keratella cochlearis, Kellicottia longispina, Filina terminalis, Conochilus unicornis,* and *Collotheca pelagica*). Two additional crustacean taxa (*Daphnia pulicaria*, and *Daphnia ambigua*) were observed at extremely low densities in a few months (only one individual counted in split subsample). Total zooplankton densities ranged from 6 x 10$^5$/m$^2$ in July to 16.6 x 10$^5$/m$^2$ in September (Fig. 17). Total densities were relatively low compared to most observations since 1985 (Fig. 17). The abundances of the taxa from 1985 through 2002 are shown in Figures 18-29. Several taxa tended to be consistently present from year to year (*Bosmina longirostris, Synchaeta oblonga, Polyarthra dolichoptera*, and *Filina*

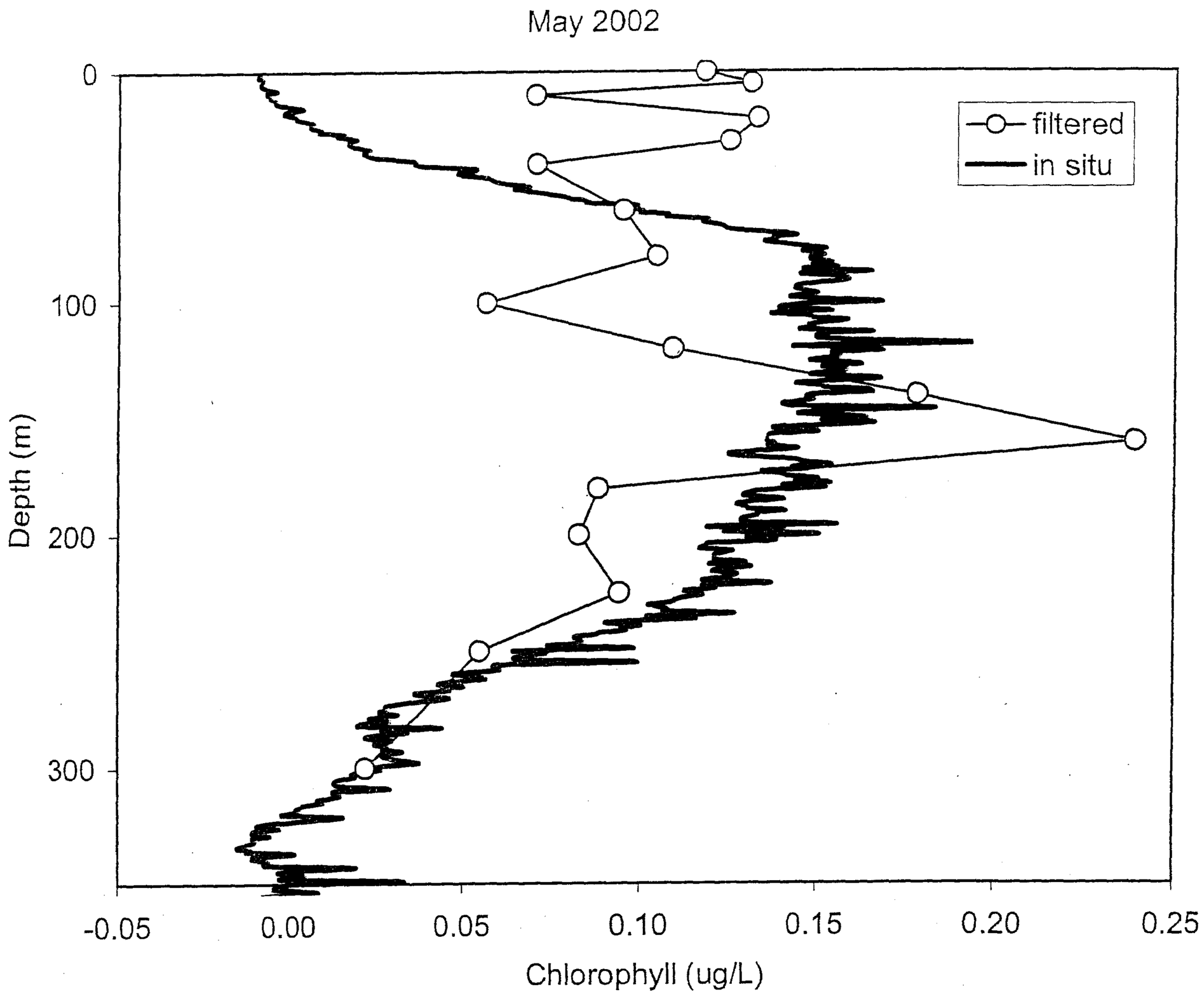



Figure 10. Chlorophyll profile near surface to 300 m, May 15, 2002 at Station 13.

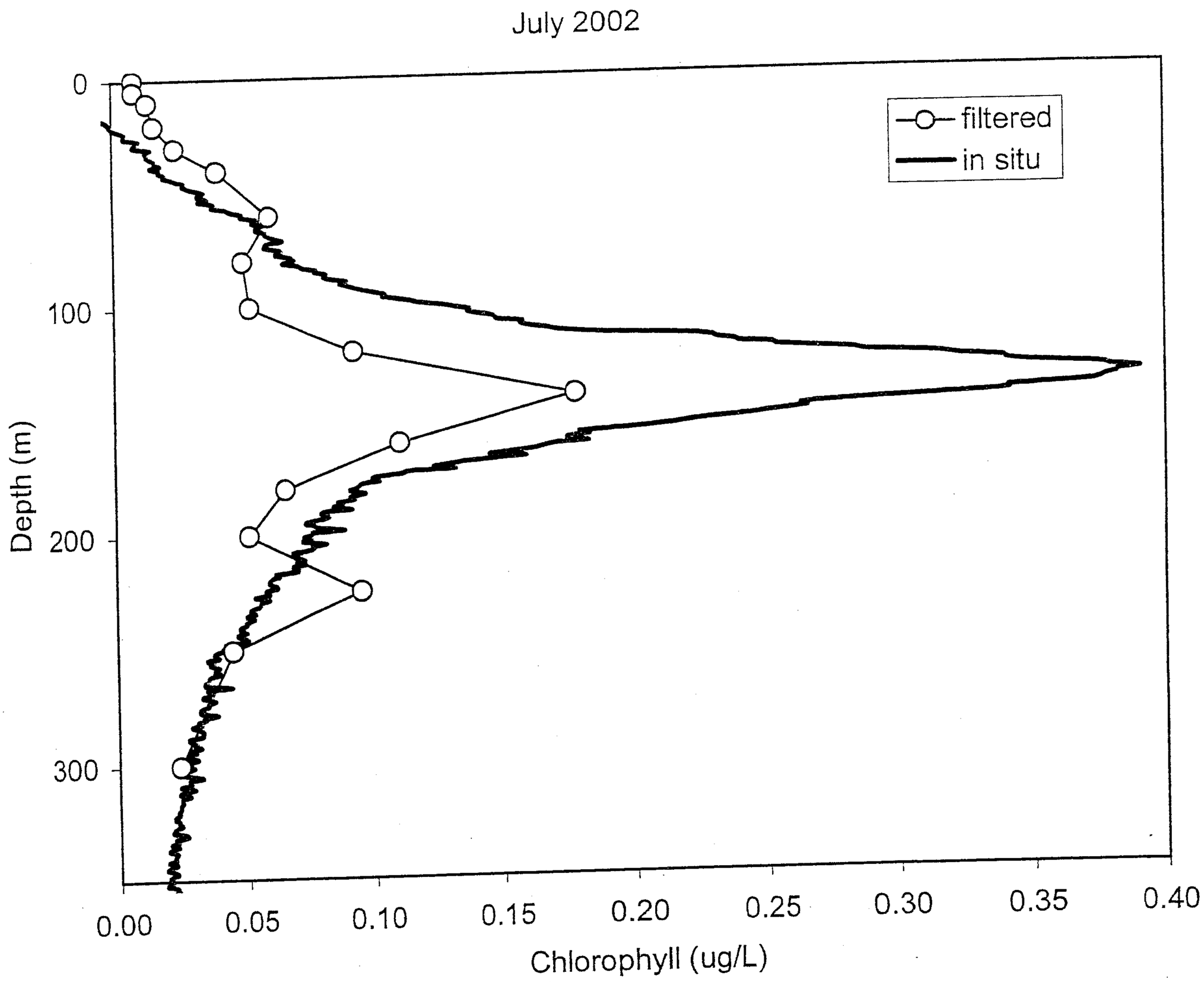



Figure 11. Chlorophyll profile near surface to 300 m, July 16, 2002 at Station 13.

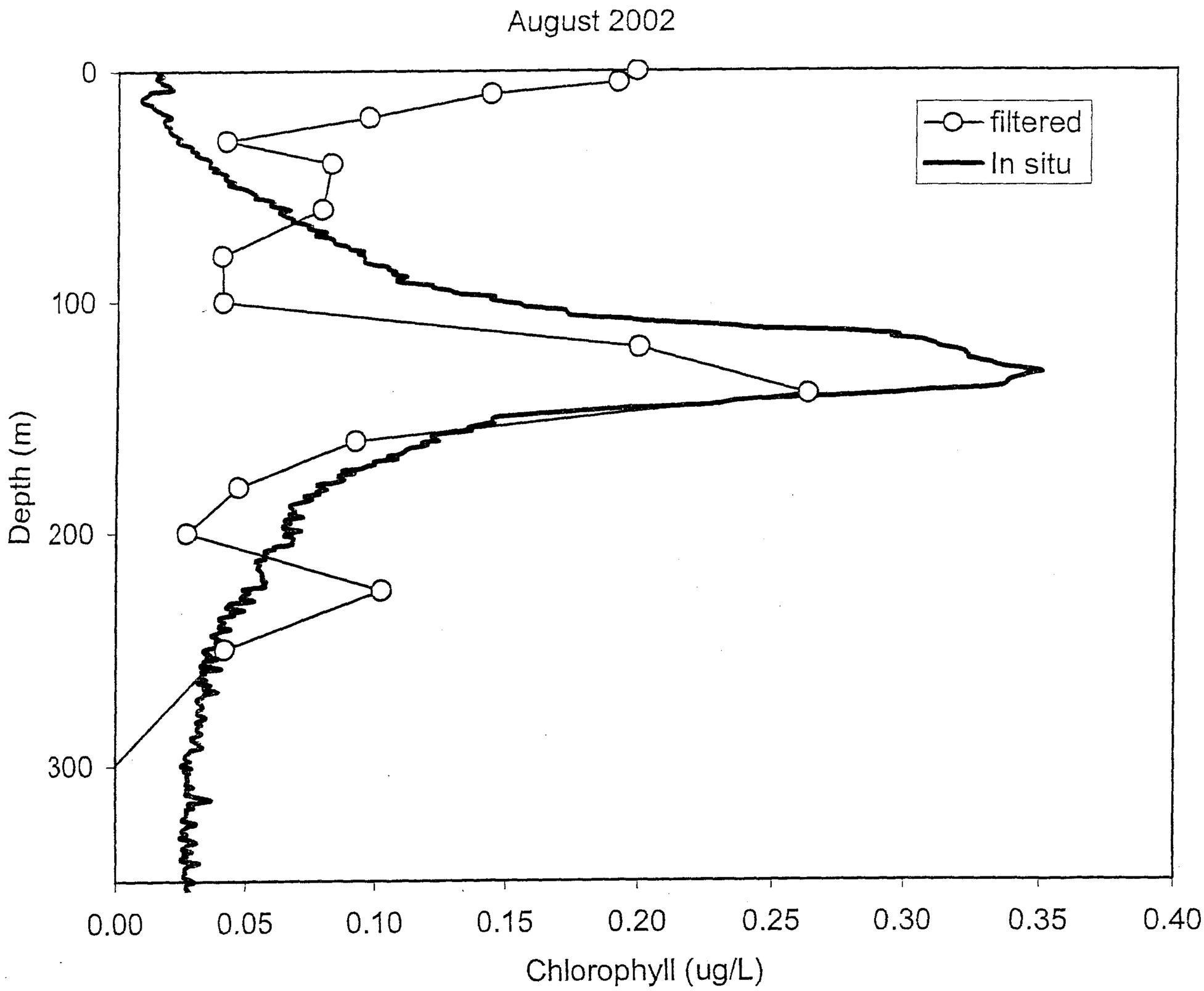



Figure 12. Chlorophyll profile near surface to 300 m, August 13, 2002 at Station 13.

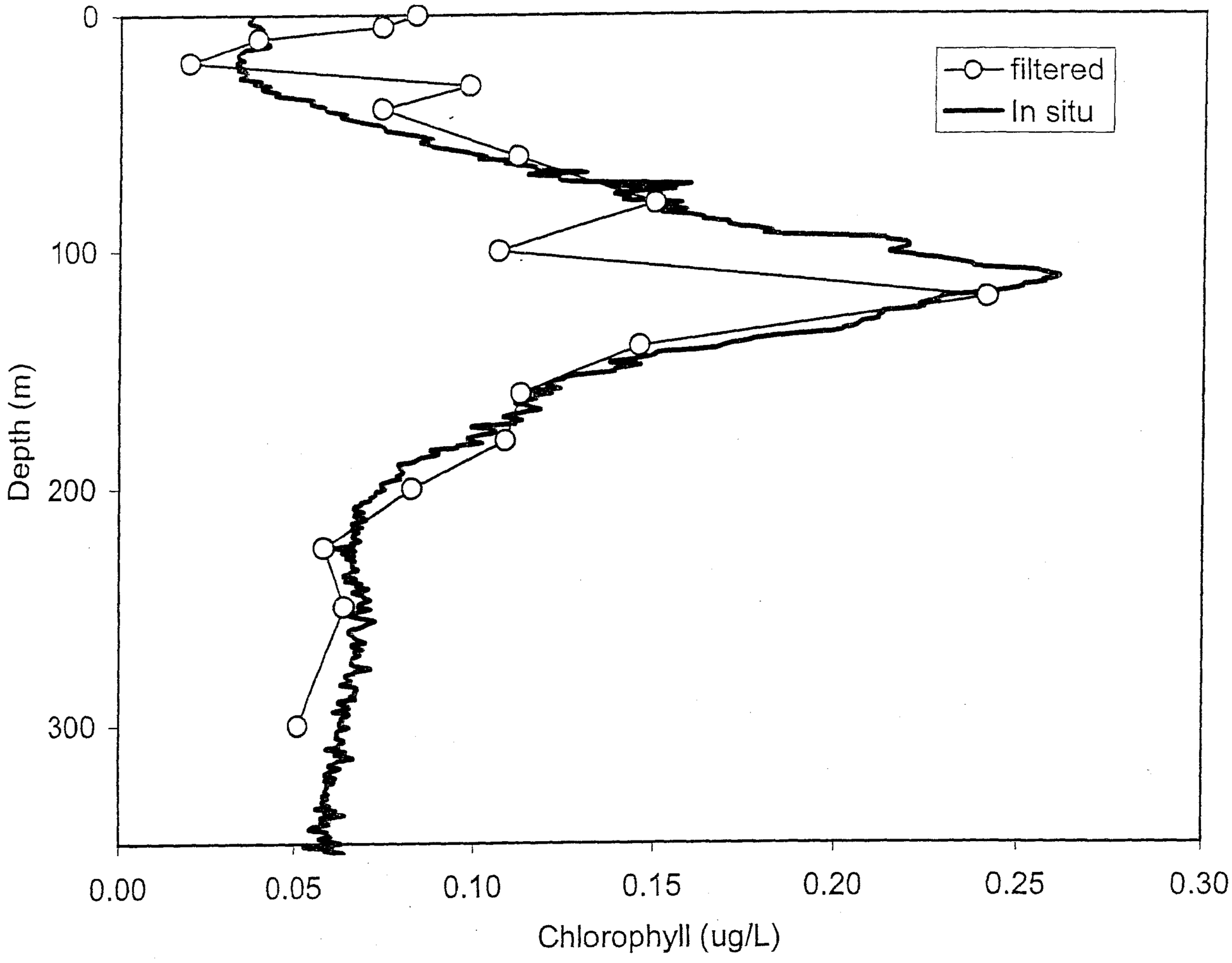



Figure 13. Chlorophyll profile near surface to 300 m, September 10, 2002 at Station 13.

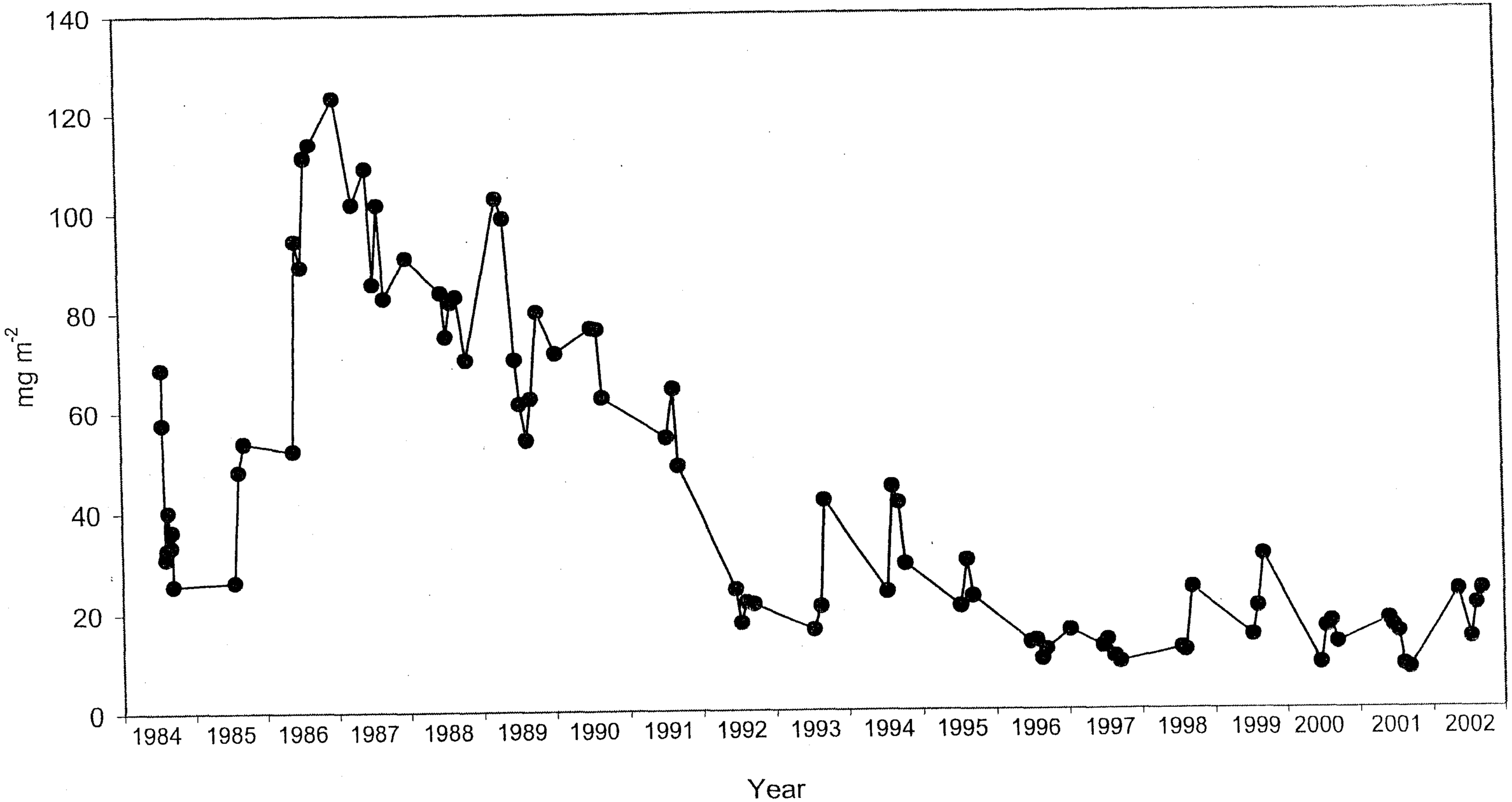



Figure 14. Chlorophyll concentrations integrated to a depth of 200 m in Crater Lake from 1984 to 2002.

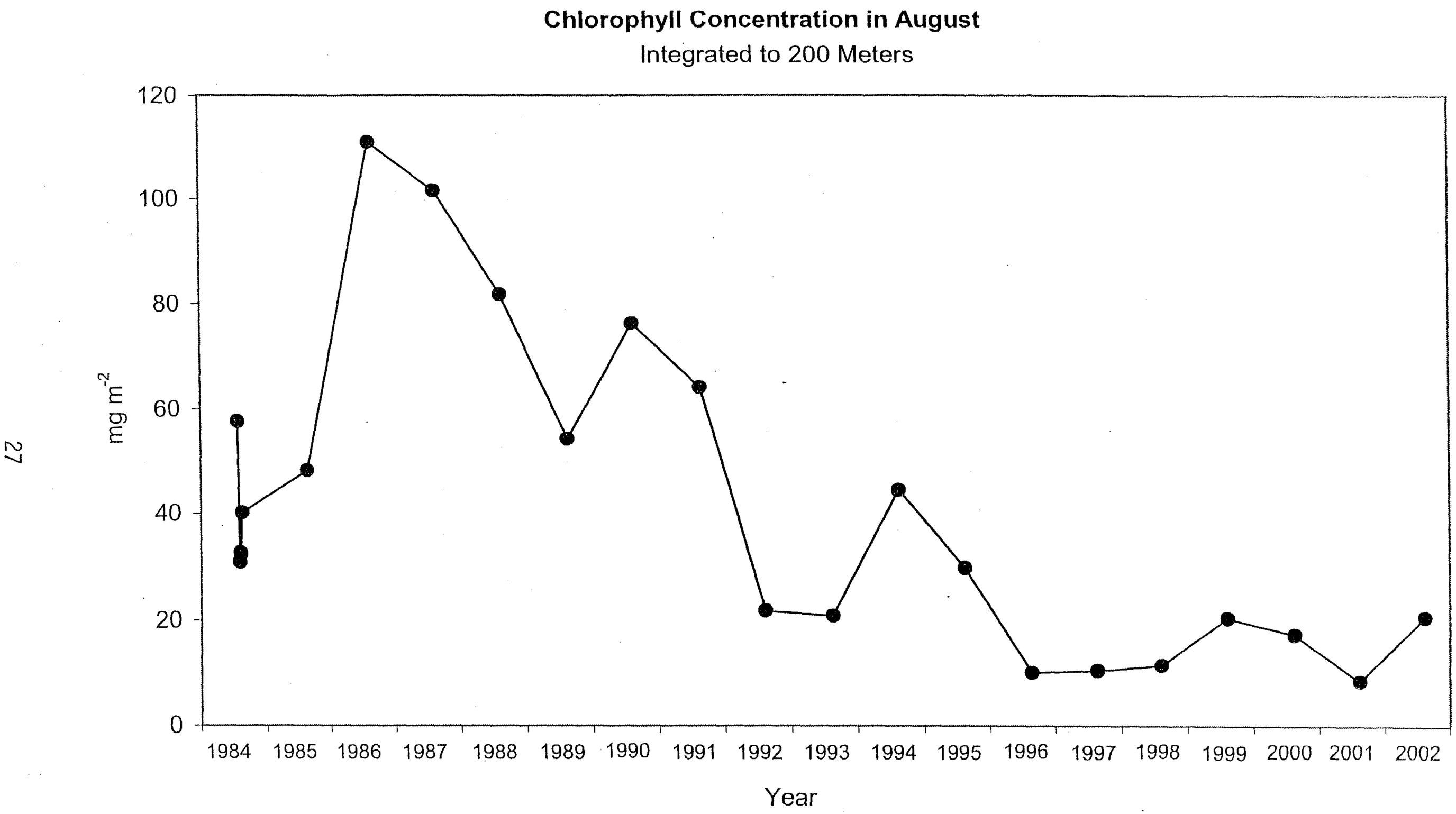



Figure 15. Chlorophyll concentrations integrated to a depth of 200 m in Crater Lake in August from 1984 to 2001.

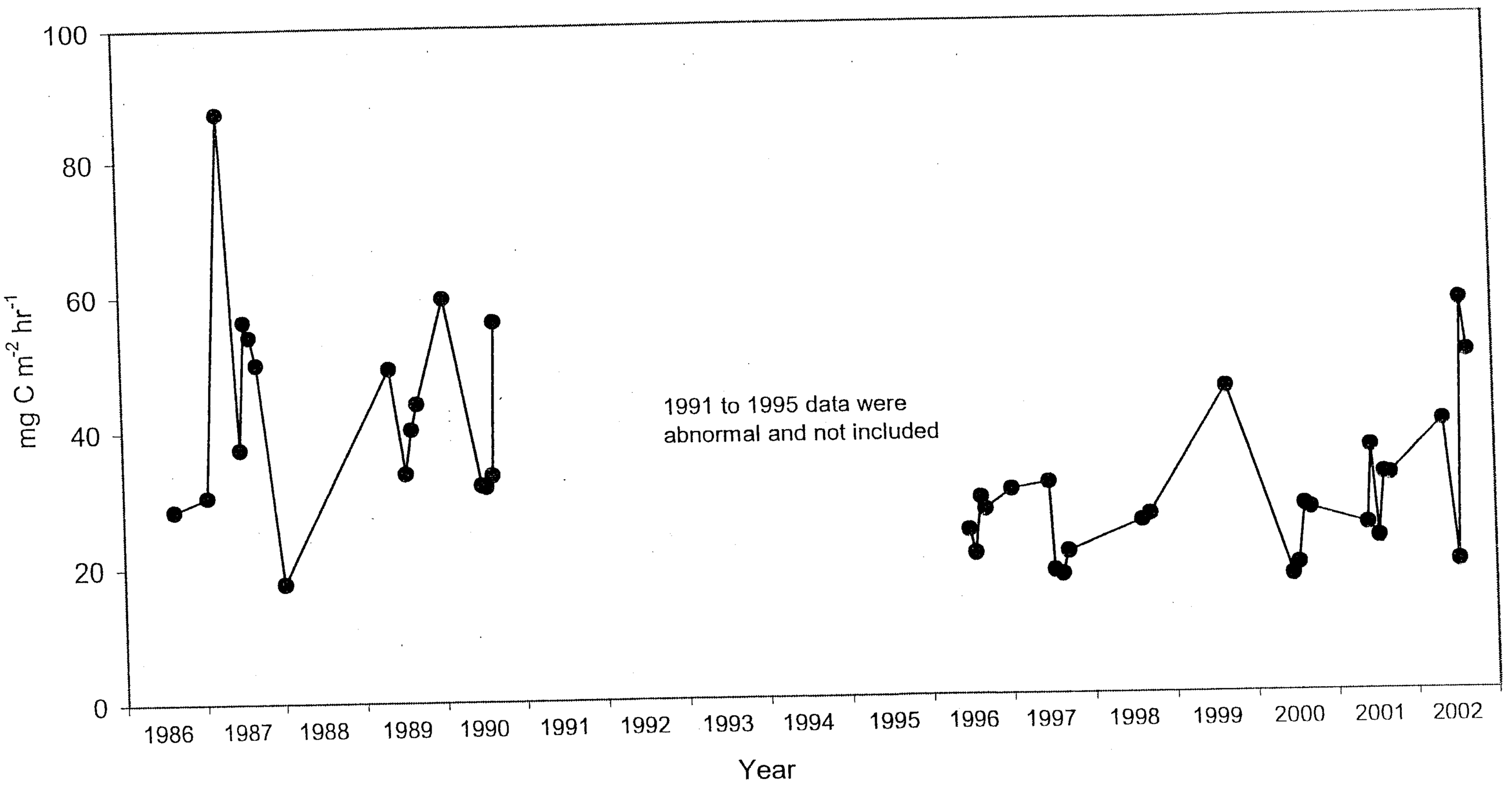



Figure 16. Primary production integrated to a depth of 180 m in Crater Lake from 1986 to 2002, except 1991 to 1995 and July 1999.

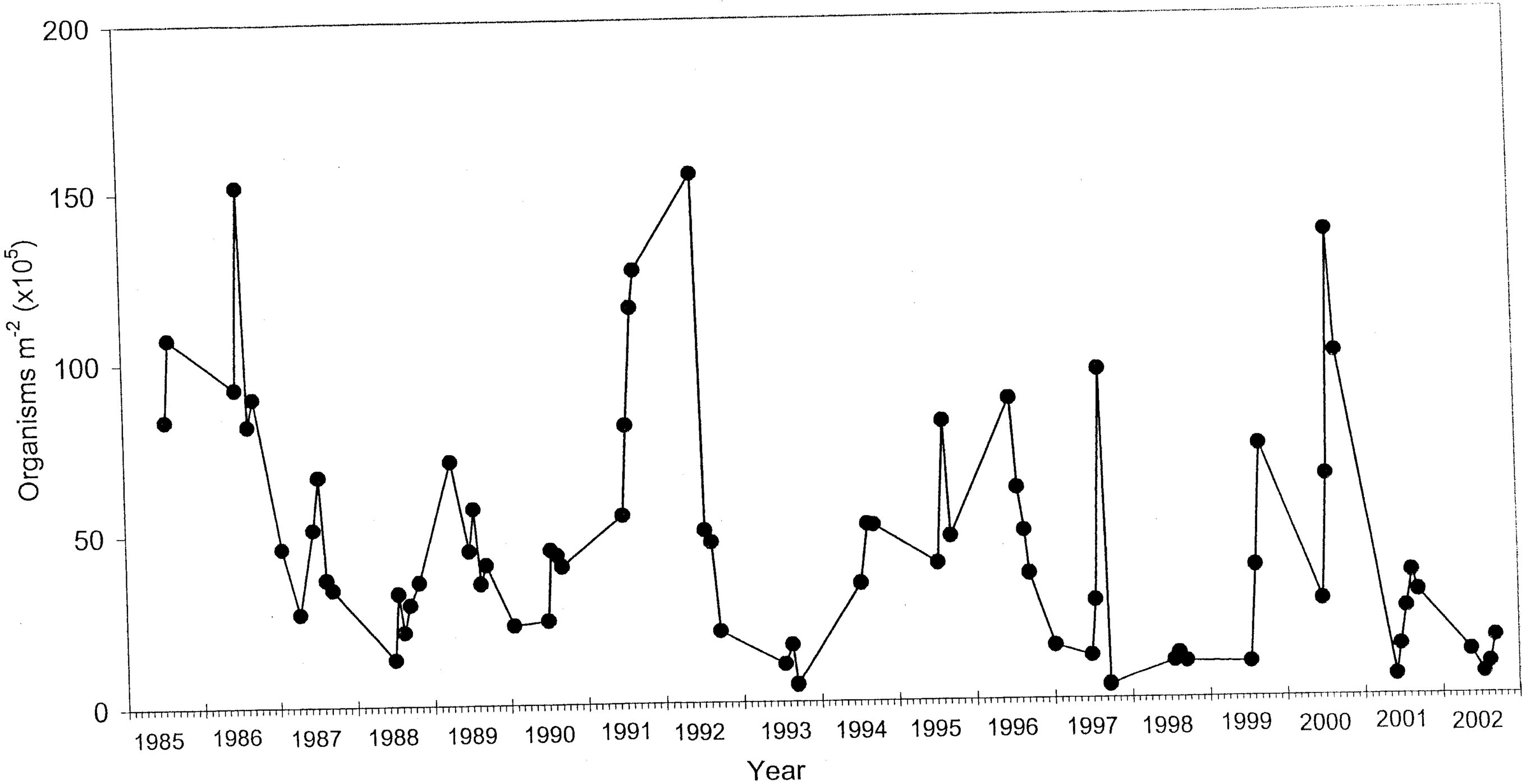



Figure 17. Zooplankton densities integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

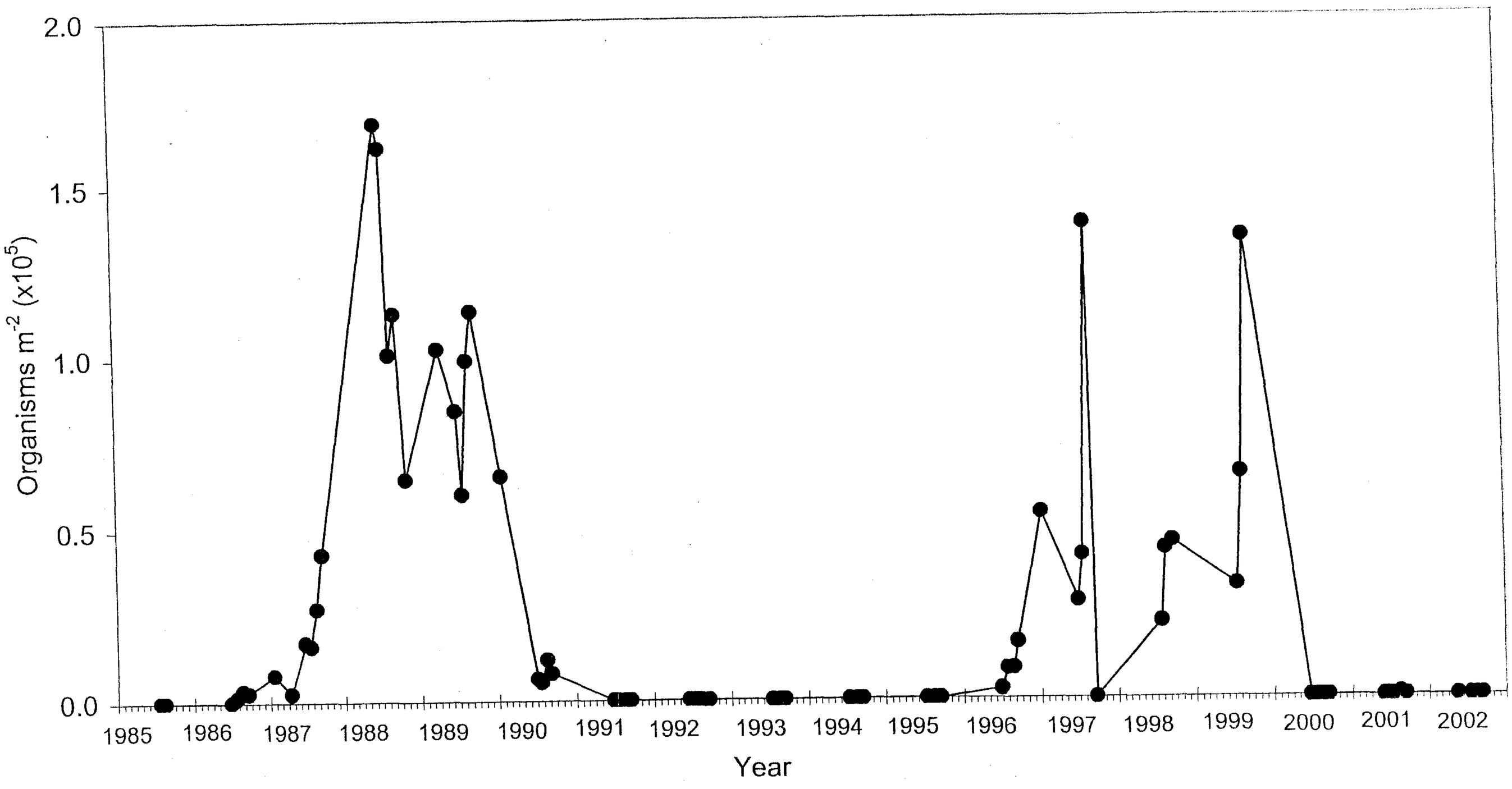



Figure 18. Densities of *Daphnia pulicaria* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

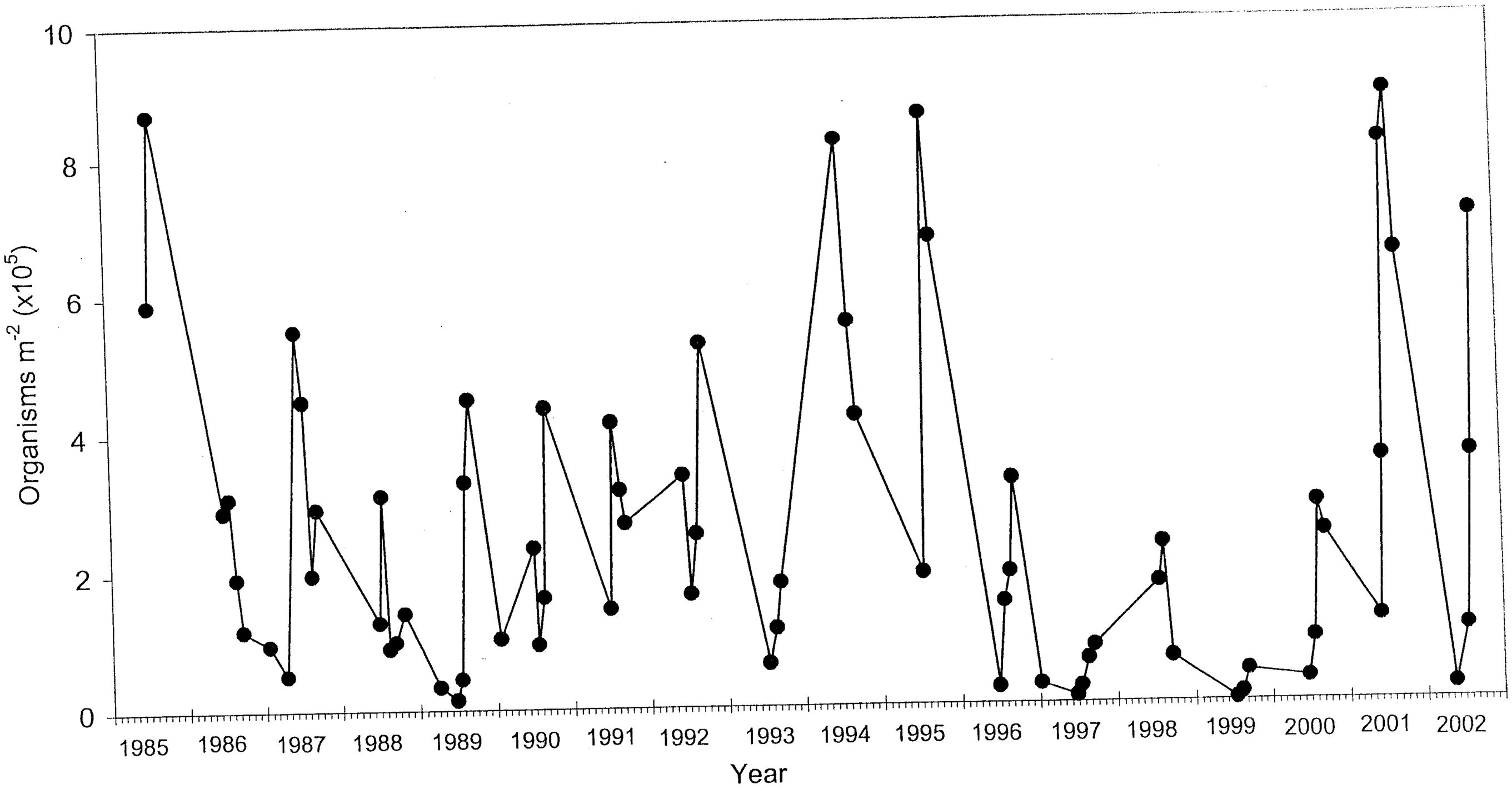



Figure 19. Densities of *Bosmina longirostris* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

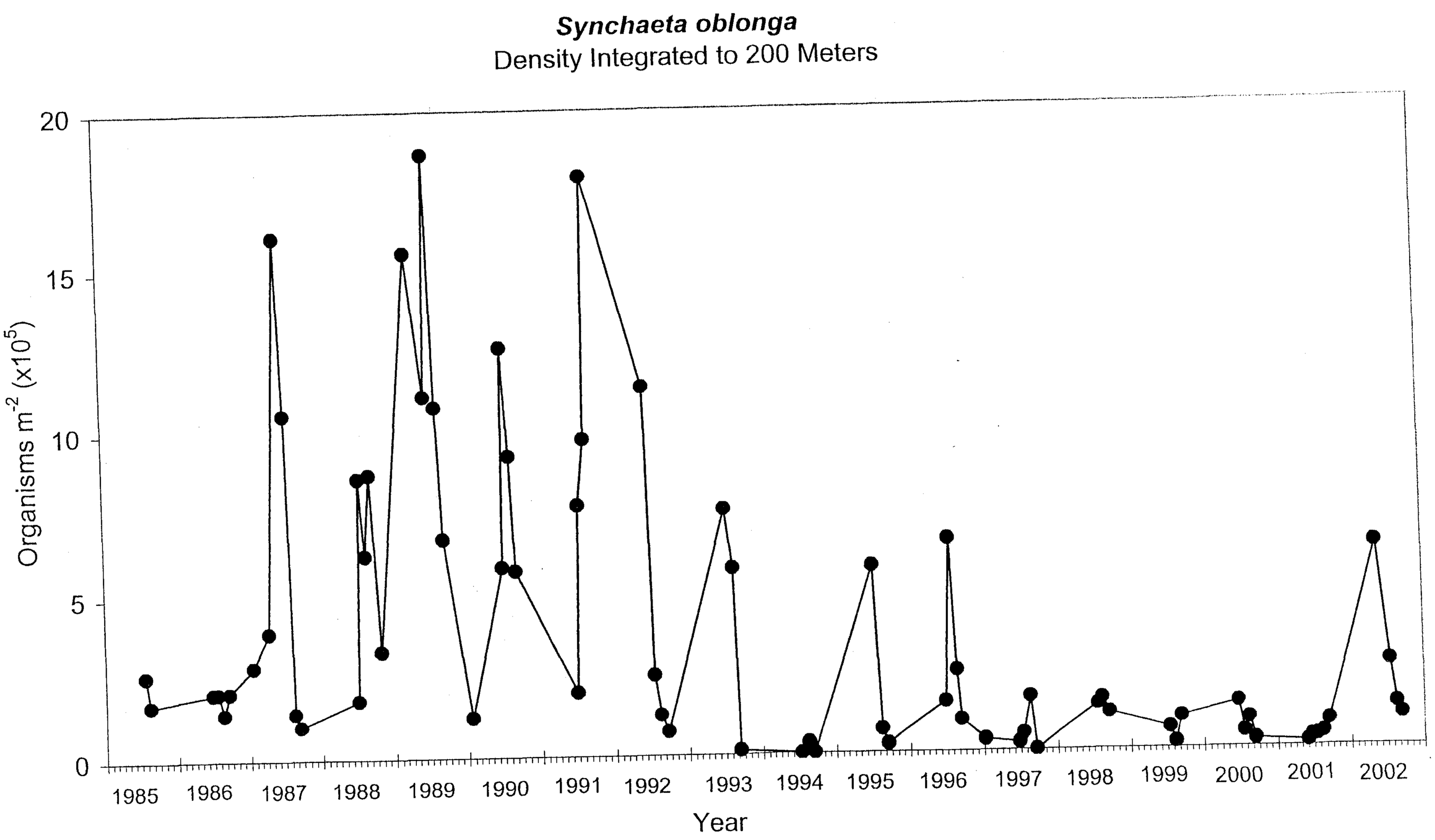



Figure 20. Densities of *Synchaeta oblonga* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

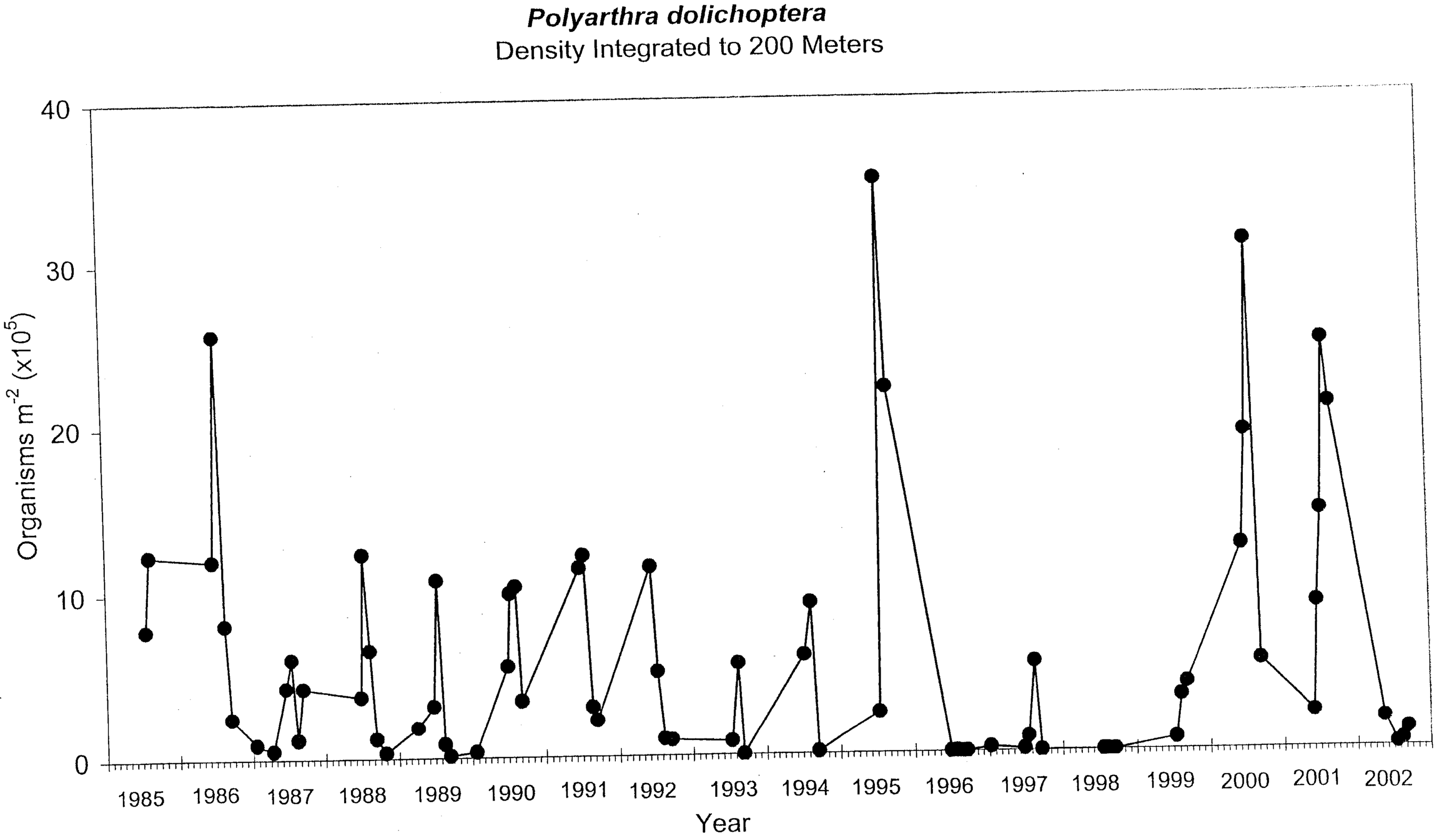



Figure 21. Densities of *Polyarthra dolichoptera* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

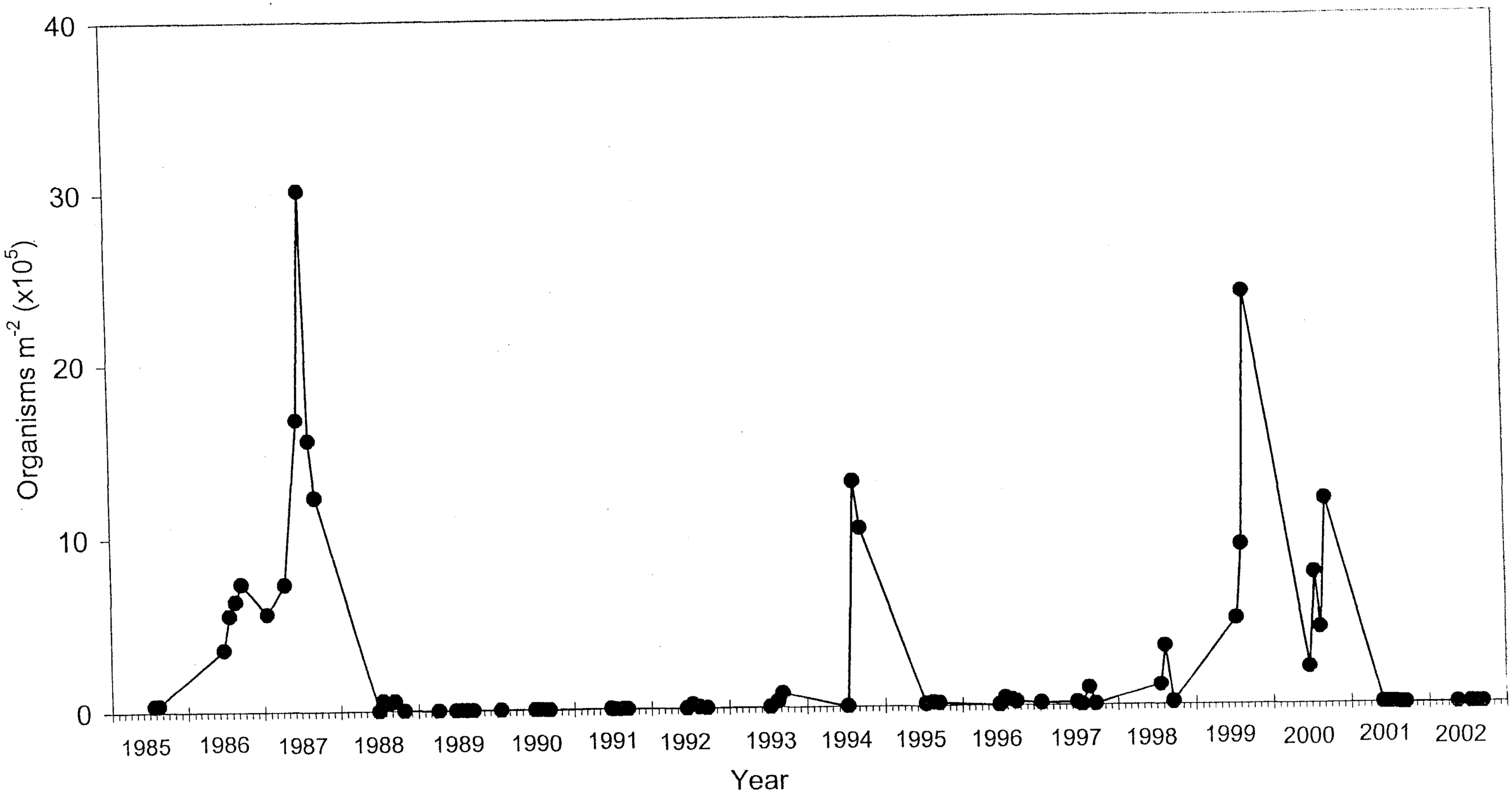



Figure 22. Densities of *Philodina acuticornis* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

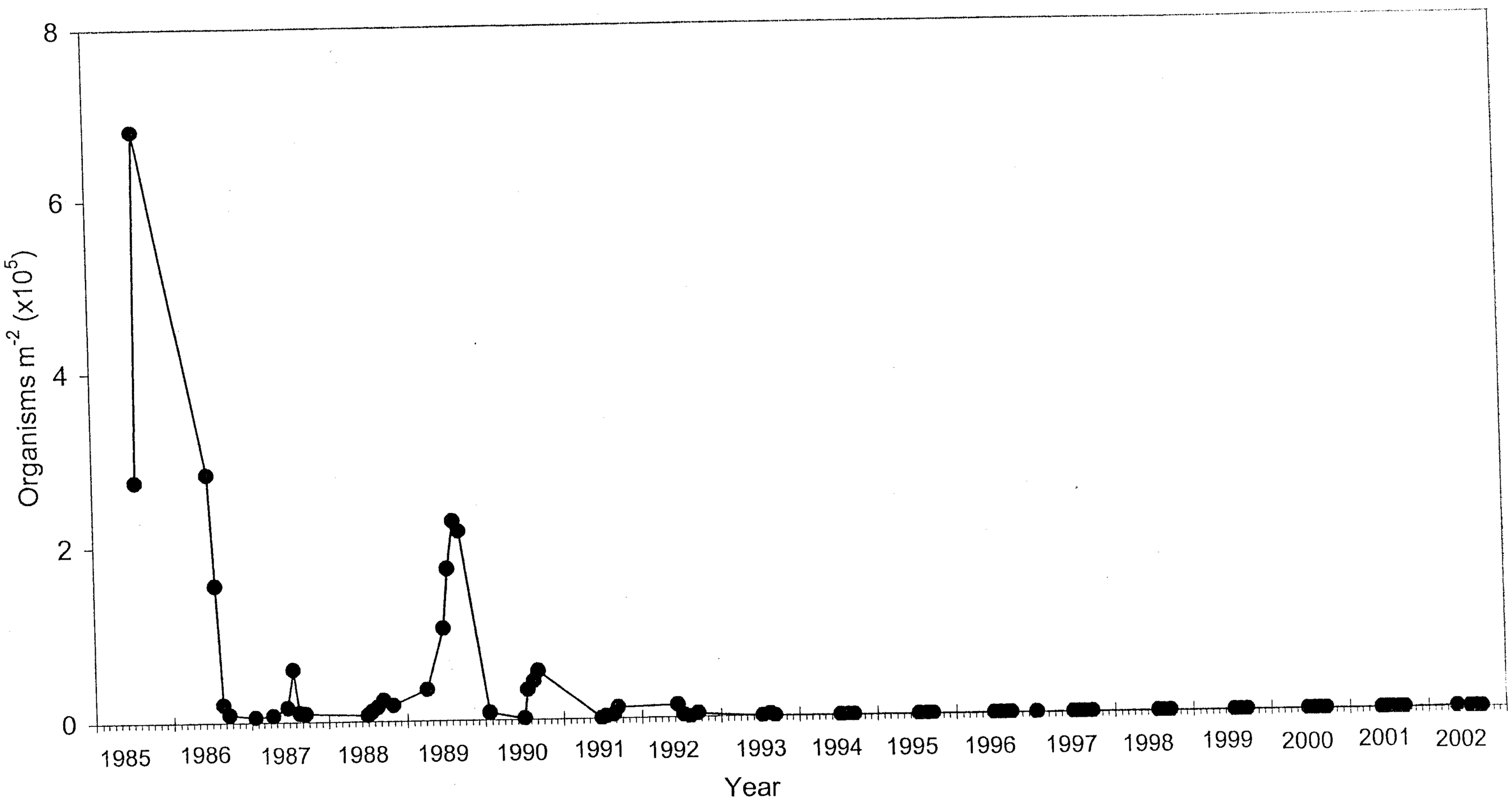



Figure 23. Densities of *Keratella quadrata* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

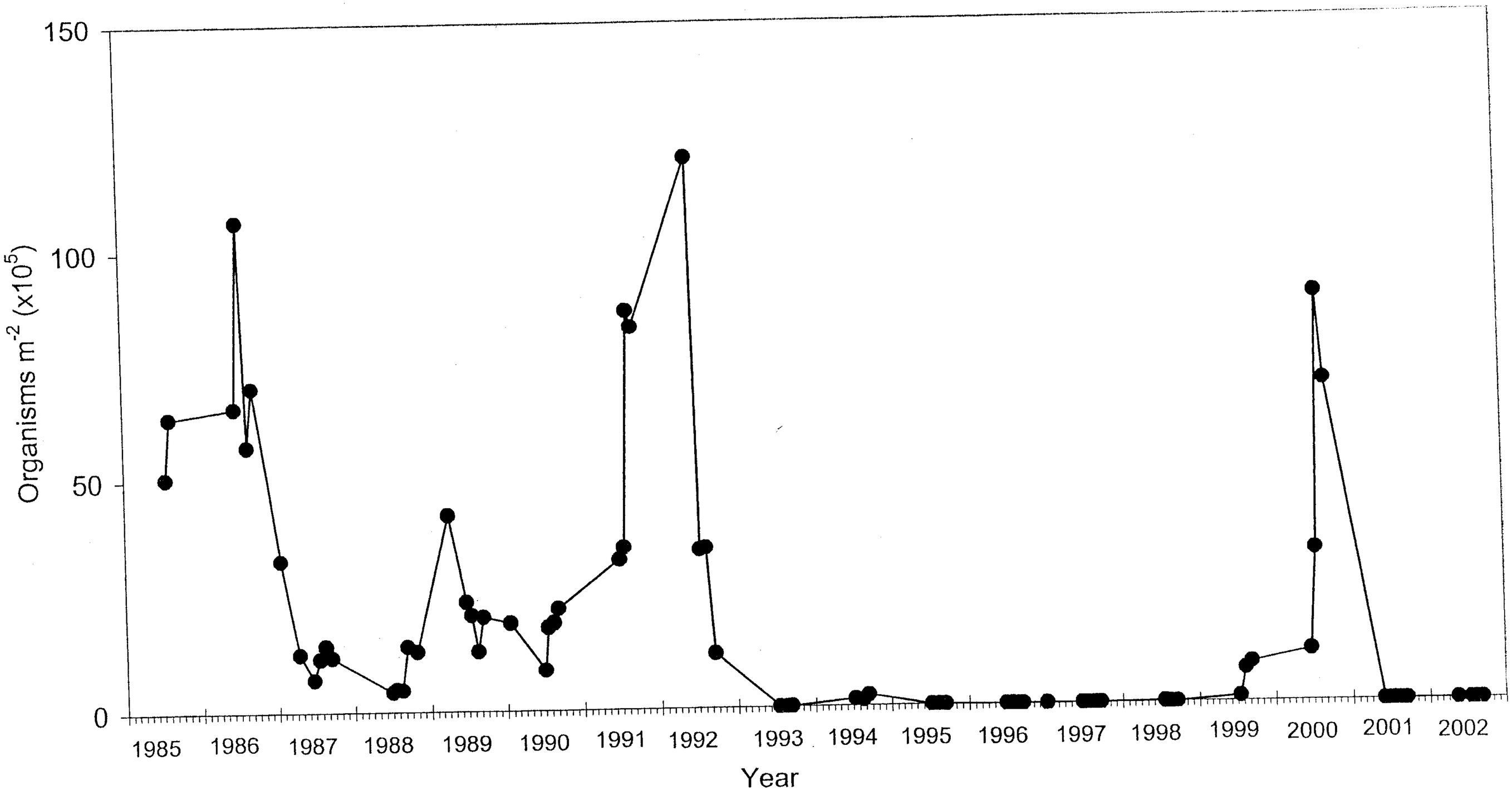



Figure 24. Densities of *Keratella cochlearis* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

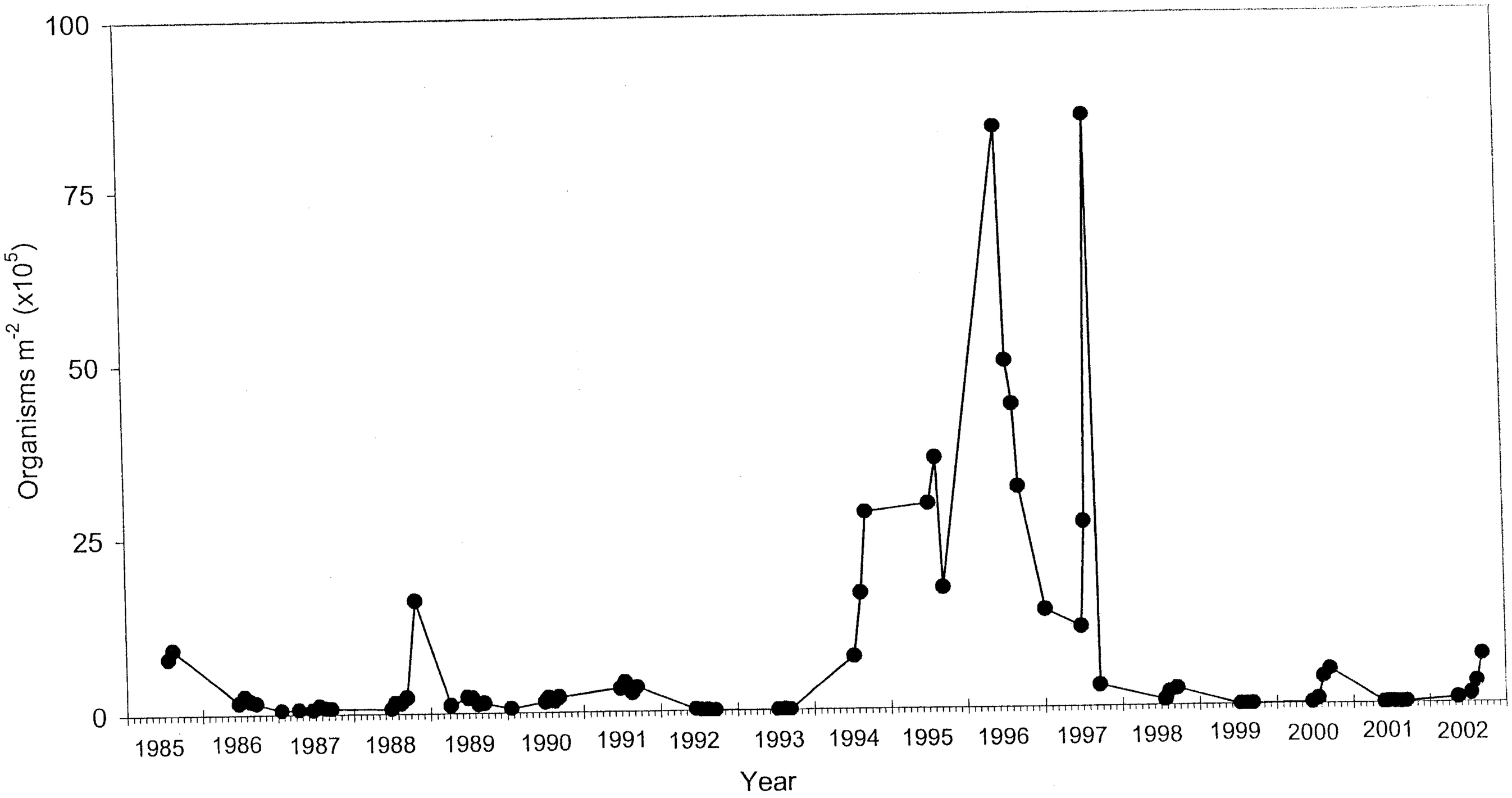



Figure 25. Densities of *Kellicottia longispina* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

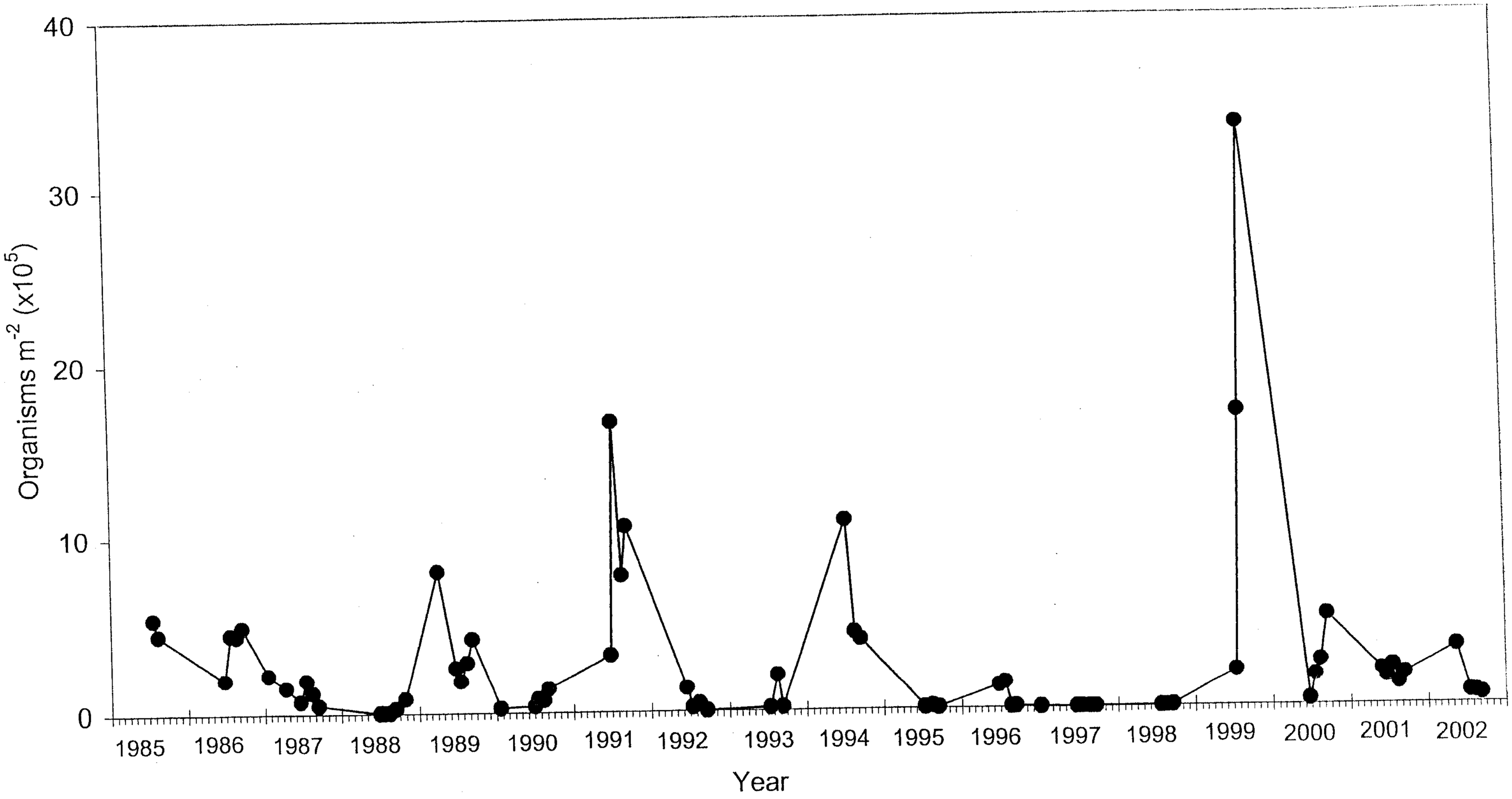



Figure 26. Densities of *Filinia terminalis* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

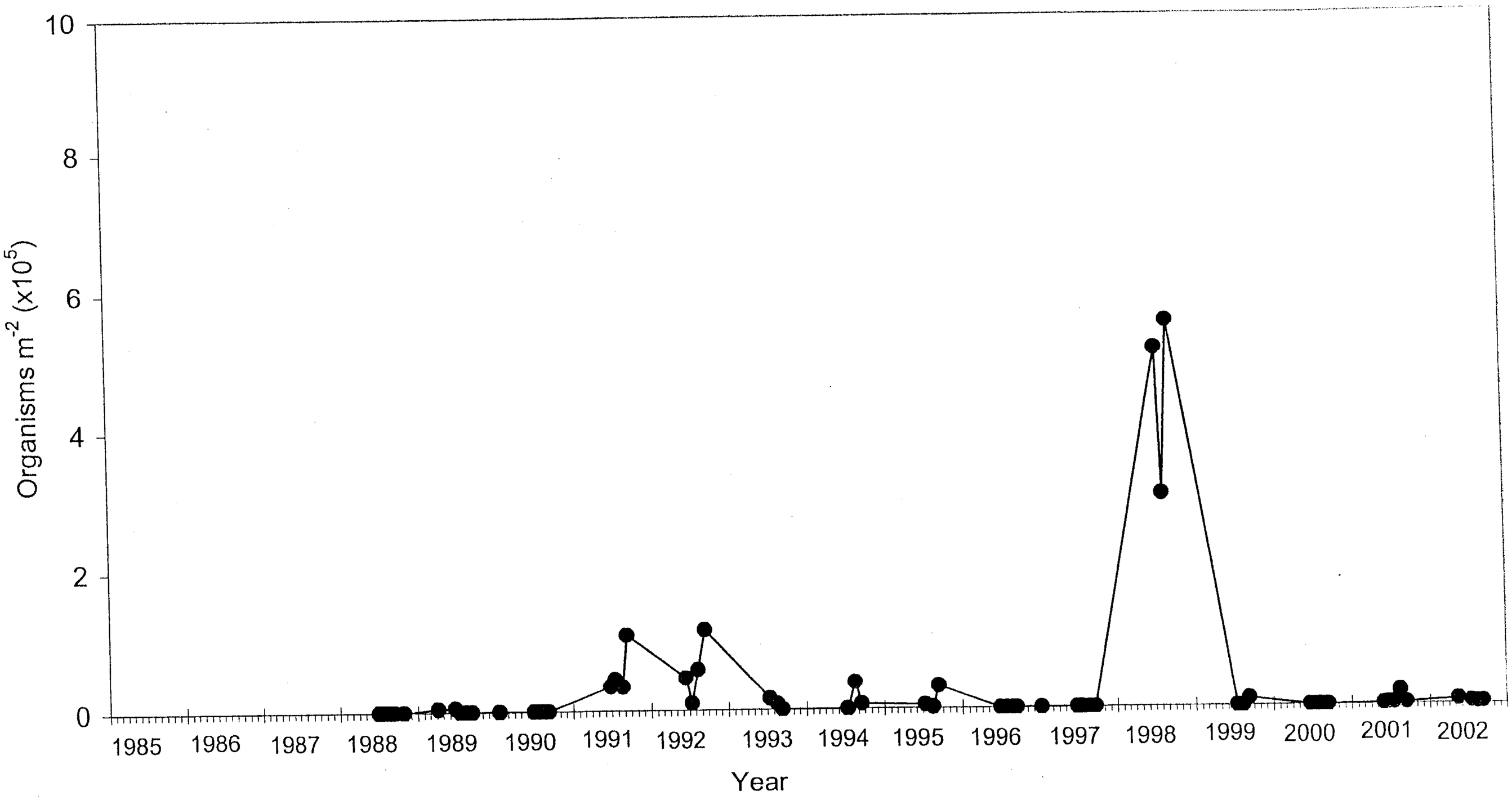



Figure 27. Densities of *Conochilus unicornis* integrated to a depth of 200 m in Crater Lake from 1988 to 2002.

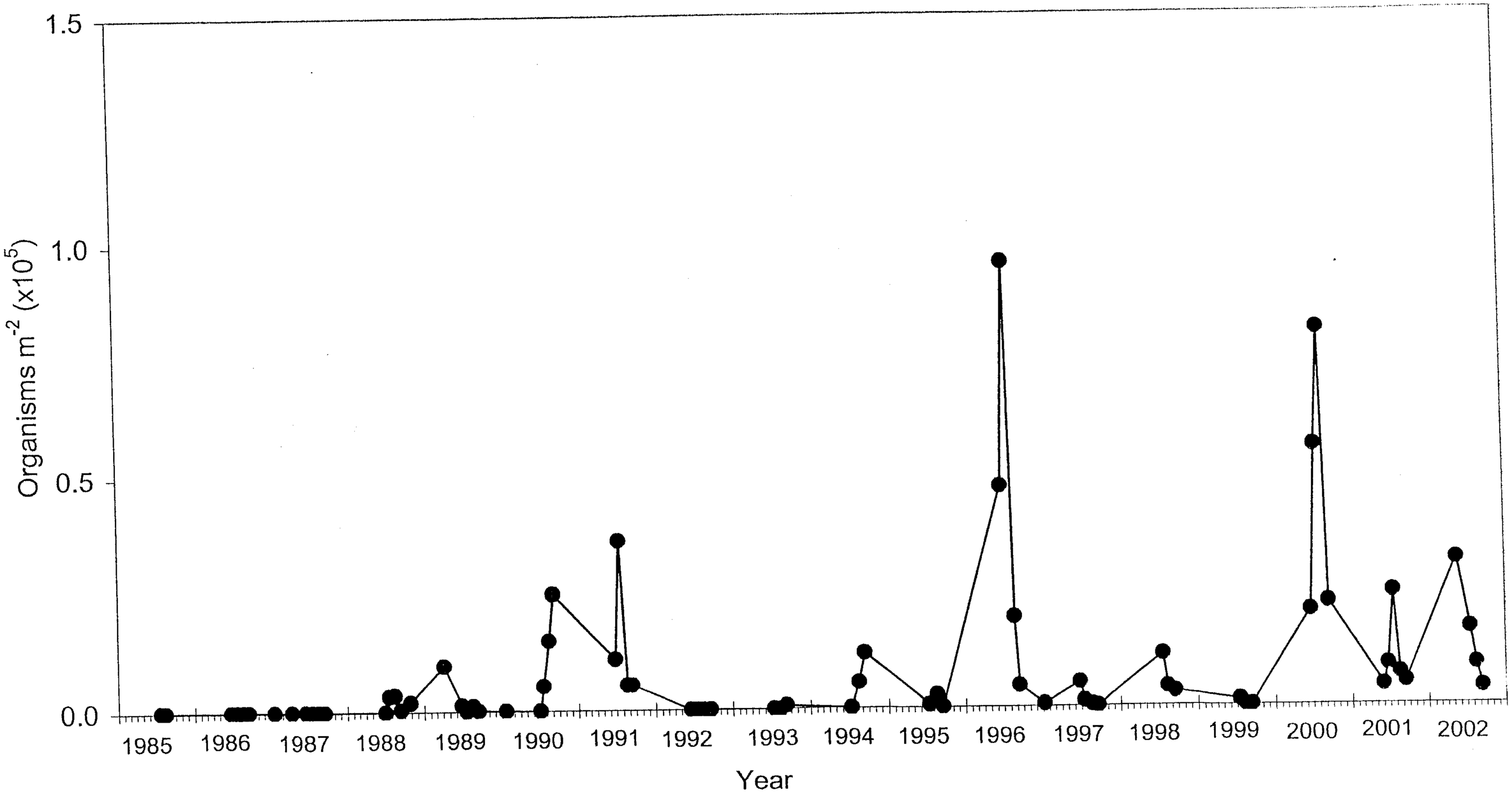



Figure 28. Densities of *Collotheca pelagica* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

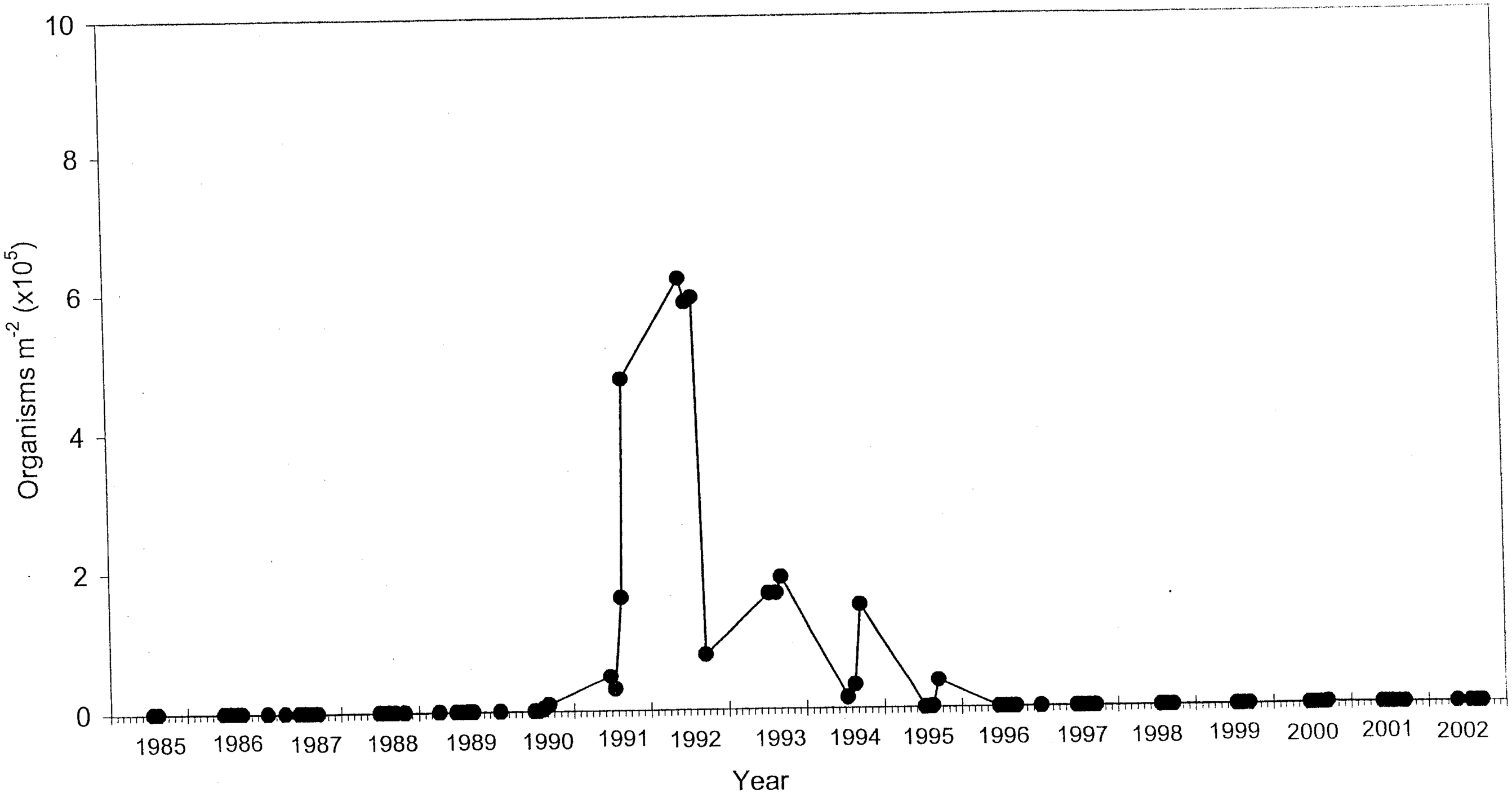



Figure 29. Densities of *Asplanchna priodonta* integrated to a depth of 200 m in Crater Lake from 1985 to 2002.

*terminalis*), whereas the others were more transient. The results clearly demonstrate that there has been considerable internannual variation in the abundances of the individual taxon.

Intracaldera Spring Water Quality

Spring samples were taken from three areas (Discovery Point, Rim Village, and Chaski Slide) around the caldera (Fig. 30 ). Springs 38 and 39 had the highest temperatures during the sampling season (Table 7). Spring 42 ranged between 2 to 4°C. Collectively, spring pH ranged between 7.5 and 8.0. Total alkalinity and conductivity varied among the springs. Spring 38 and Spring 42 had the highest alkalinities and Spring 38 had the highest conductivity throughout the sampling period. These data were consistent with the data base (Larson 1999).

Nutrient chemistry of the caldera springs was variable, but consistent with the data base (Larson 1999; Table 8). Ammonia-N was below detection limits in all springs except Spring 42 in May. Total phosphorus and orthophosphate-P were lowest in Spring 39, nitrate-N was highest in Spring 42, and total Kjeldahl-N was highest in Spring 39. As in previous years, concentrations of nitrate-N increased in Spring 42 during the sampling season (Fig. 31).

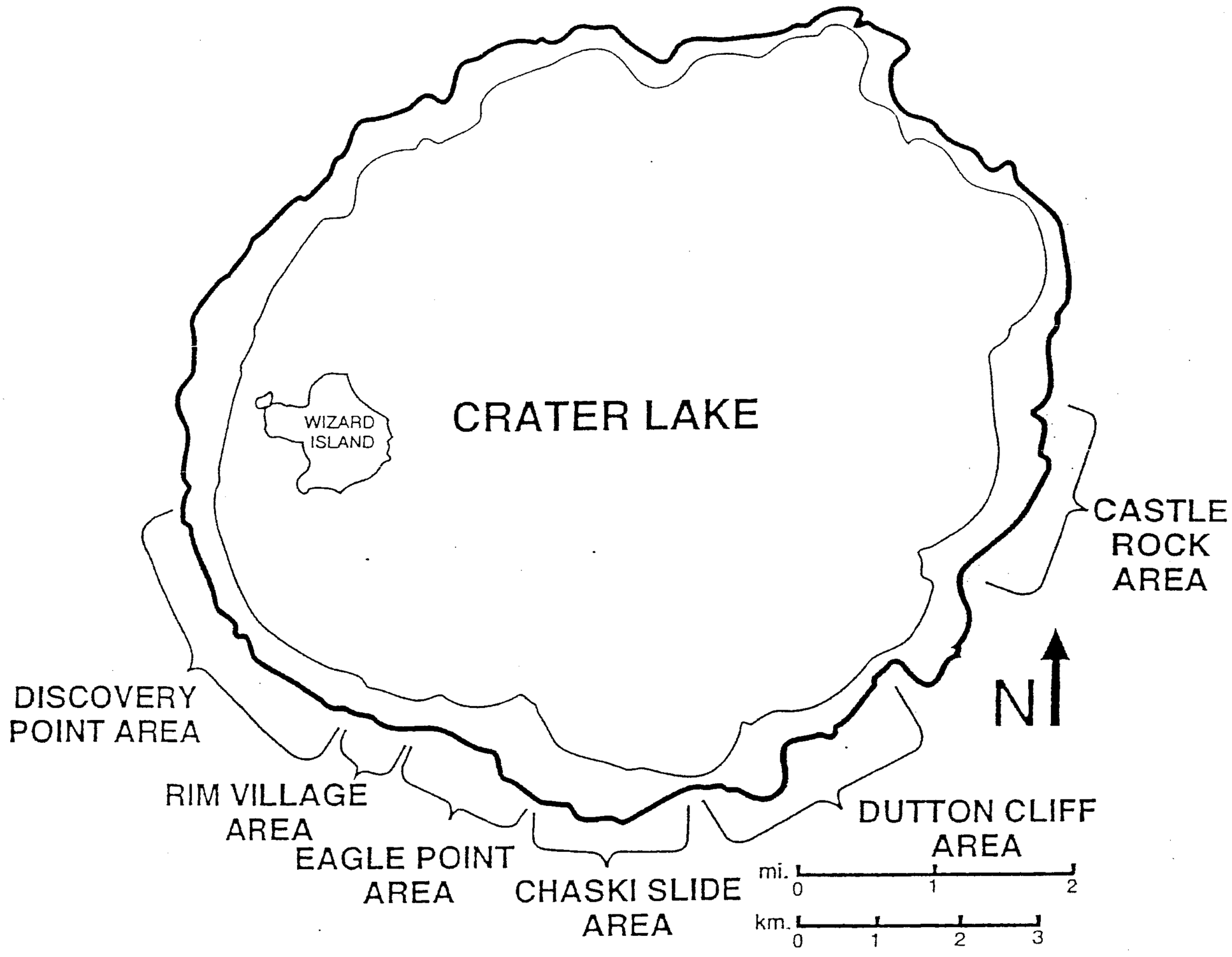



Figure 30. Approximate locations of the areas from which spring samples were collected from 1983-1989. In 2002, samples were collected from Discovery Point, Rim Village, and Chaski Slide.

Table 7. Summary of Crater Lake Caldera Spring Water Chemistry, 2002.

| | Spring Number and Area[1] | | | | |
|---|---|---|---|---|---|
| Date | 20 CS | 38 RV | 39 RV | 42 RV | 48 DP |
| | | | Temperature | | |
| 5-15 | 3.0 | - | - | 3.0 | - |
| 7-16 | 6.0 | 13.0 | 13.0 | 4.0 | 5.0 |
| 8-13 | 8.0 | 11.0 | 16.0 | 3.0 | 5.0 |
| 9-10 | 6.0 | 6.0 | 8.0 | 2.5 | - |
| | | | pH | | |
| 5-15 | 7.6 | - | - | 7.6 | - |
| 7-16 | 7.7 | 7.6 | 7.6 | 7.5 | 7.5 |
| 8-13 | 7.7 | 7.8 | 8.0 | 7.8 | 7.9 |
| 9-10 | 7.6 | 7.6 | 7.8 | 7.6 | 7.7 |
| | | | Total Alkalinity | | |
| 5-15 | 13.8 | - | - | 13.0 | - |
| 7-16 | 11.5 | 16.9 | 4.2 | 16.0 | 12.8 |
| 8-13 | 14.5 | 19.4 | 6.3 | 19.3 | 13.7 |
| 9-10 | 15.9 | 21.1 | 7.6 | 21.8 | 14.3 |
| | | | Conductivity | | |
| 5-15 | 77.0 | - | - | 30.8 | - |
| 7-16 | 39.0 | 68.1 | 20.8 | 39.7 | 30.8 |
| 8-13 | 56.9 | 85.7 | 24.8 | 47.9 | 32.4 |
| 9-10 | 69.4 | 94.7 | 30.6 | 52.9 | 33.5 |

[1]CS - Chaski Slide, RV - Rim Village, and DP - Discovery

Table 8. Selected Chemical Characteristics of Caldera Springs in May and August, 2002, except for Nitrate-Nitrogen which was sampled in July, August, and September. Concentrations in µg/L.

| Spring No. | Area | TP | $PO_4$-P | Total Kjeldahl-N | $NO_3$-N | $NH_3$-N |
|---|---|---|---|---|---|---|
| May | | | | | | |
| 20 | Chaski Slide | 52 | 39 | 30 | 24 | 0 |
| 42 | Rim Village | 34 | 26 | 40 | 106 | 11 |
| August | | | | | | |
| 20 | Chaski Slide | 49 | 42 | 20 | 24-68 | 0 |
| 38 | Rim Village | 64 | 55 | 20 | 4-7 | 0 |
| 39 | Rim Village | 28 | 21 | 40 | 30-59 | 0 |
| 42 | Rim Village | 47 | 43 | 0 | 106-266 | 0 |
| 48 | Discovery Point | 45 | 39 | 0 | 12-14 | 0 |

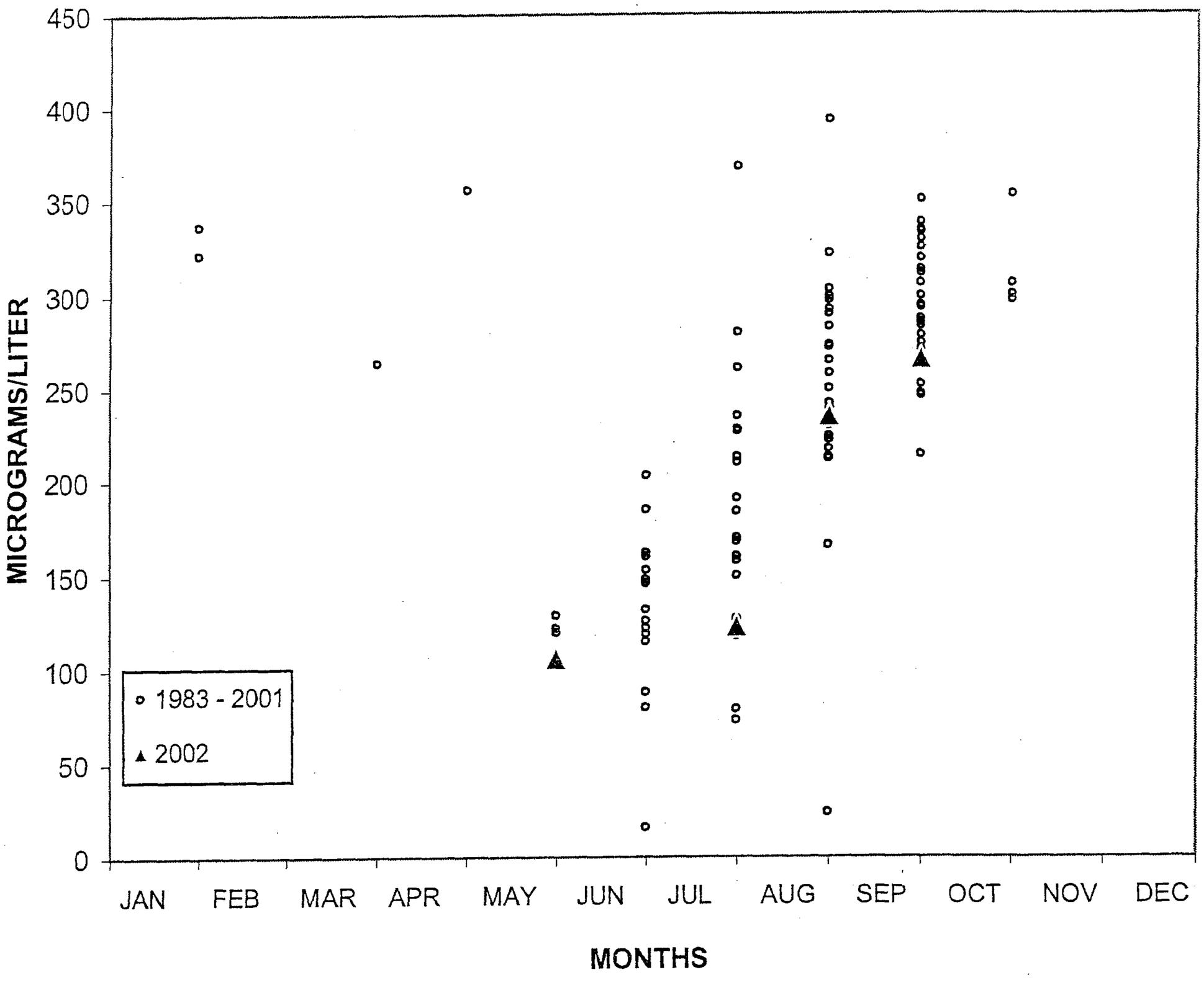



Figure 31 . Temporal patterns of nitrate-N in spring 42 from 1983 to 2002.

## Program Planning 2003

The 10-year limnological study of Crater Lake revealed many of the components and processes important to lake clarity and to the dynamics of the lake ecosystem as a whole. Although the relative importance of these components was well documented in many instances, many questions were generated which could not be addressed in sufficient detail within the scope of the program. These questions provide a focus for the long-term monitoring program. Specific hypotheses, which guide routine monitoring and other scientific studies, will emerge from these questions. These hypotheses will direct the sampling effort of the long-term monitoring program toward specific components and processes of the lake. The sampling program is designed to focus on features of the lake system that affect clarity of the water column and are also sensitive to changing environmental conditions. Thus, the long-term monitoring program is structured to optimize park management's ability to detect and track changes in the lake.

Implementation of the long-term monitoring program required additional funding. Such funding was received in fiscal year 1994. Priority in fiscal year 2003 will be given to: 1) revising the monitoring program to fulfill the recommendations in the final report from the 10-year limnological study (Larson et al. 1993); 2) continuing to develop a data management program; 3) modeling the physical and biochemical components of the lake ecosystem; and 4) providing on-going support for a global climate change project, a sedimentation project, and an optical project.

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