Final Report

Survey of Sensitivity of Southern California Lakes to Acid Deposition

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Abstract

During 1985-1986 solute composition of 23 California lakes and ponds and of streams entering the lakes was determined. The strategy was to sample the same waters during the autumn and under ice or soon after ice out and to evaluate the necessity of sampling at multiple stations and from more than one depth. Chemical parameters measured included pH, alkalinity, conductance, major cations (calcium, magnesium, sodium, and potassium), major anions (nitrate, sulfate, chloride), silica, nutrients (ammonium and phosphate), total and total dissolved nitrogen and phosphorus, and total and dissolved levels of aluminum, iron, and manganese.

Coastal ponds and low elevation (<1700 m) lakes exhibited circumneutral to alkaline pH, high alkalinity (500-6000 $\mu eq \cdot l^{-1}$) and high levels of dissolved ions (20-150 $meq \cdot l^{-1}$). Among the high altitude (>1800 m) lakes, pH was circumneutral to slightly acid and alkalinity was low (16-338 $\mu eq \cdot l^{-1}$). Insignificant spatial variation in pH, alkalinity and dissolved constituents was observed in these lakes during September-October 1985 and July-August 1986. Under ice cover in May 1986 lakes had vertical differences in alkalinity and other constituents. Dissolved and total nutrient determinations for Sierra Nevada lakes suggested that the availability of nitrogen is greater than that of phosphorus. Trace element levels for total aluminum (<22 $\mu g \cdot l^{-1}$), total iron (<73 $\mu g \cdot l^{-1}$), and total manganese (<11 $\mu g \cdot l^{-1}$) were very low in autumn 1985, increased slightly under ice-cover (but were less than 81, 390, 17 $\mu g \cdot l^{-1}$, respectively) and were somewhat higher than the previous autumn in July-August 1986 for high altitude lakes with aluminum exhibiting the greatest and manganese the smallest change. Levels of chemical constituents in lakes sampled previously (1981 through 1984) or monitored by other surveys were within range of values observed.

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Disclaimer

Table of Contents

List of Tables

List of Figures

Summary and Conclusions

1. Coastal ponds and lakes under strong anthropogenic influence had circumneutral to alkaline pH, high alkalinity (>500 $\mu eq \cdot l^{-1}$) and high levels of dissolved ions and need not be considered in current monitoring efforts concerned with sensitivity to acid loading.
2. High altitude lakes in the Sierra Nevada had circumneutral to slightly acid pH values, low alkalinity (16-338 $\mu eq \cdot l^{-1}$) and low conductance (3-44 $\mu S \cdot cm^{-1}$, 25°C). The majority of these mountain lakes are extremely dilute and very weakly buffered lakes.
3. Insignificant spatial variation in pH, alkalinity, and dissolved constituents was observed during September-October 1985 and during July-August 1986. Sampling from multiple stations is not necessary for lakes similar to those monitored in this survey during the ice-free period.
4. Ice-covered lakes (May 1986) exhibited depression in pH compared to values in autumn 1985 and vertical differences in water chemistry. Under such conditions sampling from more than one depth is requisite for characterization of a lake's chemical status. Sampling during ice-cover is necessary if a composite picture over an entire year is desired.
5. While levels of the trace elements aluminum and iron had seasonal change during this survey, manganese concentrations were not different and could be eliminated from monitoring schemes in the areas visited by this survey.
6. Conductance and levels of ions in inflows were higher in September 1985 but more variable with respect to recipient lakes in July and August 1986.

Recommendations

1. Future monitoring efforts should be continued with greater frequency of measurements within all seasons of fewer lakes representative of southern California's mountain lakes.
2. Surveys should sample lakes during the dry period, under ice, and during spring run-off to assess seasonal fluctuations in lake chemistry. The data acquired may then be compared with data obtained during the ice-free season, and hence ascertain if long term trends can be recognized with samples collected only during the ice-free season.
3. Chemistry of conspicuous inflows to lakes should be monitored to determine sources of ions and their levels.
4. To ensure credible data from a monitoring project quality assurance guidelines are requisite. Calibration and precision evaluations of all instruments should be performed and recorded. Interlaboratory evaluations should be performed with independently prepared reference materials to assess the accuracy of laboratory instruments and personnel.

Statement of the Problem

Acid precipitation is falling on California's coast, inland valleys and Sierra Nevada (Lawson and Wendt 1982). The Los Angeles basin (Liljestrand and Morgan 1981), the San Francisco Bay area (McColl and Bush 1978), the coast between those two urban areas (Sickman and Melack 1984) and the Central Valley (McColl 1980) all receive acid rain. Furthermore, dry deposition of acids and other contaminants (Kerr 1981) and acid fogs (Waldman et al. 1982) increase acidic inputs. In the Sierra Nevada, the Tahoe basin (Leonard et al. 1981), and the eastern and western slopes (Melack et al. 1982; Stohlgren and Parsons 1987; Laird et al. 1986) receive acid precipitation during portions of the year.

Acid deposition is known to have adverse consequences in terrestrial and aquatic environments and in urban settings (Overrein et al. 1980, NRC Canada 1981). In regions such as Scandinavia and the northeastern US where acid precipitation is known to have impacts, the first are noted often in aquatic habitats (Cowling and Linthurst 1981, Almer et al. 1974). Loss of fish and elevated levels of metals are but two of the effects of degraded water quality that can result from acidification. To evaluate the effectiveness of various mitigation measures requires assessment of the current status of California's aquatic resources and of possible responses to altered rates of acid deposition.

Project Objectives

To evaluate existing (e.g., Melack et al. 1985) and ongoing (ARB's Statewide Survey of Aquatic Ecosystem Chemistry) lake surveys and to help design a monitoring program for detection of changes in lakes as a result of acid deposition requires information on the temporal and spatial variability within and among lakes. A portion of the required information is provided by this survey which examined selected lakes at more than one station per lake at two times over a one year period.

The Sierran lakes were selected to provide samples in additional years for lakes previously sampled (Melack et al. 1985) or to add new lakes in areas not represented in previous work. The ponds along the central coast were selected to complement the ARB survey being done in northern California, Sierra Nevada and Los Angeles area. In the lakes, samples were obtained from multiple depths and stations to evaluate within lake differences in chemistry.

Methods

Sampling Scheme

Selection of lakes was based on susceptibility to acidification as deduced from bedrock geology and proximity to sources of acidic materials, accessibility, extraneous influences on water quality, prior sampling, and consultation with ARB staff (Figure 1).

Water samples were collected from each of twenty lakes and inflowing streams, if flowing and accessible, from September to November 1985 and from eighteen lakes from April to August 1986 (Tables 1, 2 and 3). Nine of these lakes were sampled when ice covered in April and May 1986. Coastal ponds and Zaca, Oriole and Hume Lakes were sampled in September-October 1985 only. Three ponds on Vandenburg Air Force Base were sampled in April 1986 only. Samples were obtained from two depths (subsurface and near-bottom) for each of two stations in the lake except when lakes were ice covered (one station) or shallow (subsurface only). These stations were off-center, one towards the inlet and the other towards the outlet sides, of each lake.

Sample Collection

Collection was made from an inflatable boat via tygon tubing connected to a peristaltic pump directly into linear polyethylene bottles reserved for water samples only and previously cleaned in 10% HCl and rinsed five times with deionized water. Bottles were rinsed three times with lake water before obtaining the sample. Unfiltered water was collected for conductance, pH, alkalinity, total aluminum, iron, and manganese, and total nitrogen and phosphorus determinations. Filtered water (Gelman A/E, glass fiber filters) was used for ammonium, phosphate, major cations and anions, silica, and total dissolved nitrogen and phosphorus determinations. Filters were rinsed with 100-150 ml of lake water before obtaining the samples.

A plastic filter housing containing a 0.1 micron polycarbonate membrane filter was used to filter water into polypropylene bottles cleaned according to Tonnessen (1983) and containing 0.2 ml Ultrex nitric acid per 30 ml sample for dissolved trace metals (Al, Fe, and Mn). Unfiltered samples for trace metals were stored similarly. Samples were maintained at ambient lake temperature by transport in insulated bags and then stored at 4°C until assay; those for total and total dissolved N and P analysis were frozen until analyzed.

Field Analyses

Water depth and Secchi disk readings were taken at each station. A 20-cm disk with black and white quadrants was used to determine the Secchi depth. A weighted sounding line was used to measure the depth of the water (Tables 4 and 5).

Laboratory Analyses

Ammonium, phosphate, conductance, pH and alkalinity were determined within a few hours of collection. Ammonium and phosphate were determined by the phenolhypochlorite method (Koroleff 1969) and molybdenum blue method (Strickland and Parsons 1972), respectively. Conductance was measured with a temperature compensating meter (Yellow Springs Instruments Model 32) and a coefficient of 2% per degree Celsius. The conductivity cell was calibrated with solutions of KCl and conductances were corrected for deviation from the theoretical value. The pH measurements were made with combination electrodes suitable for use in dilute waters (Sargent-Welsh S-30072-15 or Ross 8104) and a Fisher Acumet 805 pH meter. For each trial the electrode was calibrated with pH 7.00 and pH 4.00 reference buffers and washed twice for 3 minutes with stirred deionized water (Melack et al. 1982). The electrode was rinsed with an aliquot of sample, and the temperature compensated pH determination made on a fresh, quiescent sample after 5 minutes. Other precautions in our protocol include standardization before and after with 10^{-4} N and 10^{-5} N solutions of HCl (Galloway et al. 1979), equilibrating samples and buffers to ambient temperature, and thorough rinsing of electrode with deionized water between readings. Acid neutralizing capacity (ANC) was measured by the Gran titration procedure (Stumm and Morgan 1981; Talling 1973); 0.01 N HCl was dispensed from a micrometer buret stepwise with stirring, and pH was measured after equilibration without stirring as described above. ANC is the total acid-combining capacity of a water sample determined by titration with a strong acid and includes alkalinity (carbonate species) as well as other basic species (EPA, 1986). ANC and alkalinity are used interchangeably here.

The major cations, calcium, magnesium, sodium and potassium, were analyzed with a Varian-AA6 atomic absorption spectrophotometer (A.A.S.). An air-acetylene flame was used; addition of lanthanum chloride suppressed chemical and ionization interferences during calcium and magnesium determinations. The anions chloride, nitrate, and sulfate were measured by ion chromatography (I.C.). A Dionex Model 2010i, employing chemical ion suppression and conductivity detection, was used. Silica was analyzed using the molybdenum blue method (Strickland and Parsons 1972); oxalate was added to prevent phosphate interference. Total and total dissolved nitrogen and phosphorus were determined as nitrate and phosphate, respectively, after digestion in an autoclave with persulfate according to Valderrama (1981). Trace metals were measured by graphite-furnace atomic-absorption spectrophotometry (Perkin-Elmer) and auto-sampling device.

Quality Control

Our quality control program incorporated the following features. A standard protocol was followed for sample collection, storage and analysis. Trace metal blanks were determined in acid-cleaned sample bottles containing 30 ml of 0.1 micron filtered deionized water and 0.2 ml Ultrex nitric acid. Duplicate analyses were performed where appropriate. Freshly prepared calibration standards and reagent blanks were used in every assay. Deionized water having a conductance of 0.2-0.5 $\mu S \cdot cm^{-1}$ was used throughout. This was obtained from a Millipore Milli-Q water purification system consisting of one prefilter, one carbon and two ion exchange cartridges; feed water to this Milli-Q system was deionized via ion exchange tanks and had a conductance of ca. 1.0 $\mu S \cdot cm^{-1}$. Precision evaluations for I.C. and A.A.S. techniques were performed (Tables 6 and 7) and detection limits of chemical methods (Table 8) were determined. For ion analyses, known additions assessed the accuracy of the methods (Tables 9 and 10). And finally, quality control standards (USGS and NBS) were periodically analyzed (Tables 11 and 12). Overall accuracy of ion analyses were estimated by ion balance (Tables 13 and 14). The ratio of total positive charges to total negative charges was usually between 0.85 and 1.0 and indicated a slight deficiency in cations.

Results

Hydrogen Ion Activity and Alkalinity

Hydrogen ion activity ranged from 1.6 to 0.03 $\mu eq \cdot l^{-1}$ (5.80-7.55 pH units) for southern Sierra lakes of altitude greater than 1800 meters. Lakes sampled under ice cover and during summer had consistently lower pH values (0.3-1.1 pH units) than in the autumn (Tables 13 and 14). Alkalinity in these lakes ranged from 16-338 microequivalents per liter (Tables 13 and 14). While levels under ice either slightly increased or slightly decreased from autumn values (exceptions were Gem and Piute Lakes which increased about twofold), distinct decreases occurred in lakes sampled during July and August 1986 compared to their levels in September and October 1985.

Oriole, a low elevation, tea-stained lake surrounded by forest, exhibited high (420 $\mu eq \cdot l^{-1}$) acid neutralizing capacity. Pear and Heather Lakes had the lowest alkalinity levels. Hume Lake and Zaca Lake, both under strong anthropogenic influence and excluded from range values here, had high subsurface alkalinity values of 446 and 4600 $\mu eq \cdot l^{-1}$, respectively. Likewise excluded are the brackish, alkaline ponds at Arroyo Grande and Vandenburg Air Force Base having alkalinities greater than 5000 $\mu eq \cdot l^{-1}$.

Spatial variation in alkalinity was not detectable for the majority of southern Sierra lakes during the autumn; the station-to-station subsurface values differed by less than 5 $\mu eq \cdot l^{-1}$. Four lakes (Crystal, Gem, Up. Granite, and Golden Trout) had interstation subsurface values differing by 11-15 $\mu eq \cdot l^{-1}$. Similarly, variation of near-bottom values among lakes was insignificant; only three lakes (McCloud, Golden Trout, and Unnamed) had values differing by >6 $\mu eq \cdot l^{-1}$. Only McCloud, Gem, and Up. Granite Lakes exhibited variation with depth (differing by 15, 12, and 9 $\mu eq \cdot l^{-1}$, respectively) at one of the two stations in each case. While McCloud and Up. Granite showed increases with depth, the reverse was true of Gem Lake. Where alkalinity increased with depth, pH decreased correspondingly by 0.2-0.5 pH units.

While spring and summer alkalinities also showed minimal spatial heterogeneity between stations, vertical differences existed in some (7 of 9) ice-covered but not in ice-free lakes (Table 14). McCloud, Crystal, Piute, Emerson and Heather had higher alkalinities at depth whereas the reverse was true for Gem and Pear Lakes. Zaca Lake showed more dramatic changes in alkalinity and pH with depth from 4500 $\mu eq \cdot l^{-1}$ and 8.48 pH units to 7050 $\mu eq \cdot l^{-1}$

and 7.41 pH units, respectively. Three lakes had conspicuous inflows during autumn 1985. While Pear Lake's inflow had pH and ANC values similar to the lake itself, Gem and Piute Lakes' inflows had nearly twice the acid neutralizing capacity and were less acidic than their respective lake waters.

In April and May 1986 the nine ice-covered lakes sampled (Table 14) had ranges in pH and alkalinity of 5.76-6.60 pH units and 37-226 $\mu eq \cdot l^{-1}$, respectively. While the pH was lower in all cases, differences greater than 5 $\mu eq \cdot l^{-1}$ in under-ice alkalinity from autumn values occurred in six (three higher and three lower) of the nine lakes. Notably, Gem and Piute Lakes had twice the acid neutralizing capacity than in the previous autumn. Variation of ANC with depth occurred in six of these lakes.

Conductance and Major Cations and Anions

Conductance varied from 3-44 $\mu S \cdot cm^{-1}$ with no spatial variation within montane lakes sampled during autumn 1985 (Table 13). These same lakes when sampled in summer 1986 had conductances similar to their autumn 1985 values (Table 14). Inflows always had higher conductances than recipient lakes in the autumn. Zaca Lake and brackish ponds had conductances of 1 and 1.9-3.5 $mS \cdot cm^{-1}$, repectively. Of the nine ice-covered lakes, only Gem and Up. Treasure lakes had conductances of nearly twice their fall values (Table 14).

Autumn levels of calcium and magnesium ranged 16-345 and 1.6-18 $\mu eq \cdot l^{-1}$, respectively; in Golden Trout Lake levels of both ions were three time those of other montane lakes (Table 15). Sodium and potassium levels ranged 5-43 and 1-8.6 $\mu eq \cdot l^{-1}$, respectively; Gem Lake had 43 $\mu eq \cdot l^{-1}$ of sodium. Chloride, sulfate, and nitrate ranged 1-6, 5-118, undetectable-11.5 $\mu eq \cdot l^{-1}$, respectively. Of the three major anions, sulfate exhibited the greatest interlake variability. Zaca Lake and coastal ponds, excluded above, had ion concentrations in the $meq \cdot l^{-1}$ range. Major ion concentrations under ice-covered lakes were either similar to (4 lakes) or different from (5 lakes) levels determined in the autumn (Table 16). In Gem Lake calcium and sodium levels doubled and Piute, Upper Treasure, Heather and Pear Lakes had higher concentrations of ions compared to autumn levels. Of the six southern Sierra lakes sampled in July and August 1986, five had calcium levels lower than in September and October 1985; Crystal (M.K.) Lake remained similar in calcium concentration (Table 16). The co-varying anion was either bicarbonate or sulfate.

Nutrients

Autumn (Sept.-Oct.) and summer (July-Aug.) levels of ammonium and phosphate ranged from undetectable-0.6 μM and silica varied from 3-60 μM for Sierra lakes (Tables 17 and 18). Nitrate was present in moderate amounts (2-12 μM) in all high altitude lakes. Nutrient levels were higher for seven of the nine ice-covered lakes compared to their autumn values (Tables 17 and 18); nitrate increased at least two times in these lakes. Western Sierra ice-covered lakes had augmented phosphate levels whereas in the eastern Sierra increases in ammonium surpassed phosphate levels. In addition, vertical differences in concentration were apparent (Table 18). Eastern Sierra lakes sampled in July and August 1986 were ice-free and showed dramatic increases in nitrate, whereas Up. Mosquito and Crystal (M.K.) Lakes in the western Sierra (Mineral King) showed no change (Table 18). Silica levels in Sierra lakes ranged from 3-60 μM in the autumn (Table 17) and no vertical differences were observed. These lakes, when ice-covered, had silica concentrations higher than in autumn with vertical differences apparent (Table 18). Of the lakes sampled in July-August 1986, Golden Trout and Unnamed lakes had silica levels less than and greater than in the previous autumn (Tables 17 and 18), respectively.

Trace Metals

Total and total dissolved aluminum concentrations ranged 0.30-1.6 μM (8-43 $\mu g \cdot l^{-1}$) and 0.15-0.78 μM (4-21 $\mu g \cdot l^{-1}$), respectively in autumn 1985 (Table 19). Up. Mosquito Lake was highest (0.78 μM) and Heather, Up. Granite, Up. Gaylor, and Gem Lakes were at the upper end of the range (0.48-0.52 μM) in their dissolved Al levels.

Total and total dissolved iron concentrations in autumn 1985 ranged from 0.05-1.29 μM (3-72 $\mu g \cdot l^{-1}$) and undetectable-0.50 μM (undetectable-28 $\mu g \cdot l^{-1}$), respectively (Table 19). In general, the differences between total iron and total dissolved iron was greater than the corresponding differences for aluminum. Of the eastern Sierra lakes McCloud and Crystal had the highest levels of total iron and in the western Sierra, total iron in surface Heather Lake water was three times more abundant than in Pear Lake.

Autumn values of total and total dissolved manganese concentrations ranged from undetectable-0.13 and undetectable-0.13 μM (undetectable-7 $\mu g \cdot l^{-1}$), respectively; these two values were similar in all lakes. Heather Lake ranked highest in both total and total dissolved manganese concentration.

No differences between stations or with depth were discernible for trace metal concentrations in these lakes during September-October 1985, whereas under ice cover (May 1986) variability was apparent with depth (Table 20). Moreover, trace metal levels increased in ice-covered lakes compared to levels in the autumn (Tables 19 and 20). Aluminum showed the greatest and manganese the smallest change; increase in iron was intermediate. Ice-free lakes in the eastern Sierra (4 lakes) sampled during July and August 1986 had higher levels of trace metals than in autumn 1985, while no seasonal change was observed for two lakes in the western Sierra.

Discussion

Surveys of lake chemistry

The effect of increases in acid loading on aquatic resources is a pressing issue both regionally (Melack et al. 1985) and nationally (Likens et al. 1979, Lewis et al. 1980, Schindler 1980). To ascertain long-term effects of acid deposition requires baseline information within a spatial and temporal framework. Baseline data for California's lakes and streams has been accumulating. Surveys of Sierra Nevada lakes initiated in the early 1980's by Melack (Melack et al. 1982, Melack et al. 1985), Tonnessen (Tonnessen and Harte 1982) and Southern California Edison (G. Bradford, personal communication) include reliable and representative measurements of pH, alkalinity and major solutes. Bradford et al. (1968) surveyed 170 alpine lakes in Sequoia, Kings Canyon and Yosemite National Parks, and determined trace metals with methods now called into question as well as five major elements. Unfortunately, their pH measurements were made about two weeks after the collection of samples and alkalinity was not determined. Several additional analyses of major ions in Sierra Lakes are provided by Baas et al. (1976), LADWP (1972, Twin Lakes near Mammoth Lakes), and Silverman and Erman (1979, Rae Lakes).

Results from Melack et al.'s (1985) recent survey of 73 lakes indicate that most Sierra Nevada lakes are extremely dilute and very weakly buffered; 70% of the lakes sampled have summer alkalinities below 90 μeq l^{-1}. The few lakes with alkalinities above 210 μeq l^{-1} are either located below 3000 m above sea level or in basins with calcareous rocks. The major cation in Sierran lakes is calcium, and bicarbonate is the major anion in most lakes. The few lakes with as much or more sulfate or chloride as bicarbonate lie in basins with considerable coverage of volcanic rocks or are especially dilute waters on granite. Summer pH values in surface waters are usually between 6 and 8. These major ion and pH data indicate that the Sierran lakes' chemistry are the expected result of weak acid weathering within their basins.

Tonnessen and Harte (1982) sampled 26 subalpine lakes on the western slopes of the Sierra Nevada during the summers of 1980 and 1981 and reported a pH range of 6.0 to 8.5 and that about 40 percent of the lakes had alkalinities below 100 μeq l^{-1}. Southern California Edison (SCE) has sampled

124 lakes located in Sequoia, Kings Canyon and Yosemite National Parks in June or July from 1980 to 1985. Mean pH's range from 6.3 to 6.7, and mean alkalinities range from ca. 32 to 42 µeq l^{-1}. Calcium is the major cation.

In 1985 ARB sponsored a statewide survey of 50 California lakes by the California Department of Fish and Game. Lakes sensitive to acid deposition were located in northern California, and additional data on sensitive Sierra Nevada lakes were obtained. Lakes in the mountains above Los Angeles and coastal waters were well buffered.

To further characterize lakes in the Sierra Nevada the survey reported here evaluates the importance of sampling at multiple stations and from multiple depths and provides samples from autumn (September-October), spring (May) and early summer (July-August) for 1985-1986.

Alkalinity and pH

Acid neutralizing capacity indicates ability to neutralize acid and is a parameter commonly employed to predict the response of surface waters to acidic inputs. Lake water alkalinity integrates the many contributing biological and chemical processes of the entire watershed and is the key indicator for characterizing the acid-base status of surface water (Gherini et al. 1985). However, its use is not without uncertainties. Titration models (Henriksen 1980), although corrected for contributions from calcium and magnesium salts (Henriksen 1983, Wright 1983), may be confounded by differences among watersheds, and seasonal differences in ANC in autumn, under ice-cover, and during initial spring melt may differ substantially. Moreover, alkalinity may be modified by within lake processes. For example, in Gem Lake Stoddard (1986) concluded that lake sediment as well as soils in the watershed contribute to alkalinity dynamics of the water, and Nodvin et al. (1986) report alkalinity increases with depth when Eastern Brook Lake is chemically stratified under ice cover.

Alkalinities and pH for lakes with elevations greater than 1800 meters inclusive of our three sampling intervals ranged from 16-338 µeq l^{-1} and 5.80-7.55 pH units, respectively (Tables 13 and 14). Table 21 presents mean pH and ANC values of near surface water of two stations and two depths for each lake at different seasons. This integrated record shows a clear decrease in pH from autumn to spring or summer for all lakes. Similar findings of snow melt induced pH depression documented for central Ontario lakes (Jeffries et al. 1979) and in the Adirondacks lakes basin (Troutman and Peters 1982) have been attributed to acidic melt water. In the Sierra Nevada declines in alkalinity during spring snow melt are likely caused mainly by dilution rather than acidification (Stoddard 1986), although some evidence of titration by nitric and sulfuric acid comes from Emerald Lake (Melack, unpublished). Ice-out in the southern Sierra was in late June to mid-July for 1986, hence the lower pH's exhibited by lakes sampled in July-August 1986 compared to their values in September-October 1985 are a reasonable consequence of residual influence of snowmelt.

Of the nine lakes which were ice-covered in spring 1986 some showed a slight increase and some showed a slight decrease in alkalinity from their autumn values. When lakes are stratified under ice-cover, and the epilimnion receives melt water (ca. 0°C) which is less dense than the lake water at 4°C, a very dilute surface layer may occur. The extent of this layer is likely to be dependent upon the ratio of runoff volume to lake size among other factors, hence, whether only the surface waters of lakes or the entire vertical water column is diluted will be variable.

Gem Lake was notable with a twofold increase in alkalinity from autumn 1985 to spring 1986; this agrees with Stoddard (1986) who studied this lake intensively during 1982-1984 and reported an increase in alkalinity during ice cover. Alkalinity levels increased in winter as a result of hydrolysis of minerals in the watershed and lake sediments and then decreased when bicarbonate ions were flushed from the lake during spring discharge (Stoddard 1986). For lakes sampled during July-August 1986 distinct decreases in alkalinity occurred in Up. Gaylor and Up. Granite Lakes, while Up. Mosquito and Crystal (M.K.) Lakes exhibited slight decreases; levels in Golden Trout and Unnamed Lakes were similar to autumn values (Table 21). As ice melts and lakes destratify surface water mixes with and dilutes the hypolimnia thereby diluting dissolved constituents. This apparently had not occurred yet for Golden Trout and Unnamed Lakes in July 1986.

Lakes under strong anthropogenic influence (Hume), and coastal ponds with alkalinities greater than 5000 μeq l^{-1}, need not be considered in current monitoring efforts concerned with sensitivity to acid loading.

Our results from sampling multiple stations and depths during autumn or summer (Tables 13 and 14) indicate insignificant spatial variation in alkalinity levels. However, ice-covered lakes do show distinct vertical differences in alkalinity (Table 14). Five of the ice-covered lakes had lower alkalinity just under the ice than at lower depths; this is a natural consequence of dilution of lake water with snow melt water just under the ice layer.

Comparison of current pH and alkalinity values with levels reported in other surveys is shown in Table 22. Of the four lakes (McCloud, Piute, Golden Trout, and Pear) also sampled in 1985 by the California Department of Fish and Game (McCleneghan et al. 1985), pH and alkalinity values are in good agreement for three; a disparity exists for Golden Trout Lake. Our data are also consistent with pH and alkalinity values from earlier surveys of the Sierra Nevada by Melack et al. (Table 22).

A better perspective on the significance of the water chemistry for Sierra Nevada lakes reported here can be obtained by comparing the 1985-1986 data with means, standard errors and ranges of chemical constituents in these waters over a two to five year period (Tables 23 and 24). In general, dissolved ion concentrations determined in lakes sampled during autumn 1985 are within calculated standard errors (Tables 15 and 23). Two lakes are exceptions. Gem Lake had levels of calcium, sodium, bicarbonate and sulfate outside the standard errors (higher) of multiple years as did Up. Gaylor Lake for calcium and bicarbonate only. The decreases in pH observed in the same lakes from autumn 1985 to spring or summer 1986 are greater than the standard error in pH values for multiple years (Tables 13 and 24). Hence, the pH depression that occurred from 1985 to 1986 is likely to be a real change. Changes in ANC are close to the standard error of measurements made over many years for the majority of lakes and hence are less clearly interpretable (Tables 13 and 24).

Results from our 1985-1986 surveys indicate that all Sierra Nevada lakes sampled except Golden Trout Lake are sensitive (ANC < 200 μeq l^{-1}, Kramer 1980, Turk and Adams 1983) to acid deposition. The limited buffering capacity of these high-altitude waters categorize them as sensitive to acidification. High-altitude lakes elsewhere in the western United States have been similarly delineated (Turk and Adams 1983). Moreover, the data we collected in September-October 1985 vs. July-August 1986 indicates dilution of surface waters can occur, and lake sensitivity to acid loading will vary seasonally and susceptibility would be greatest just after snow melt. Although acidification of surface waters is frequently defined as a decrease in alkalinity (Schofield et al. 1985), interpretation of such data requires caution. While on a watershed basis the net alkalinity supply rate is determined by the relative rates of acid input and base supply, lakes may also undergo dilution events and concomitant decrease in concentration of major ions, including bicarbonate.

Patterns in ice-covered lakes

While significant pH depression occurred in all Sierra lakes under ice in May 1986, accompanying changes in ANC (Table 21) were small and either increased or decreased. The data further indicated no overall ion dilution when May values are compared to the previous autumn (Tables 13 and 14), but elevated levels of nitrate and sulfate (Tables 15 and 16) and aluminum (Tables 19 and 20). The source of these ions (basin, lake, or snow) is unresolvable with the current data. The elevated concentrations of aluminum suggests transport of chemical weathering products occurred from basin or sediments to lake water. Two potential sources of nitrate are the snow pack itself and augmented loading due to reduced biological activity in the watersheds and in the lakes.

Major ions and nutrients

Most of the alpine lakes of the Sierra Nevada are bicarbonate lakes and the dominant cation is calcium (Melack et al. 1985). A linear regression between calcium and bicarbonate has an r^2 of 0.97 for the high altitude lakes (n=15) in this survey. The general pattern for these lakes sampled in September 1985 and again in July and August 1986 was a decrease in concentration of major ions including bicarbonate (Tables 15 and 16), a decrease in hydrogen ion activity (Table 21), and trace metal levels were similar in western Sierra but elevated in eastern Sierra (Golden Trout and Unnamed) lakes. While dilution of dissolved constituents in western Sierra lakes can be accounted for by runoff of spring discharge, floating ice was still in Golden Trout and Unnamed Lakes and snow was present around the lakes' perimeters.

Linear regressions for ANC versus the sum of Ca and Mg and for Ca vs. SO_4 are presented in Figures 2 through 5. Mean values from two stations and two depths of each lake were used to compute the regression. Golden Trout Lake was eliminated from the data set because its ANC value (320 $\mu eq \cdot l^{-1}$) was substantially higher than all other lakes; its inclusion gave a spuriously high r^2 value.

Having established a relation between ANC and the sum of Ca and Mg (r^2 = 0.82, Figure 2) we employed Burns' et al. (1981) method for comparing measurements of bicarbonate alkalinity to the sum of the four base cations, Ca, Mg, Na, and K. Their method proposes an alternative to Henriksen's approach (1980) for assessing acidification of surface waters in upland areas where organic acids are unimportant and sulfide mineral content is low. By comparing bicarbonate alkalinity to the sum of the base cations, the occurrence of strong acid weathering may be established and the relative importance of precipitation-generated H^+ versus carbonic acid-generated H^+ may be assessed. That is, the smaller the ANC to base cation ratio, the greater the role of strong acids is in generating H^+; i.e. carbonic acid remains undissociated in the soil, base cations are exchanged and no bicarbonate is generated.

Table 25 presents the ratio of ANC to sum of base cations for Sierra Nevada lakes sampled during 1985-1986. A ratio greater than 0.8 was obtained for all lakes in autumn 1985 excepting Crystal (M.K.) Lake. A ratio less than 0.6 was obtained for low-alkalinity (~200 $\mu eq \cdot l^{-1}$) surface waters in Maine and Connecticut where lowered pH and alkalinity is believed due to acid precipitation (Burns et al. 1981). For this survey the ratio was 1.0 or close to 1.0 for all lakes except Up. Mosquito and Crystal (M.K.) Lakes. A ratio of 1.0 implies that alkalinity is generated from weathering reactions within the watershed with carbonic-acid dissociation as the source of H^+ and one equivalent of HCO_3^- made available for each equivalent of base cation released.

Concentrations of nutrients, ammonium and phosphate, were undetectable in the majority of high altitude lakes sampled in September and October 1985 (Table 17). Under ice-cover phosphate was detectable in those lakes and ammonium increased in a few lakes (Table 18). The nutrient ratios, TN/TP and TDN/TDP, for these lakes in autumn 1985 (Table 24) varied widely but suggest that the availability of nitrogen is greater than that of phosphorus.

DIN/TDP ratios (Table 25) further suggest that any nutrient regulation of phytoplankton abundance in southern Sierra lakes is likely to be controlled by availability of phosphorus. The DIN/TDP ratio has been recently used as a predictor of N or P regulation of phytoplankton biomass in mountain lakes in central Colorado (Morris and Lewis 1986).

In autumn 1985 inflows to Gem, Piute and Pear Lakes had higher conductances than their recipient waters. This is an expected consequence of base flow conditions. The inflow to Piute Lake had higher levels of all ions whereas levels of individual ions in Gem Lake's inflow were either greater or less than respective concentrations in the lakes. Pear and Gem Lakes' inflows had potassium concentrations similar to their respective lakes. The Pear and Gem watersheds are predominantly igneous intrusive rock rich in potassium feldspars (Table 3), hence similar levels in potassium between inflows and lakes are reasonable. While bicarbonate levels for Pear Lake and its inflow were similar, Gem Lake's inflow had twice the alkalinity than the lake.

During July and August 1986 conductance of inflows to Up. Mosquito and Crystal (M.K.) Lakes were similar to but concentrations of individual ions were higher or lower than lake waters. Up. Gaylor Lake's inflow had both higher conductance and elevated levels of calcium and bicarbonate than the lake.

The small number of lakes having inflows at the time of sampling during this survey and mitigating factors such as differential watershed processes and flow paths makes a general interpretation difficult and points to the need to further characterize this facet of interaction between watershed and lake.

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Figure 1. Location of lakes sampled indicated by circled numbers: 1 - Upper Gaylor and Upper Granite, 2 - McCloud and Crystal, 3 - Ruby, Upper Treasure and Gem, 4 - Piute and Emerson, 5 - Golden Trout and Unnamed, 6 - Hume, 7 - Heather and Pear, 8 - Oriole, 9 - Upper Mosquito and Crystal (Mineral King), 10 - Black and Twin, 11 - Rancho-Oeste, Lompoc-Casmalia and Dune, 12 - Zaca.

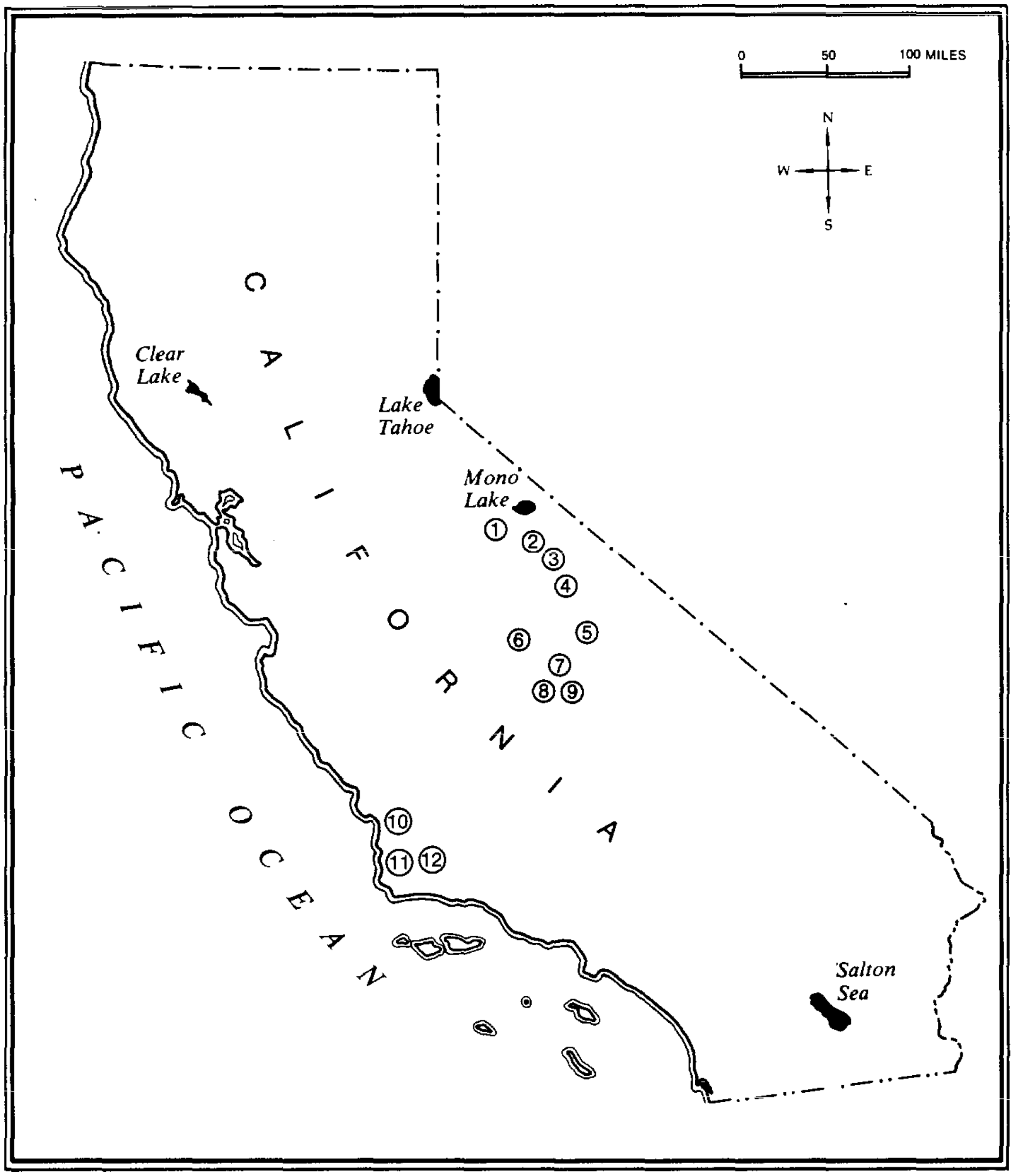
0
50
100 MILES
N
W
E
S
CALIFORNIA
PACIFIC OCEAN
Clear Lake
Lake Tahoe
Mono Lake
Salton Sea
①
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Figure 2

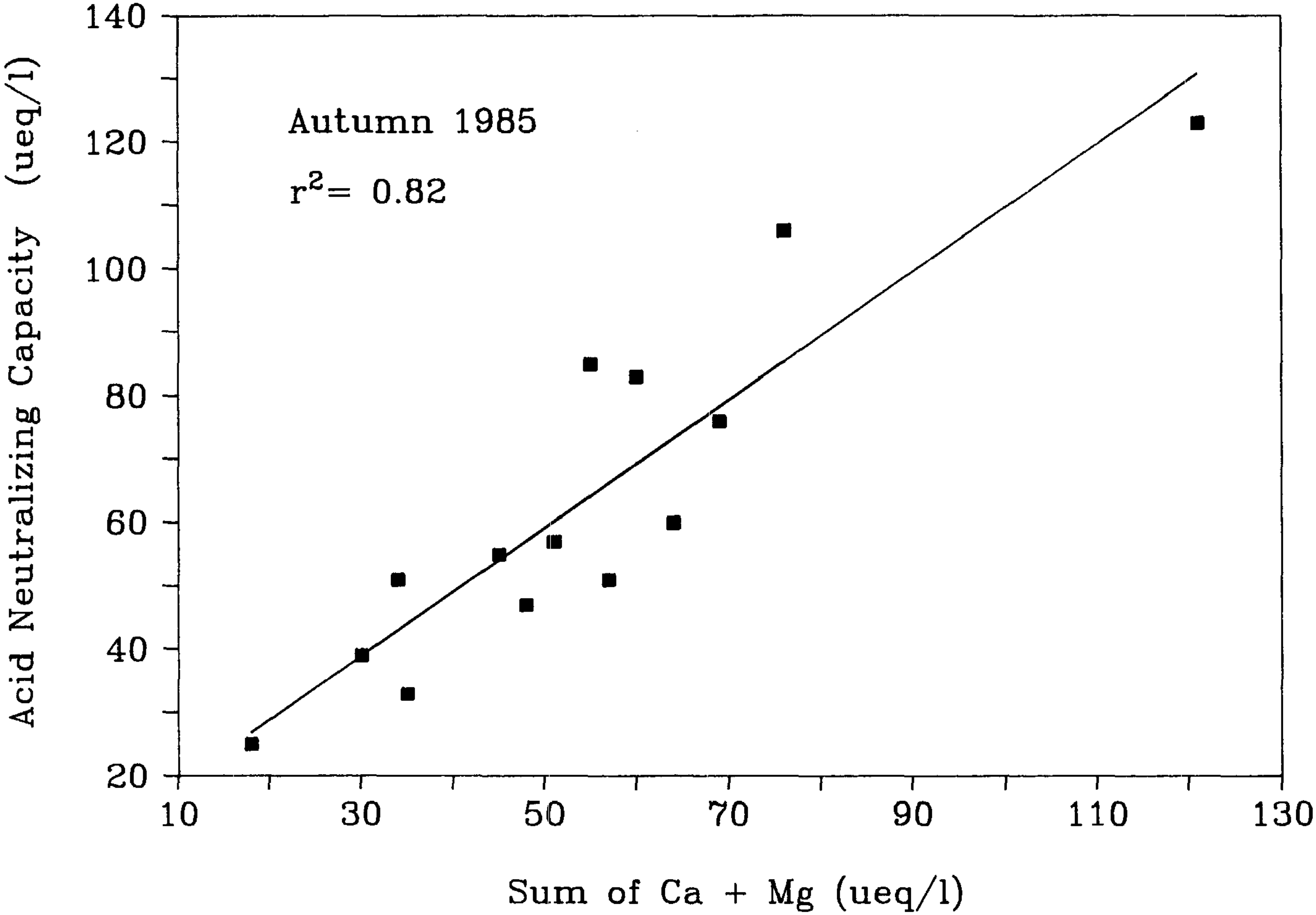

Autumn 1985
$r^2 = 0.82$
Acid Neutralizing Capacity (ueq/l)
140
120
100
80
60
40
20
10
30
50
70
90
110
130
Sum of Ca + Mg (ueq/l)

Figure 3

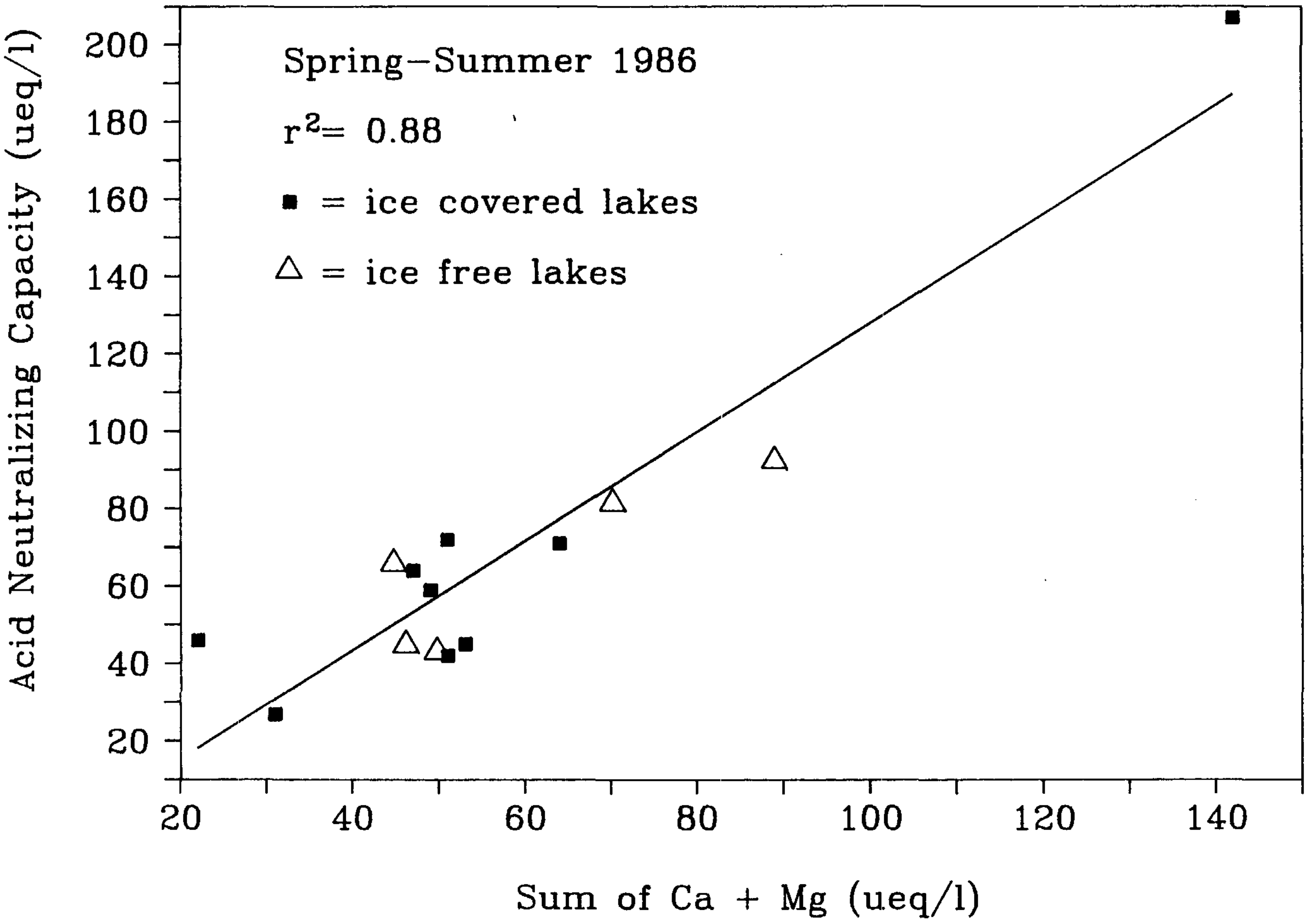
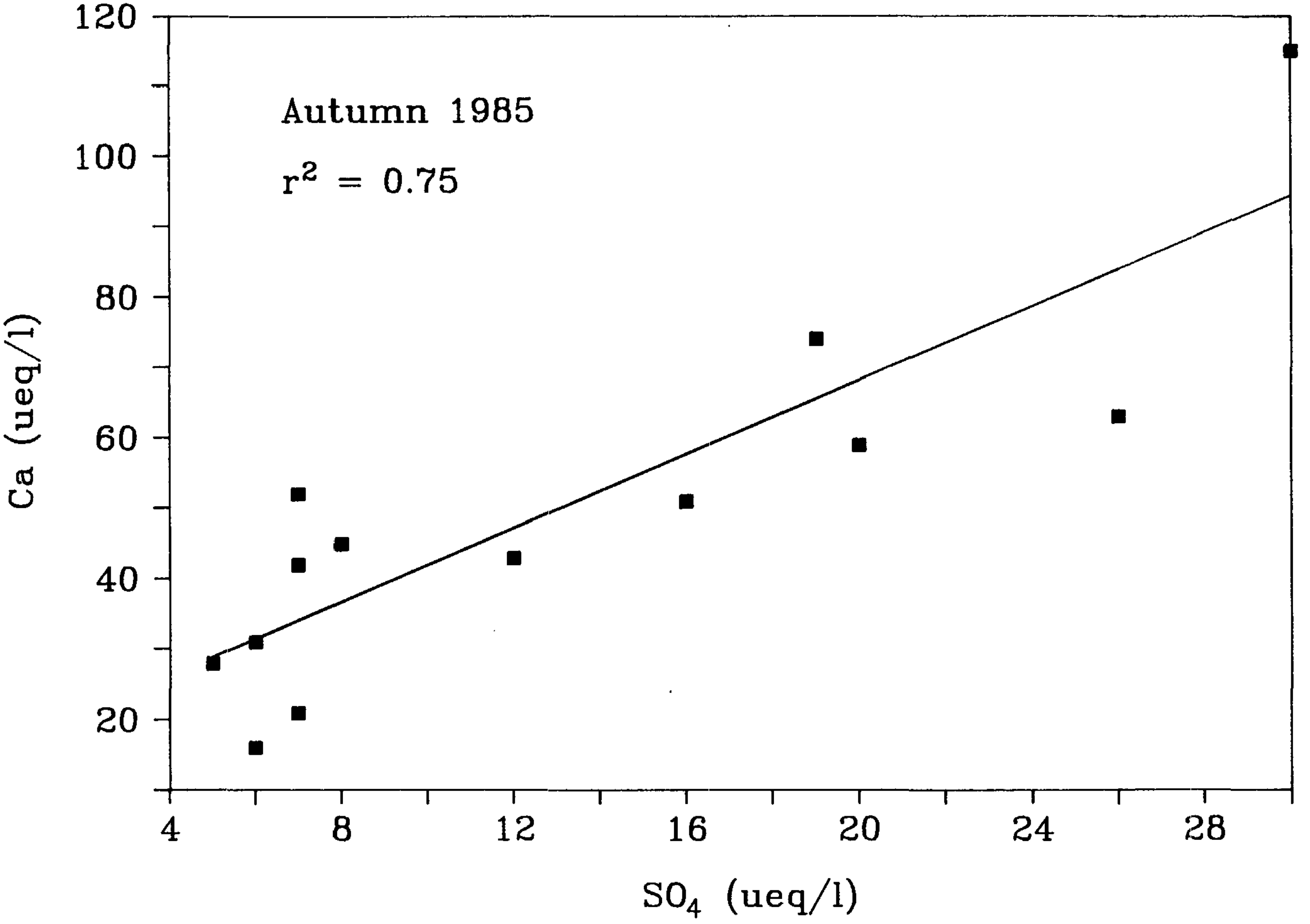

Spring–Summer 1986
$r^2 = 0.88$
■ = ice covered lakes
△ = ice free lakes
Acid Neutralizing Capacity (ueq/l)
200
180
160
140
120
100
80
60
40
20
20
40
60
80
100
120
140
Sum of Ca + Mg (ueq/l)

Figure 4


Autumn 1985
$r^2 = 0.75$
Ca (ueq/l)
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100
80
60
40
20
4
8
12
16
20
24
28
SO_4 (ueq/l)

Figure 5

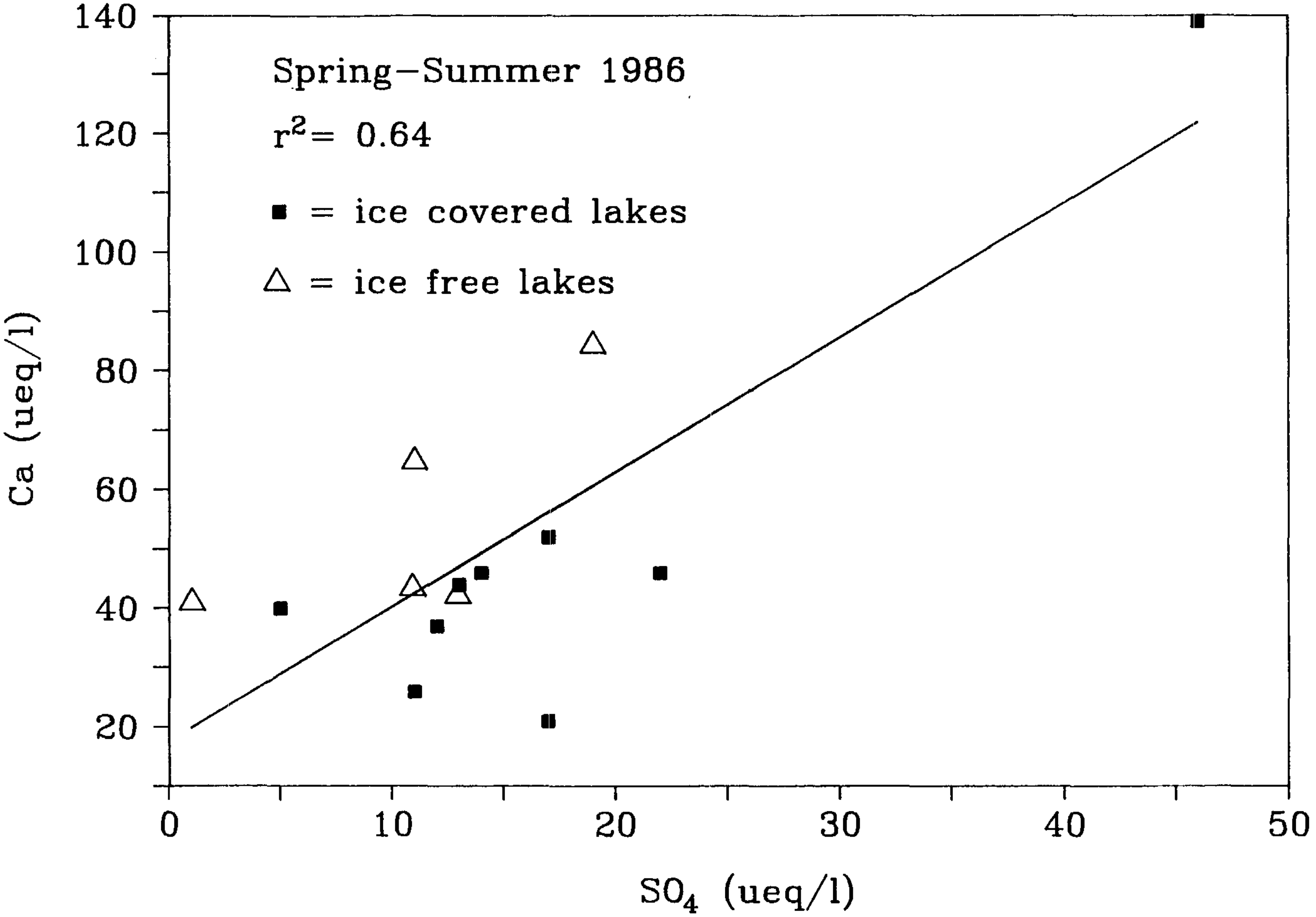
Spring–Summer 1986
$r^2 = 0.64$
■ = ice covered lakes
△ = ice free lakes
Ca (ueq/l)
140
120
100
80
60
40
20
0
10
20
30
40
50
SO_4 (ueq/l)

TABLE 1: Lakes sampled during autumn 1985.

LAKE	QUADRANGLE	LATITUDE	LONGITUDE	ALTITUDE (m)
Upper Gaylor	Toulumne Meadows	37°55'20"	119°16'01"	3121
Upper Granite	Toulumne Meadows	37°55'32"	119°16'42"	3170
McCloud	Devils Postpile	37°36'29"	119°01'47"	2829
Crystal	Devils Postpile	37°35'41"	119°01'04"	2902
Ruby	Mt. Abbott	37°24'50"	118°46'15"	3365
Upper Treasure	Mt. Abbott	37°23'13"	118°46'00"	3389
Gem	Mt. Abbott	37°23'05"	118°45'20"	3330
Piute	Mt. Goddard	37°14'04"	118°40'12"	3342
Emerson	Mt. Goddard	37°13'49"	118°39'57"	3413
Golden Trout	Mt. Pinchot	36°46'50"	118°22'04"	3488
Unnamed	Mt. Pinchot	36°47'18"	118°21'55"	3488
Hume	Tehipite Dome	36°47'29"	118°54'18"	1585
Heather	Triple Divide	36°36'02"	118°41'15"	2804
Pear	Triple Divide	36°36'02"	118°40'00"	2899
Oriole	Mineral King	36°27'37"	118°44'10"	1707
Upper Mosquito	Mineral King	36°24'53"	118°37'35"	3048
Crystal (M.K.)	Mineral King	36°26'30"	118°34'11"	3267
Black	Arroyo Grande	35°03'19"	120°36'14"	10
Twin	Arroyo Grande	35°04'06"	120°36'31"	24
Zaca	Zaca Lake	34°46'40"	120°02'20"	731

TABLE 2: Lakes sampled during spring and summer 1986.

LAKE	QUADRANGLE	LATITUDE	LONGITUDE	ALTITUDE (m)
Upper Gaylor	Toulumne Meadows	37°55'20"	119°16'01"	3121
Upper Granite	Toulumne Meadows	37°55'32"	119°16'42"	3170
McCloud	Devils Postpile	37°36'29"	119°01'47"	2829
Crystal	Devils Postpile	37°35'41"	119°01'04"	2902
Ruby	Mt. Abbott	37°24'50"	118°46'15"	3365
Upper Treasure	Mt. Abbott	37°23'13"	118°46'00"	3389
Gem	Mt. Abbott	37°23'05"	118°45'20"	3330
Piute	Mt. Goddard	37°14'04"	118°40'12"	3342
Emerson	Mt. Goddard	37°13'49"	118°39'57"	3413
Golden Trout	Mt. Pinchot	36°46'50"	118°22'04"	3488
Unnamed	Mt. Pinchot	36°47'18"	118°21'55"	3488
Heather	Triple Divide	36°36'02"	118°41'15"	2804
Pear	Triple Divide	36°36'02"	118°40'00"	2899
Upper Mosquito	Mineral King	36°24'53"	118°37'35"	3048
Crystal (M.K.)	Mineral King	36°26'30"	118°34'11"	3267
Rancho-Oeste	Casmalia	34°46'46"	120°34'00"	18
Lompoc-Casmalia	Casmalia	34°47'00"	120°32'20"	36
Dune	Surf	34°41'25"	120°36'00"	3

Table 3. Geographic features and watershed characteristics of Sierra Nevada lakes sampled in 1985-1986.

Lake Name	Altitude (m)	Lake Area (ha)	Basin Area (ha)	Vegetation Class†	Rock Type†
Up. Gaylor	3121	4.66	41.2	a	A
Up. Granite	3170	6.73	119.0	b	B
McCloud	2829	4.29	198.3	c	C
Crystal	2902	3.66	133.0	c	C
Ruby	3365	14.50	202.0	b	C
Up. Treasure	3389	2.85	184.0	b	B
Gem	3330	1.04	80.8	b	B
Piute	3342	9.39	298.8	-	B and C
Emerson	3413	1.12	125.9	-	C
Golden Trout	3488	2.49	86.3	-	D
Unnamed	3488	3.62	105.9	-	B
Heather	2804	2.07	57.0	c	B
Pear	2899	7.55	157.0	c	C
Up. Mosquito	3048	3.11	76.7	b	B
Crystal (M.K.)	3267	4.14	60.6	a	C

†Vegetation classes are designated as follows (see Melack et al. 1985 for further description): (a) Alpine meadow and meadowlike vegetation above timberline (often at lakeside) above 3100 m. (b) Whitebark pine forest, 3000-3350 m. (c) Mixed subalpine forest, 2800-3350 m. Rock types are designated as follows: (A) volcanic rocks, (B) igneous intrusive rocks rich in calcium sodium feldspars, and (C) igneous intrusive rocks rich in potassium feldspars. (D) Mafic plutonic rock primarily plagioclase and pyroxene. Dash indicates no data.

TABLE 4: Lakes sampled during autumn 1985. Stations are suffixed 1, 2, or 3. I refers to conspicuous inflow(s) to the lake; subscripts indicate more than one. Depth of water of station sampled (Z) and Secchi depth (Zs) are in meters. Dash indicates no data.

Lake/Station	Date	Z	Zs
Up. Gaylor-1	24 Sep 85	6.5	6.5
Up. Gaylor-2	24 Sep 85	5.5	5.5
Up. Granite-1	24 Sep 85	9.0	9.0
Up. Granite-2	24 Sep 85	7.0	7.0
McCloud-1	22 Sep 85	5.5	5.5
McCloud-2	22 Sep 85	7.5	6.0
Crystal-1	22 Sep 85	10.0	8.0
Crystal-2	22 Sep 85	7.0	7.0
Ruby-1	23 Sep 85	>18	11.0
Ruby-2	23 Sep 85	>18	11.2
Up. Treas-1	23 Sep 85	2.2	2.2
Up. Treas-2	23 Sep 85	4.0	4.0
Gem-1	23 Sep 85	5.5	5.5
Gem-2	23 Sep 85	5.5	5.5
Gem-I	23 Sep 85	-	-
Piute-1	25 Sep 85	5.0	5.0
Piute-2	25 Sep 85	11.5	10.0
Piute-I	25 Sep 85	-	-
Emerson-1	25 Sep 85	>18	5.5
Emerson-2	25 Sep 85	>18	5.0
Golden Trout-1	26 Sep 85	11.5	7.0
Golden Trout-2	26 Sep 85	10.5	8.5
Unnamed-1	26 Sep 85	>18	7.0
Unnamed-2	26 Sep 85	>18	7.0
Hume-1	9 Sep 85	4.0	2.2
Hume-I_1	9 Sep 85	-	-
Hume-I_2	9 Sep 85	-	-
Heather-1	5 Sep 85	6.0	-
Pear-1	6 Sep 85	6.0	-
Pear-2	14 Oct 85	9.8	9.0
Pear-3	14 Oct 85	-	-
Pear-I	14 Oct 85	-	-

TABLE 4 (cont.)

Lake/Station	Date	Z	Zs
Oriole-1	28 Oct 85	5.8	2.0
Oriole-2	28 Oct 85	6.2	2.0
Up. Mosquito-1	29 Oct 85	7.2	7.2
Up. Mosquito-2	29 Oct 85	4.0	4.0
Crystal (M.K.)-1	30 Oct 85	16.5	9.0
Crystal (M.K.)-2	30 Oct 85	17.5	8.0
Black-1	6 Nov 85	1.0	0.5
Black-2	6 Nov 85	3.5	0.5
Up. Twin-1	6 Nov 85	0.75	0.12
Zaca-1	9 Oct 85	11.5	2.5
Zaca-2	9 Oct 85	-	2.5

TABLE 5: Lakes sampled during spring and summer 1986. Stations are suffixed numerically, I refers to conspicuous inflows into the lake, subscripts indicate more than one. Depth of water at station sampled (Z), Secchi depth (Zs) and ice thickness are in meters. Dash indicates no data.

Lake/Station	Date	Z	Zs	Ice Thickness
Up. Gaylor-1	30 Jul 86	4.5	4.5	0
Up. Gaylor-2	30 Jul 86	5.5	5.5	
Up. Gaylor-I	30 Jul 86	-	-	
Up. Granite-1	30 Jul 86	9.0	6.0	0
Up. Granite-2	30 Jul 86	10.0	6.0	
McCloud-1	14 May 86	6.6	-	1.6
Crystal-2	14 May 86	8.3	-	1.6
Ruby-2	15 May 86	>15	-	1.8
Up. Treas-1	15 May 86	3.4	-	2.7
Gem-1	15 May 86	6.1	-	2.6
Piute-2	16 May 86	8.3	-	1.8
Emerson-2	16 May 86	10.5	-	2.2
Golden Trout-1	31 Jul 86	11.0	11.0	0
Golden Trout-2	31 Jul 86	4.5	4.5	
Unnamed-1	31 Jul 86	12.0	6.0	0
Unnamed-2	31 Jul 86	10.5	6.0	
Heather-2	15 Apr 86	6.0	-	2.5
Pear-4	15 Apr 86	-	-	2.5
Up. Mosquito-1	10 Aug 86	3.3	3.3	0
Up. Mosquito-2	10 Aug 86	5.6	5.6	
Up. Mosquito-I	10 Aug 86	-	-	
Crystal (M.K.)-1	10 Aug 86	33.0	16.5	0
Crystal (M.K.)-2	10 Aug 86	19.0	11.0	
Crystal (M.K.)-I	10 Aug 86	-	-	

TABLE 5 (cont.)

Lake/Station	Date	Z	Zs	Ice Thickness
Rancho Oeste-1	28 Apr 86	0.8	0.7	0
Lompoc-Casmalia-1	28 Apr 86	1.5	1.3	0
Dune-1	28 Apr 86	-	-	0

TABLE 6. Precision evaluation of the Dionex 2010i Ion Chromatograph (200 μl injection, 3 μS attenuation) on 24 November 1985. Gem Lake water and snow melt from Mammoth Mountain were run alternately each six times. A mean and standard deviation were used to calculate the coefficient of variation (C.V.). The water samples had been stored at 4°C since 1983.

Ion	Gem Lake Water		Mammoth Snow Melt	
	mean (μeq·l^{-1})	C.V. (%)	mean (μeq·l^{-1})	C.V. (%)
Chloride	7.5	11.0	1.8	68.0
Nitrate	5.0	0	0.9	5.0
Sulfate	5.3	2.2	1.0	5.2

TABLE 7. Precision evaluation of Varian AA6 atomic absorption spectrophotometer (direct, air-acetylene) on 27 November 1985. A mean and standard deviation of six separate readings alternated between Gem Lake water and snow melt water from Mammoth Mountain was used to calculate the coefficient of variation (C.V.). Both samples had been stored at 4°C since 1983.

	Gem Lake		Mammoth Snow	
Element	Mean (μeq·l^{-1})	C.V. (%)	Mean (μeq·l^{-1})	C.V. (%)
Calcium	25.0	2.5	2.8	18.0
Magnesium	2.2	2.5	0.5	9.8
Sodium	20.2	1.2	1.5	5.6
Potassium	1.9	2.4	0.8	10.3

Table 8: Standard deviation (S.D.) and method detection limit† (MDL = 2 SD) of chemical methods. Replicate determinations (n) of deionized water (DIW) or analyst prepared standards† (the levels tabulated are the theoretical concentrations) were measured on separate days except where indicated (*) when a single trial on one day was used.

Constituent	n	Standard	SD	MDL
Ammonium, μM	10	DIW	0.15	0.30
Phosphate, μM	10	DIW	0.03	0.06
Silica, μM	7	DIW	0.20	0.40
Nitrate, $\mu eq \cdot l^{-1}$	7*	0.50	0.10	0.20
Chloride, $\mu eq \cdot l^{-1}$	7*	0.50	0.19	0.38
Sulfate, $\mu eq \cdot l^{-1}$	7*	0.75	0.22	0.44
Calcium, $\mu eq \cdot l^{-1}$	4	2.50	0.50	1.00
Magnesium, $\mu eq \cdot l^{-1}$	4	2.06	0.16	0.32
Sodium, $\mu eq \cdot l^{-1}$	6	1.09	0.25	0.50
Potassium, $\mu eq \cdot l^{-1}$	6	0.64	0.22	0.45

†Limits of detection for major ions were established in accord with the Scientific Apparatus Makers Association (SAMA) definition for detection limit: that concentration which yields an absorbance equal to twice the standard deviation of a series of measurements of a solution whose concentration is detectable above, but close to the blank absorbance. Determination of method detection limits for ions by ion chromatography (Dionex 2010i ion chromatograph, 200 μl sample loop, 3 μS attenuation) or atomic absorption spectrophotometry (direct, air-acetylene) necessitated the use of a low level standard as DIW gave no signal under our routine operating conditions.

TABLE 9. Recovery of known additions of chloride, nitrate, and sulfate at two levels on 3 June 1986. Aliquots of UCSB calibration standards were dispensed into volumetric flasks and these were brought to volume with USGS-P8 reference material. All values are in microequivalents per liter. Each sample was replicated six times.

Sample	Chloride		Nitrate		Sulfate	
	Calc	Meas	Calc	Meas	Calc	Meas
USGS-P8	-	2.5±0.1	-	3.9±0.0	-	6.7±0.4
USGS-P8(2)	4.5	4.6±0.5	5.9	5.1±0.0	8.7	8.7±0.5
USGS-P8(4)	6.5	6.5±0.5	7.9	8.0±0.1	10.7	10.9±0.5

TABLE 10. Recovery of known additions of calcium, magnesium, sodium, and potassium at two levels on 5 June 1986. Aliquots of UCSB calibration standards were dispensed into volumetric flasks and these were brought to volume with USGS-P8 reference material. All values are in microequivalents per liter.

Sample	Ca		Mg		Na		K	
	Calc	Meas	Calc	Meas	Calc	Meas	Calc	Meas
USGS-P8	-	9.7	-	2.3	-	3.4	-	1.3
USGS-P8(+)	12.2	13.7	6.4	6.8	5.6	5.5	2.6	2.8
USGS-P8(++)	15.9	17.0	12.6	12.8	8.8	8.8	4.5	4.9

TABLE 11. Evaluation of Standard Reference Materials from the National Bureau of Standards (NBS) and from the United States Geological Survey (USGS) on 3 June 1986. NBS-2694 is simulated rainwater and USGS-P8 is snow melt water. Anion concentrations were determined on a Dionex 2010i ion chromatograph. All values are in microequivalents per liter.

Reference Material	Date of Certification	Chloride		Nitrate		Sulfate	
		Certified	UCSB	Certified	UCSB	Certified	UCSB
NBS-2694-I	23 Apr 1986	6.8+	7.1	†	8.2	57.3±1.1	58.4
NBS-2694-II	23 Apr 1986	28.2+	39.6	114±2.5	122	227±4.2	254
USGS-P8	July 1986*	2.5±0.9	2.0	3.9±0.4	4.3	8.5±4.0	7.7

+ Uncertified value reported by NBS.

† NBS notification of 27 May 1986 claims nitrate value to be out of certification due to bacterial or fungal activity.

* Report of the U.S. Geological Survey's Analytical Evaluation Program - Standard Reference Water Samples M6, M94, T95, N16, P8, and SED3. USGS, Denver, Colorado, July 1986. The certified values of Cl, NO_3, and SO_4 are means and standard deviations of 9, 4, and 13 individual laboratories each employing ion chromatography for analysis of chloride, nitrate, and sulfate, respectively. UCSB's average rating was 3 in overall laboratory performance for values of anions submitted. Rating 3 was 0.51 to 1.00 standard deviations; the highest rating was 4 with 0.00 to 0.50 standard deviations.

TABLE 12. Evaluation of Standard Reference Materials from the National Bureau of Standards (NBS) and from the United Stated Geological Survey (USGS) on 5 June 1986. NBS-2694 is simulated rainwater and USGS-P8 is snow melt water. Cation concentrations were determined on a Varian AA6 atomic absorption spectophotometer. All values are in microequivalents per liter.

Reference Material	Date of Certification	Ca		Mg		Na		K	
		Certified	UCSB	Certified	UCSB	Certified	UCSB	Certified	UCSB
NBS-2694-I	23 Apr 1986	0.7±0.2	1.1	2.0±0.2	2.4	8.9±0.4	8.1	1.3±0.2	1.9
NBS-2694-II	23 Apr 1986	2.5±0.6	3.0	4.2±0.3	4.5	18.2±0.7	17.4	2.7±0.2	2.8
USGS-P8	July 1986*	11.7±2.0	9.7	2.7±0.8	2.3	1.3±0.9	3.4	1.4±0.6	1.3

* Report of the U.S. Geological Survey's Analytical Evaluation Program - Standard Reference Water Samples M6, M94, T95, N16, P8, and SED3. USGS, Denver, Colorado, July 1986. The certified values of Ca, Mg, Na, and K are means and standard deviations of 37, 35, 33, and 31 individual laboratories each employing atomic absorption spectrophotometry for analysis of cations. UCSB's average rating was 3 in overall laboratory performance for values of cations submitted. Rating 3 was 0.51 to 1.00 standard deviations; the highest rating was 4 with 0.00 to 0.50 standard deviations.

TABLE 13: Acid neutralizing capacity (ANC), pH, Conductance at 25°C (Cond), and ion balance of subsurface and near-bottom samples for lakes sampled during autumn 1985. Sample depth is in meters. Dash indicates no data.

Lake/Station	Date	Sample Depth	pH	ANC $\mu eq \cdot l^{-1}$	Cond. $\mu S \cdot cm^{-1}$	Σ pos. $\mu eq \cdot l^{-1}$	Σ neg.
Up. Gaylor-1	24 Sep 85	0.2	7.01	123	11.2	142	152
Up. Gaylor-1	24 Sep 85	4.0	6.86	125	11.0	130	164
Up. Gaylor-2	24 Sep 85	0.2	6.91	119	11.6	133	146
Up. Gaylor-2	24 Sep 85	4.0	7.07	123	10.5	130	167
Up. Granite-1	24 Sep 85	0.2	6.97	89	6.8	83	99
Up. Granite-1	24 Sep 85	8.0	7.18	84	6.9	81	97
Up. Granite-2	24 Sep 85	0.2	7.01	74	6.7	79	84
Up. Granite-2	24 Sep 85	4.0	6.79	86	6.8	81	98
McCloud-1	22 Sep 85	0.2	6.72	44	4.6	53	58
McCloud-1	22 Sep 85	4.0	6.17	60	4.6	51	69
McCloud-2	22 Sep 85	0.2	6.70	46	4.6	51	53
McCloud-2	22 Sep 85	4.0	6.58	50	4.6	51	65
Crystal-1	22 Sep 85	0.2	6.41	71	6.5	74	83
Crystal-1	22 Sep 85	4.5	6.44	70	7.8	75	80
Crystal-2	22 Sep 85	0.2	6.40	73	6.3	75	85
Crystal-2	22 Sep 85	4.5	6.40	71	7.2	76	84
Ruby-1	23 Sep 85	0.2	6.84	56	4.9	59	66
Ruby-1	23 Sep 85	4.0	6.75	57	4.8	55	67
Ruby-2	23 Sep 85	0.2	6.75	52	5.1	57	63
Ruby-2	23 Sep 85	4.0	6.78	54	4.7	55	65
Up. Treas-1	23 Sep 85	0.2	6.65	34	3.8	42	47
Up. Treas-1	23 Sep 85	1.5	6.68	33	3.8	38	50
Up. Treas-2	23 Sep 85	0.2	6.65	32	3.9	44	46
Up. Treas-2	23 Sep 85	3.0	6.60	33	3.8	44	48
Gem-1	23 Sep 85	0.2	7.03	113	10.3	118	149
Gem-1	23 Sep 85	4.0	6.99	104	11.0	120	136
Gem-2	23 Sep 85	0.2	7.18	101	10.4	119	135
Gem-2	23 Sep 85	4.0	7.09	107	10.5	126	138
Gem-I	23 Sep 85	0.1	7.26	229	22.7	240	276
Piute-1	25 Sep 85	0.2	6.71	-	5.6	-	-
Piute-1	25 Sep 85	4.0	6.72	47	5.2	62	62
Piute-2	25 Sep 85	0.2	6.89	45	5.4	60	61
Piute-2	25 Sep 85	9.0	6.83	49	4.9	58	66
Piute-I	25 Sep 85	0.1	6.98	88	9.1	111	132

TABLE 13 (cont.)

Lake/Station	Date	Sample Depth	pH	ANC	Cond.	Σ pos.	Σ neg.
				$\mu eq \cdot l^{-1}$	$\mu S \cdot cm^{-1}$	$\mu eq \cdot l^{-1}$	
Emerson-1	25 Sep 85	0.2	6.99	58	5.8	73	76
Emerson-1	25 Sep 85	9.0	7.00	56	6.0	66	71
Emerson-2	25 Sep 85	0.2	7.03	58	5.9	63	71
Emerson-2	25 Sep 85	9.0	7.01	55	5.7	62	69
Golden Trout-1	26 Sep 85	0.2	7.47	323	45.3	384	441
Golden Trout-1	26 Sep 85	8.0	7.46	322	44.2	389	439
Golden Trout-2	26 Sep 85	0.2	7.55	338	43.3	392	463
Golden Trout-2	26 Sep 85	6.0	7.45	332	42.8	392	453
Unnamed-1	26 Sep 85	0.2	7.10	80	7.6	79	122
Unnamed-1	26 Sep 85	9.0	6.99	67	7.8	78	82
Unnamed-2	26 Sep 85	0.2	7.00	79	9.0	82	120
Unnamed-2	26 Sep 85	9.0	7.14	77	8.1	78	93
Hume-1	9 Sep 85	0.2	6.95	445	50.0	472	470
Hume-1	9 Sep 85	3.0	6.98	446	48.5	484	468
Hume-I_1	9 Sep 85	0.1	7.23	-	57.9	-	-
Hume-I_2	9 Sep 85	0.1	7.44	-	48.3	-	-
Heather-1	5 Sep 85	0.2	6.07	52	5.4	55	62
Heather-1	5 Sep 85	5.0	6.30	50	5.2	53	60
Pear-1	6 Sep 85	0.2	6.10	16	2.9	27	22
Pear-1	6 Sep 85	5.0	6.25	-	2.8	-	-
Pear-2	14 Oct 85	1.0	6.42	24	3.1	29	40
Pear-2	14 Oct 85	9.5	6.43	25	3.2	28	40
Pear-3	14 Oct 85	1.0	6.43	25	3.2	29	42
Pear-3	14 Oct 85	9.0	6.33	25	3.4	28	39
Pear-I	14 Oct 85	0.1	6.45	26	4.8	37	53
Oriole-1	28 Oct 85	0.2	6.89	423	43.1	422	496
Oriole-1	28 Oct 85	4.0	6.84	412	42.6	419	476
Oriole-2	28 Oct 85	0.2	6.90	418	42.6	429	481
Oriole-2	28 Oct 85	4.0	6.80	-	43.1	426	-
Up. Mosquito-1	29 Oct 85	0.2	6.86	62	7.5	78	79
Up. Mosquito-1	29 Oct 85	6.5	6.87	61	7.5	80	84
Up. Mosquito-2	29 Oct 85	0.2	6.87	61	7.7	78	91
Up. Mosquito-2	29 Oct 85	3.5	6.70	55	7.7	78	75
Crystal (M.K.)-1	29 Oct 85	0.2	6.66	50	6.6	75	72
Crystal (M.K.)-1	29 Oct 85	9.0	6.84	53	6.8	81	83
Crystal (M.K.)-2	29 Oct 85	0.2	6.57	50	6.7	74	76
Crystal (M.K.)-2	29 Oct 85	9.0	6.76	49	7.3	79	70

TABLE 13 (cont.)

Lake/Station	Date	Sample Depth	pH	ANC $\mu eq \cdot l^{-1}$	Cond. $\mu S \cdot cm^{-1}$	Σ pos. $\mu eq \cdot l^{-1}$	Σ neg.
Black-1	6 Nov 85	0.2	8.35	6565	1784	16057	16296
Black-2	6 Nov 85	0.2	8.45	-	1803	-	-
	6 Nov 85	2.5	8.34	6585	1803	20250	16048
Up. Twin-1	6 Nov 85	0.2	8.28	15414	4224	43719	45200
Zaca-1	9 Oct 85	0.2	8.46	4663	870	10179	10281
Zaca-1	9 Oct 85	9.0	7.42	7065	958	8044	12301
Zaca-2	9 Oct 85	0.2	8.52	4572	862	9214	10013
Zaca-2	9 Oct 85	9.0	7.40	7036	960	-	-

TABLE 14: Acid neutralizing capacity (ANC), pH, Conductance at 25°C (Cond), and ion balance of subsurface and near-bottom samples for lakes sampled during spring and summer 1986. Sample depth is in meters. Dash indicates no data, and asterisks designate ice-covered lakes.

Lake/Station	Date	Sample Depth	pH	ANC $\mu eq \cdot l^{-1}$	Cond. $\mu S \cdot cm^{-1}$	Σ pos.	Σ neg.
						$\mu eq \cdot l^{-1}$	
Up. Gaylor-1	30 Jul 86	0.2	6.32	86	11.0	100	105
Up. Gaylor-1	30 Jul 86	3.5	6.17	96	10.7	101	116
Up. Gaylor-2	30 Jul 86	0.2	6.30	95	10.7	104	114
Up. Gaylor-2	30 Jul 86	4.0	6.30	89	10.9	101	112
Up. Gaylor-I	30 Jul 86	-	6.18	118	14.4	131	147
Up. Granite-1	30 Jul 86	0.2	6.00	68	8.5	68	76
Up. Granite-1	30 Jul 86	8.0	6.33	66	7.6	66	71
Up. Granite-2	30 Jul 86	0.2	5.95	63	7.5	66	69
Up. Granite-2	30 Jul 86	8.0	6.16	68	7.5	65	73
McCloud-1	14 May 86*	1.8	5.98	37	4.7	46	58
McCloud-1	14 May 86	6.0	5.84	55	6.5	64	77
Crystal-2	14 May 86*	1.7	6.15	68	8.1	76	85
Crystal-2	14 May 86	7.5	6.10	75	7.7	79	93
Ruby-2	15 May 86*	2.0	6.19	61	6.6	68	77
Ruby-2	15 May 86	12.5	6.08	56	5.9	61	74
Up. Treas-1	15 May 86*	2.8	5.82	41	6.5	66	82
Up. Treas-1	15 May 86	3.2	5.81	43	6.7	66	85
Gem-1	15 May 86*	2.8	6.60	226	18.9	236	307
Gem-1	15 May 86	5.8	6.39	191	22.3	255	238
Piute-2	16 May 86*	2.0	5.76	61	6.5	76	96
Piute-2	16 May 86	7.5	5.80	80	7.7	126	107
Emerson-2	16 May 86*	2.4	5.99	40	6.0	67	78
Emerson-2	16 May 86	9.5	6.02	50	6.7	70	73
Golden Trout-1	31 Jul 86	0.2	6.46	308	43.5	334	432
Golden Trout-1	31 Jul 86	10.0	6.50	305	45.4	355	445
Golden Trout-2	31 Jul 86	0.2	6.51	305	44.3	341	434
Golden Trout-2	31 Jul 86	3.5	6.50	309	44.0	337	436
Unnamed-1	31 Jul 86	0.2	6.16	76	9.1	85	90
Unnamed-1	31 Jul 86	11.0	6.32	88	10.5	85	103
Unnamed-2	31 Jul 86	0.2	6.35	79	8.7	85	94
Unnamed-2	31 Jul 86	9.0	6.32	82	9.1	87	96

TABLE 14 (cont.)

Lake/Station	Date	Sample Depth	pH	ANC µeq•l^{-1}	Cond. µS•cm^{-1}	Σ pos. µeq•l^{-1}	Σ neg.
Heather-2	15 Apr 86*	2.5	5.92	56	7.9	80	79
Heather-2	15 Apr 86	5.0	5.87	71	8.6	82	92
Pear-4	15 Apr 86*	3.5	5.94	32	5.7	54	51
Pear-4	15 Apr 86	14.0	5.78	22	5.3	57	49
Up. Mosquito-1	10 Aug 86	0.2	6.54	45	7.0	61	60
Up. Mosquito-1	10 Aug 86	3.0	6.70	47	5.2	60	61
Up. Mosquito-2	10 Aug 86	0.2	6.63	46	6.6	61	61
Up. Mosquito-2	10 Aug 86	5.0	6.58	43	6.9	60	59
Up. Mosquito-I	10 Aug 86	-	6.68	53	7.4	71	82
Crystal (M.K.)-1	10 Aug 86	0.2	6.34	39	6.9	68	58
Crystal (M.K.)-1	10 Aug 86	20.5	6.25	51	8.6	82	74
Crystal (M.K.)-2	10 Aug 86	0.2	6.34	41	6.4	67	60
Crystal (M.K.)-2	10 Aug 86	16.5	6.32	42	6.9	67	52
Crystal (M.K.)-I	10 Aug 86	-	6.30	17	4.4	40	25
Rancho-Oeste-1	28 Apr 86	0.2	7.78	5690	3480	27840	40540
Lompoc-Casmalia-1	28 Apr 86	0.2	7.79	5055	1845	15730	22501
Dune-1	28 Apr 86	0.2	8.88	6218	49400	74883	-

TABLE 15: Major ions for lakes sampled during autumn 1985. All values are in microequivalents per liter ($\mu eq \cdot l^{-1}$); undetectable levels are designated u; sample depths are in meters. Dash indicates no data.

Lake/Station	Date	Sample Depth	Ca	Mg	Na	K	HCO_3	NO_3	SO_4	Cl
Up. Gaylor-1	24 Sep 85	0.2	120.1	6.6	12.3	2.5	123	1.4	25.6	2.2
Up. Gaylor-1	24 Sep 85	4.0	112.7	5.8	9.0	2.5	125	1.0	36.2	2.0
Up. Gaylor-2	24 Sep 85	0.2	114.4	5.8	10.1	2.4	119	u	24.5	2.0
Up. Gaylor-2	24 Sep 85	4.0	112.7	6.2	9.0	2.5	123	u	33.1	2.8
Up. Granite-1	24 Sep 85	0.2	53.8	6.8	18.3	3.6	89	0.7	7.8	2.1
Up. Granite-1	24 Sep 85	8.0	52.9	6.7	18.3	3.5	83	1.1	7.3	5.0
Up. Granite-2	24 Sep 85	0.2	50.5	6.8	18.3	3.5	74	0.2	6.3	2.5
Up. Granite-2	24 Sep 85	4.0	52.2	6.7	18.3	3.5	86	1.2	6.7	3.9
McCloud-1	22 Sep 85	0.2	21.9	9.2	17.0	4.6	44	0.4	9.8	2.6
McCloud-1	22 Sep 85	4.0	21.0	9.4	16.1	4.6	60	u	5.8	3.2
McCloud-2	22 Sep 85	0.2	21.0	9.0	16.2	4.6	46	u	5.3	2.2
McCloud-2	22 Sep 85	4.0	21.0	9.2	16.4	4.6	50	2.4	7.5	5.2
Crystal-1	22 Sep 85	0.2	40.7	13.4	18.5	1.1	71	1.5	6.9	3.1
Crystal-1	22 Sep 85	4.5	41.5	13.4	18.5	1.1	70	0.9	6.9	2.8
Crystal-2	22 Sep 85	0.2	42.3	13.4	17.8	1.1	73	1.8	7.0	3.3
Crystal-2	22 Sep 85	4.5	43.2	13.5	18.3	1.1	71	0.5	7.0	3.9
Ruby-1	23 Sep 85	0.2	43.2	3.7	10.1	2.4	56	1.5	6.8	1.6
Ruby-1	23 Sep 85	4.0	41.5	3.3	8.0	2.3	57	1.7	6.9	1.3
Ruby-2	23 Sep 85	0.2	42.3	3.4	8.0	2.4	52	1.7	7.1	1.6
Ruby-2	23 Sep 85	4.0	40.7	3.3	8.3	2.4	54	1.4	7.0	1.5
Up. Treas-1	23 Sep 85	0.2	32.5	2.5	5.5	1.8	34	6.0	5.4	2.1
Up. Treas-1	23 Sep 85	1.5	28.4	2.2	5.4	1.8	33	5.9	8.9	2.4
Up. Treas-2	23 Sep 85	0.2	33.3	2.6	5.8	1.8	32	6.3	5.1	2.1
Up. Treas-2	23 Sep 85	3.0	33.3	2.8	5.6	1.8	33	6.1	5.8	3.0
Gem-1	23 Sep 85	0.2	70.2	2.5	42.4	2.4	113	8.3	21.9	5.3
Gem-1	23 Sep 85	4.0	71.8	2.8	42.5	2.4	104	8.3	19.2	4.6
Gem-2	23 Sep 85	0.2	72.6	2.7	41.3	2.4	101	8.1	21.0	5.0
Gem-2	23 Sep 85	4.0	77.5	2.7	42.9	2.4	107	11.5	14.5	5.1
Gem-I	23 Sep 85	0.1	114.4	1.1	123.0	2.4	229	12.0	14.6	20.0
Piute-1	25 Sep 85	0.2	43.2	4.7	12.3	2.6	-	2.3	11.7	1.8
Piute-1	25 Sep 85	4.0	43.2	6.4	9.6	2.6	47	2.7	10.4	2.0
Piute-2	25 Sep 85	0.2	43.2	4.4	9.7	2.6	45	3.9	9.5	2.2
Piute-2	25 Sep 85	9.0	41.5	4.3	9.4	2.6	49	2.1	13.8	1.3
Piute-I	25 Sep 85	0.1	73.4	7.2	25.3	5.1	88	7.9	20.1	16.3

TABLE 15 (cont.)

Lake/Station	Date	Sample Depth	Ca	Mg	Na	K	HCO_3	NO_3	SO_4	Cl
Emerson-1	25 Sep 85	0.2	44.8	5.8	9.0	3.4	58	4.3	7.3	6.1
Emerson-1	25 Sep 85	9.0	48.1	5.8	9.0	3.2	56	3.6	8.0	2.0
Emerson-2	25 Sep 85	0.2	44.8	5.5	9.0	3.3	58	3.9	6.6	2.6
Emerson-2	25 Sep 85	9.0	44.0	5.0	9.0	3.8	55	3.7	8.3	2.4
Golden Trout-1	26 Sep 85	0.2	335.4	18.1	21.8	8.4	323	3.5	115.1	5.3
Golden Trout-1	26 Sep 85	8.0	341.1	17.7	21.3	8.6	322	2.7	112.0	3.2
Golden Trout-2	26 Sep 85	0.2	344.6	17.7	21.8	8.4	338	3.2	118.0	3.1
Golden Trout-2	26 Sep 85	6.0	345.2	17.5	21.3	8.4	332	3.3	114.8	3.3
Unnamed-1	26 Sep 85	0.2	62.8	6.0	5.5	5.0	80	0.4	39.3	2.3
Unnamed-1	26 Sep 85	9.0	62.0	5.7	5.3	5.1	67	u	12.3	2.6
Unnamed-2	26 Sep 85	0.2	65.3	5.9	5.5	5.0	79	0.4	38.9	1.6
Unnamed-2	26 Sep 85	9.0	62.0	5.9	5.3	5.1	77	0.3	14.7	0.9
Hume-1	9 Sep 85	0.2	239	63.6	140	29.2	445	u	6.3	18.3
Hume-1	9 Sep 85	3.0	251	63.0	140	29.2	446	u	1.9	20.2
Hume-I_1	9 Sep 85	0.1	255	70.8	167	32.8	-	u	20.0	48.0
Hume-I_2	9 Sep 85	0.1	214	54.3	151	29.7	-	u	5.8	49.5
Heather-1	5 Sep 85	0.2	28.4	6.0	16.6	3.8	52	0.4	4.6	5.2
Heather-1	5 Sep 85	5.0	28.4	5.7	15.5	3.3	50	0.9	4.9	4.1
Pear-1	6 Sep 85	0.2	17.0	3.0	5.7	1.3	16	u	4.3	1.5
Pear-1	6 Sep 85	5.0	17.0	2.7	5.5	1.3	-	u	4.7	1.5
Pear-2	14 Oct 85	1.0	16.0	1.6	9.1	1.5	24	1.0	7.3	7.3
Pear-2	14 Oct 85	9.5	16.0	1.6	8.3	1.4	25	0.9	6.3	7.5
Pear-3	14 Oct 85	1.0	16.0	1.6	9.6	1.6	25	0.9	9.4	6.1
Pear-3	14 Oct 85	9.0	15.0	1.6	9.6	1.4	25	1.0	6.1	7.4
Pear-I	14 Oct 85	0.1	20.8	2.1	12.6	1.5	26	3.8	11.1	12.1
Oriole-1	28 Oct 85	0.2	164	52.5	157.0	48.2	423	u	11.3	61.2
Oriole-1	28 Oct 85	4.0	162	48.8	161.0	47.1	412	u	11.9	51.6
Oriole-2	28 Oct 85	0.2	170	50.7	161.0	47.4	418	u	9.0	53.7
Oriole-2	28 Oct 85	4.0	165	52.9	161.0	47.4	-	u	13.2	76.4
Up. Mosquito-1	29 Oct 85	0.2	59.2	3.8	13.1	1.9	62	2.5	16.4	0.8
Up. Mosquito-1	29 Oct 85	6.5	61.1	3.8	13.1	1.9	61	1.9	19.8	0.8
Up. Mosquito-2	29 Oct 85	0.2	59.2	3.8	13.1	2.1	61	2.2	26.9	1.1
Up. Mosquito-2	29 Oct 85	3.5	59.2	3.8	13.1	1.9	55	2.0	16.1	0.7
Crystal (M.K.)-1	29 Oct 85	0.2	50.6	5.7	15.7	3.4	50	5.2	14.5	2.3
Crystal (M.K.)-1	29 Oct 85	9.0	51.5	6.2	19.1	4.5	53	9.0	15.1	5.4
Crystal (M.K.)-2	29 Oct 85	0.2	50.6	4.8	15.2	3.3	50	4.3	19.7	3.0
Crystal (M.K.)-2	29 Oct 85	9.0	50.6	9.7	15.3	3.3	49	4.0	14.9	1.5

TABLE 15 (cont.)

Lake/Station	Date	Sample Depth	Ca	Mg	Na	K	HCO_3	NO_3	SO_4	Cl
Black-1	6 Nov 85	0.2	2470	2803	10508	276	6565	u	130.0	9593
Black-2	6 Nov 85	0.2	2491	3078	11748	280	-	u	130.0	9210
	6 Nov 85	2.5	3654	3225	12575	796	6585	0.3	130.0	9333
Up. Twin-1	6 Nov 85	0.2	2665	15270	24794	890	15414	253	14066	15169
Zaca-1	9 Oct 85	0.2	2955	6150	1006	68	4663	1.1	5271	347
Zaca-1	9 Oct 85	9.0	1800	5025	830	62	7065	u	4913	323
Zaca-2	9 Oct 85	0.2	2450	5705	985	74	4572	0.6	5090	351
Zaca-2	9 Oct 85	9.0	-	-	-	-	7036	-	-	-

TABLE 16: Major ions for lakes sampled during spring and summer 1986. All values are in microequivalents per liter ($\mu eq \cdot l^{-1}$), undetectable levels are designated u; sample depths are in meters. Dash indicates no data.

Lake/Station	Date	Sample Depth	Ca	Mg	Na	K	HCO_3	NO_3	SO_4	Cl
Up. Gaylor-1	30 Jul 86	0.2	82.7	4.8	9.6	3.0	86	u	18.0	1.2
Up. Gaylor-1	30 Jul 86	3.5	83.7	4.7	9.8	3.0	96	u	18.2	1.4
Up. Gaylor-2	30 Jul 86	0.2	86.7	4.8	9.4	3.4	95	u	18.1	1.2
Up. Gaylor-2	30 Jul 86	4.0	82.7	4.9	10.1	3.0	89	u	20.7	2.0
Up. Gaylor-I	30 Jul 86	-	112.0	4.9	11.1	3.4	118	1.5	26.6	0.9
Up. Granite-1	30 Jul 86	0.2	40.6	5.1	17.3	5.0	68	5.7	1.5	1.3
Up. Granite-1	30 Jul 86	8.0	40.6	5.0	16.1	4.1	66	3.9	u	0.9
Up. Granite-2	30 Jul 86	0.2	40.6	4.8	15.7	4.3	63	4.0	0.4	1.4
Up. Granite-2	30 Jul 86	8.0	39.6	5.0	16.3	4.1	68	3.9	u	1.1
McCloud-1	14 May 86	1.8	18.7	8.3	13.9	4.0	37	2.7	15.2	3.2
McCloud-1	14 May 86	6.0	23.8	11.1	18.5	6.4	55	0.8	18.0	3.3
Crystal-2	14 May 86	1.7	36.1	13.0	19.6	6.1	68	2.2	10.9	3.6
Crystal-2	14 May 86	7.5	37.5	14.0	20.0	6.7	75	2.1	12.7	3.1
Ruby-2	15 May 86	2.0	47.6	4.0	12.4	3.7	61	3.7	12.2	u
Ruby-2	15 May 86	12.5	42.6	3.7	10.7	3.7	56	5.0	13.0	u
Up. Treas-1	15 May 86	2.8	45.5	4.8	10.9	4.6	41	15.2	21.7	4.3
Up. Treas-1	15 May 86	3.2	46.2	4.9	10.5	4.6	43	15.8	21.8	4.1
Gem-1	15 May 86	2.8	134	3.2	93.5	5.2	226	15.7	58.5	6.6
Gem-1	15 May 86	5.8	144	4.1	99.1	7.7	188	12.4	33.2	4.9
Piute-2	16 May 86	2.0	46.9	7.4	15.0	6.1	61	12.5	18.8	3.7
Piute-2	16 May 86	7.5	57.8	15.3	41.5	11.3	80	7.7	14.0	5.3
Emerson-2	16 May 86	2.4	46.2	6.2	10.2	4.3	40	14.6	19.4	3.6
Emerson-2	16 May 86	9.5	46.2	7.4	10.1	5.2	50	10.2	9.0	3.7
Golden Trout-1	31 Jul 86	0.2	287	17.1	21.0	8.6	308	7.7	114	1.8
Golden Trout-1	31 Jul 86	10.0	305	18.0	22.7	8.6	305	8.1	130	2.1
Golden Trout-2	31 Jul 86	0.2	294	17.6	21.2	8.6	305	8.0	118	2.5
Golden Trout-2	31 Jul 86	3.5	290	17.1	21.1	8.6	309	7.8	117	2.0
Unnamed-1	31 Jul 86	0.2	64.0	5.1	9.1	6.9	76	2.8	10.0	1.3
Unnamed-1	31 Jul 86	11.0	64.1	5.5	8.1	6.9	88	2.6	11.1	1.5
Unnamed-2	31 Jul 86	0.2	65.0	5.1	8.1	6.5	79	3.0	10.5	1.3
Unnamed-2	31 Jul 86	9.0	68.0	5.1	7.2	6.9	82	2.3	10.9	1.3

TABLE 16 (cont.)

Lake/Station	Date	Sample Depth	Ca	Mg	Na	K	HCO_3	NO_3	SO_4	Cl
Heather-2	15 Apr 86	2.5	39.7	6.8	20.3	4.9	56	7.8	5.7	7.5
Heather-2	15 Apr 86	5.0	41.9	7.3	20.7	5.8	71	6.5	4.1	4.3
Pear-4	15 Apr 86	3.5	26.7	5.4	14.1	3.1	32	4.9	7.1	6.2
Pear-4	15 Apr 86	14.0	25.2	5.0	18.0	3.7	22	5.3	15.4	5.9
Up. Mosquito-1	10 Aug 86	0.2	42.5	2.5	12.4	3.0	45	1.7	10.8	1.6
Up. Mosquito-1	10 Aug 86	3.0	43.0	2.5	11.4	3.0	47	1.7	10.7	1.2
Up. Mosquito-2	10 Aug 86	0.2	42.5	2.5	11.5	3.4	46	2.4	11.3	1.2
Up. Mosquito-2	10 Aug 86	5.0	42.5	2.7	11.1	3.4	43	2.5	11.5	1.2
Up. Mosquito-I	10 Aug 86	-	54.3	2.8	11.4	3.0	53	10.9	15.5	2.1
Crystal (M.K.)-1	10 Aug 86	0.2	43.0	4.0	16.0	5.0	39	5.6	11.9	1.2
Crystal (M.K.)-1	10 Aug 86	20.5	54.3	5.1	17.1	6.0	51	6.9	15.3	1.4
Crystal (M.K.)-2	10 Aug 86	0.2	42.5	3.9	14.0	5.0	41	5.5	11.3	1.3
Crystal (M.K.)-2	10 Aug 86	16.5	43.0	4.0	14.9	5.0	32	5.6	12.8	1.3
Crystal (M.K.)-I	10 Aug 86	-	21.9	1.6	10.5	5.0	17	1.8	4.5	0.4
Rancho-Oeste-1	28 Apr 86	0.2	5747	4570	17104	415	5690	u	10390	24460
Lompoc-Casmalia-1	28 Apr 86	0.2	3613	3436	8549	131	5055	u	4050	13396
Dune-1	28 Apr 86	0.2	12917	12705	39129	10132	6218	u	20200	-

TABLE 17: Levels of major nutrients, total nitrogen (TN), total phosphorus (TP), total dissolved nitrogen (TDN) and total dissolved phosphorus (TDP) for lakes sampled during autumn 1985. All values are micromolar (μM), undetectable levels are designated u; sample depths are in meters. Dash indicates no data.

Lake/Station	Date	Sample Depth	NH_4	NO_3	PO_4	Silica	TN	TDN	TP	TDP
Up. Gaylor-1	24 Sep 85	0.2	u	1.4	0.1	13.8	2.8	1.2	0.15	0.09
Up. Gaylor-1	24 Sep 85	4.0	u	1.0	u	12.4	4.9	1.3	0.28	0.13
Up. Gaylor-2	24 Sep 85	0.2	0.5	u	u	13.1	2.2	1.5	0.28	0.11
Up. Gaylor-2	24 Sep 85	4.0	u	u	u	13.2	2.2	1.6	0.32	0.15
Up. Granite-1	24 Sep 85	0.2	u	0.7	0.1	34.0	1.2	1.5	0.31	0.09
Up. Granite-1	24 Sep 85	8.0	u	1.1	0.1	33.5	2.8	1.8	0.46	0.20
Up. Granite-2	24 Sep 85	0.2	u	0.2	u	35.3	1.3	1.3	0.26	0.14
Up. Granite-2	24 Sep 85	4.0	u	1.2	u	34.6	1.7	1.4	0.10	0.15
McCloud-1	22 Sep 85	0.2	u	0.4	0.1	44.6	2.8	2.0	0.15	0.19
McCloud-1	22 Sep 85	4.0	u	u	0.1	44.1	2.9	2.6	0.20	0.21
McCloud-2	22 Sep 85	0.2	u	u	0.1	42.5	3.2	1.5	0.26	0.21
McCloud-2	22 Sep 85	4.0	u	2.4	0.2	41.1	2.8	1.9	0.24	0.15
Crystal-1	22 Sep 85	0.2	u	1.5	0.2	54.6	1.9	1.8	0.15	0.10
Crystal-1	22 Sep 85	4.5	u	0.9	0.2	55.4	1.7	0.8	0.08	0.09
Crystal-2	22 Sep 85	0.2	u	1.8	0.1	56.8	2.2	0.5	0.09	0.11
Crystal-2	22 Sep 85	4.5	u	0.5	0.2	54.3	1.5	1.1	0.15	0.09
Ruby-1	23 Sep 85	0.2	u	1.5	u	33.2	3.1	3.5	u	u
Ruby-1	23 Sep 85	4.0	u	1.7	u	32.7	3.7	3.9	u	u
Ruby-2	23 Sep 85	0.2	u	1.7	u	33.0	3.0	2.8	u	u
Ruby-2	23 Sep 85	4.0	u	1.4	u	34.3	3.2	2.9	u	u
Up. Treas-1	23 Sep 85	0.2	u	6.0	u	26.8	6.9	6.1	0.13	u
Up. Treas-1	23 Sep 85	1.5	u	5.9	u	27.8	7.4	6.3	0.10	u
Up. Treas-2	23 Sep 85	0.2	u	6.3	u	27.2	6.4	6.0	0.10	u
Up. Treas-2	23 Sep 85	3.0	u	6.1	u	26.7	6.4	6.2	0.10	0.09
Gem-1	23 Sep 85	0.2	0.4	8.3	u	59.5	7.8	7.0	u	u
Gem-1	23 Sep 85	4.0	u	8.3	u	60.5	8.1	7.4	u	0.10
Gem-2	23 Sep 85	0.2	0.4	8.1	u	57.0	8.3	7.5	0.15	0.10
Gem-2	23 Sep 85	4.0	u	11.5	u	58.3	7.7	8.2	0.10	0.10
Gem-I	23 Sep 85	0.1	u	12.0	u	117	11.0	11.0	0.18	0.10
Piute-1	25 Sep 85	0.2	u	2.3	0.1	30.9	1.8	2.2	0.23	0.07
Piute-1	25 Sep 85	4.0	u	2.7	u	29.9	2.1	2.3	0.23	0.05
Piute-2	25 Sep 85	0.2	u	3.9	0.1	30.4	2.0	2.6	0.10	0.08
Piute-2	25 Sep 85	9.0	u	2.1	0.1	29.8	1.9	1.9	0.29	0.08
Piute-I	25 Sep 85	0.1	u	7.9	0.1	54.9	4.1	3.4	0.25	0.11

TABLE 17 (cont.)

Lake/Station	Date	Sample Depth	NH_4	NO_3	PO_4	Silica	TN	TDN	TP	TDP
Emerson-1	25 Sep 85	0.2	u	4.3	u	33.1	8.4	3.4	0.26	0.05
Emerson-1	25 Sep 85	9.0	u	3.6	u	31.5	6.9	2.5	0.31	0.10
Emerson-2	25 Sep 85	0.2	u	3.9	0.1	31.7	3.9	2.9	0.37	0.10
Emerson-2	25 Sep 85	9.0	u	3.7	u	31.5	5.7	3.0	0.32	0.10
Golden Trout-1	26 Sep 85	0.2	u	3.5	0.1	16.3	5.8	5.7	u	u
Golden Trout-1	26 Sep 85	8.0	u	2.7	u	16.2	7.3	5.9	u	u
Golden Trout-2	26 Sep 85	0.2	u	3.2	u	16.4	6.3	5.5	u	u
Golden Trout-2	26 Sep 85	6.0	u	3.3	u	17.8	6.7	6.0	u	u
Unnamed-1	26 Sep 85	0.2	u	0.4	u	3.8	4.1	2.8	u	u
Unnamed-1	26 Sep 85	9.0	u	u	u	2.9	4.8	4.8	0.25	0.22
Unnamed-2	26 Sep 85	0.2	u	0.4	0.1	3.6	4.1	3.1	u	u
Unnamed-2	26 Sep 85	9.0	u	0.3	0.1	2.9	4.5	5.0	0.20	0.20
Hume-1	9 Sep 85	0.2	0.4	u	0.2	190	11.0	10.2	0.56	0.43
Hume-1	9 Sep 85	3.0	0.5	u	u	198	13.7	11.2	0.60	0.43
Hume-I_1	9 Sep 85	0.1	u	u	0.1	195	-	-	-	-
Hume-I_2	9 Sep 85	0.1	1.3	u	u	304	-	-	-	-
Heather-1	5 Sep 85	0.2	0.2	0.4	0.05	17.3	13.3	4.9	0.18	0.20
Heather-1	5 Sep 85	5.0	0.6	0.8	u	17.3	8.9	5.1	0.20	0.17
Pear-1	6 Sep 85	0.2	0.2	u	u	11.3	2.6	2.1	0.17	0.07
Pear-1	6 Sep 85	5.0	0.4	u	u	11.2	3.9	1.2	0.15	0.10
Pear-2	14 Oct 85	1.0	0.3	1.0	u	10.7	3.9	4.1	0.20	0.10
Pear-2	14 Oct 85	9.5	0.3	0.9	u	10.7	3.4	3.8	0.20	0.10
Pear-3	14 Oct 85	1.0	0.6	0.9	u	10.3	4.4	3.3	0.20	0.10
Pear-3	14 Oct 85	9.0	0.5	1.0	u	10.7	4.7	3.4	0.20	0.20
Pear-I	14 Oct 85	0.1	u	3.8	u	43.9	2.2	3.3	u	u
Oriole-1	28 Oct 85	0.2	u	u	u	261	8.3	4.7	0.29	0.11
Oriole-1	28 Oct 85	4.0	u	u	u	263	10.1	5.1	0.54	0.07
Oriole-2	28 Oct 85	0.2	u	u	u	275	8.7	5.7	0.44	0.25
Oriole-2	28 Oct 85	4.0	u	u	u	274	10.0	7.9	0.52	0.30
Up. Mosquito-1	29 Oct 85	0.2	u	2.5	u	26.4	5.2	4.0	0.10	0.10
Up. Mosquito-1	29 Oct 85	6.5	u	4.1	u	25.8	5.1	4.2	0.10	0.10
Up. Mosquito-2	29 Oct 85	0.2	u	3.8	u	25.8	5.2	3.6	0.10	0.10
Up. Mosquito-2	29 Oct 85	3.5	u	3.0	u	25.7	4.9	4.4	0.20	0.10
Crystal (M.K.)-1	29 Oct 85	0.2	u	5.2	u	31.7	6.0	3.0	0.40	u
Crystal (M.K.)-1	29 Oct 85	9.0	u	9.0	u	31.8	4.2	3.3	0.20	u
Crystal (M.K.)-2	29 Oct 85	0.2	u	4.3	u	31.6	4.1	3.1	0.30	u
Crystal (M.K.)-2	29 Oct 85	9.0	u	4.0	u	30.6	3.8	3.7	0.20	u

TABLE 17 (cont.)

Lake/Station	Date	Sample Depth	NH_4	NO_3	PO_4	Silica	TN	TDN	TP	TDP
Black-1	6 Nov 85	0.2	u	u	8.2	36.2	192	160	20.0	20.0
Black-2	6 Nov 85	0.2	u	u	8.3	35.2	-	166	21.0	18.0
	6 Nov 85	2.5	u	0.3	8.7	15.0	192	170	19.0	18.0
Up. Twin-1	6 Nov 85	0.2	100	253	45.0	35.5	455	449	54.0	54.0
Zaca-1	9 Oct 85	0.2	0.6	1.1	0.4	110	22.4	16.2	1.3	0.91
Zaca-1	9 Oct 85	9.0	327	-	30.1	288	294	298	1.2	1.2
Zaca-2	9 Oct 85	0.2	u	0.6	0.3	107	23.9	15.4	1.2	0.77
Zaca-2	9 Oct 85	9.0	-	-	-	-	-	-	-	-

TABLE 18: Levels of major nutrients for lakes sampled during spring and summer 1986. All values are micromolar (μM), undetectable levels are designated u. Sample depths are in meters.

Lake/Station	Date	Sample Depth	NH_4	NO_3	PO_4	Silica
Up. Gaylor-1	30 Jul 86	0.2	u	u	0.1	18.9
Up. Gaylor-1	30 Jul 86	3.5	u	u	0.1	19.8
Up. Gaylor-2	30 Jul 86	0.2	u	u	0.1	19.0
Up. Gaylor-2	30 Jul 86	4.0	u	u	0.2	19.4
Up. Gaylor-I	30 Jul 86	-	u	1.5	0.1	30.9
Up. Granite-1	30 Jul 86	0.2	u	5.7	u	36.4
Up. Granite-1	30 Jul 86	8.0	u	3.9	u	33.5
Up. Granite-2	30 Jul 86	0.2	u	4.0	0.1	35.5
Up. Granite-2	30 Jul 86	8.0	u	3.9	0.1	36.1
McCloud-1	14 May 86	1.8	1.3	2.7	u	36.0
McCloud-1	14 May 86	6.0	3.8	0.8	u	46.2
Crystal-2	14 May 86	1.7	0.7	2.2	0.2	53.6
Crystal-2	14 May 86	7.5	0.3	2.1	0.2	46.1
Ruby-2	15 May 86	2.0	u	3.7	u	45.0
Ruby-2	15 May 86	12.5	u	5.0	u	40.3
Up. Treas-1	15 May 86	2.8	u	16.7	0.1	48.4
Up. Treas-1	15 May 86	3.2	u	15.8	u	50.4
Gem-1	15 May 86	2.8	u	15.7	0.2	114
Gem-1	15 May 86	5.8	u	12.4	0.1	126
Piute-2	16 May 86	2.0	0.8	12.5	0.3	49.4
Piute-2	16 May 86	7.5	3.8	7.7	1.3	60.6
Emerson-2	16 May 86	2.4	0.3	14.6	u	43.4
Emerson-2	16 May 86	9.5	1.3	10.2	u	39.1
Golden Trout-1	31 Jul 86	0.2	u	7.7	u	34.7
Golden Trout-1	31 Jul 86	10.0	u	8.1	0.1	37.4
Golden Trout-2	31 Jul 86	0.2	u	8.0	u	34.0
Golden Trout-2	31 Jul 86	3.5	u	7.8	0.1	34.0
Unnamed-1	31 Jul 86	0.2	u	2.8	0.1	9.8
Unnamed-1	31 Jul 86	11.0	u	2.6	0.1	10.7
Unnamed-2	31 Jul 86	0.2	u	3.0	0.1	9.8
Unnamed-2	31 Jul 86	9.0	u	2.3	0.1	9.8

TABLE 18 (cont.)

Lake/Station	Date	Sample Depth	NH_4	NO_3	PO_4	Silica
Heather-2	15 Apr 86	2.5	u	7.8	2.4	55.2
Heather-2	15 Apr 86	5.0	u	6.5	5.9	45.5
Pear-4	15 Apr 86	3.5	u	4.9	0.8	30.3
Pear-4	15 Apr 86	14.0	u	5.3	0.5	21.9
Up. Mosquito-1	10 Aug 86	0.2	0.4	1.7	u	24.7
Up. Mosquito-1	10 Aug 86	3.0	0.5	1.7	u	25.5
Up. Mosquito-2	10 Aug 86	0.2	0.5	2.4	u	24.4
Up. Mosquito-2	10 Aug 86	5.0	u	2.5	u	25.0
Up. Mosquito-I	10 Aug 86	-	u	10.9	0.1	23.3
Crystal (M.K.)-1	10 Aug 86	0.2	u	5.6	u	29.9
Crystal (M.K.)-1	10 Aug 86	20.5	u	6.9	u	36.6
Crystal (M.K.)-2	10 Aug 86	0.2	u	5.5	u	30.5
Crystal (M.K.)-2	10 Aug 86	16.5	u	5.6	u	32.6
Crystal (M.K.)-I	10 Aug 86	-	u	1.8	u	27.3
Rancho-Oeste-1	28 Apr 86	0.2	1.8	u	99.8	632
Lompoc-Casmalia-1	28 Apr 86	0.2	0.7	u	42.0	644
Dune-1	28 Apr 86	0.2	u	u	u	20.1

TABLE 19: Levels of trace metals (Al, Fe, Mn) in lakes sampled during autumn 1985. All concentrations are in micromolar, undetectable levels are designated u. Sample depths are in meters.

			Aluminum		Iron		Manganese	
Lake/Station	Date	Sample Depth	Total	Total Dissolved	Total	Total Dissolved	Total	Total Dissolved
Up. Gaylor-1	24 Sep 85	0.2	0.87	0.62	0.37	0.19	0.02	0.01
Up. Gaylor-1	24 Sep 85	4.0	1.55	0.48	0.46	0.19	0.02	0.01
Up. Gaylor-2	24 Sep 85	0.2	1.44	0.47	0.42	0.19	0.03	0.03
Up. Gaylor-2	24 Sep 85	4.0	0.71	0.58	0.36	0.18	0.02	0.02
Up. Granite-1	24 Sep 85	0.2	0.55	0.52	0.06	0.04	0.01	u
Up. Granite-1	24 Sep 85	8.0	0.57	0.54	0.05	0.06	0.01	u
Up. Granite-2	24 Sep 85	0.2	0.51	0.52	0.16	0.03	0.01	u
Up. Granite-2	24 Sep 85	4.0	0.61	0.47	0.17	0.03	0.01	u
McCloud-1	22 Sep 85	0.2	0.81	0.23	1.19	0.13	0.05	0.04
McCloud-1	22 Sep 85	4.0	0.77	0.18	1.23	0.09	0.04	0.03
McCloud-2	22 Sep 85	0.2	0.79	0.33	1.15	0.50	0.04	0.03
McCloud-2	22 Sep 85	4.0	0.75	0.35	1.19	0.28	0.04	0.04
Crystal-1	22 Sep 85	0.2	0.35	0.10	0.94	0.25	0.04	0.02
Crystal-1	22 Sep 85	4.5	0.33	0.41	0.93	0.22	0.05	0.02
Crystal-2	22 Sep 85	0.2	0.31	0.12	0.93	0.16	0.05	0.02
Crystal-2	22 Sep 85	4.5	0.31	0.12	0.92	0.19	0.04	0.02
Ruby-1	23 Sep 85	0.2	0.21	0.13	0.18	0.09	0.01	0.01
Ruby-1	23 Sep 85	4.0	0.24	0.14	0.15	0.09	0.01	u
Ruby-2	23 Sep 85	0.2	0.23	0.10	0.17	0.05	0.01	u
Ruby-2	23 Sep 85	4.0	0.26	0.11	0.17	0.08	0.01	u
Up. Treas-1	23 Sep 85	0.2	0.69	0.19	0.20	0.07	0.01	u
Up. Treas-1	23 Sep 85	1.5	0.72	0.20	0.24	0.07	0.02	u
Up. Treas-2	23 Sep 85	0.2	0.57	0.43	0.19	0.14	0.02	0.01
Up. Treas-2	23 Sep 85	3.0	0.57	0.25	0.20	0.06	0.02	u
Gem-1	23 Sep 85	0.2	0.58	0.38	0.10	0.02	u	0.01
Gem-1	23 Sep 85	4.0	0.57	0.49	0.14	0.01	u	u
Gem-2	23 Sep 85	0.2	0.56	0.44	0.14	u	u	u
Gem-2	23 Sep 85	4.0	0.55	0.47	0.10	0.02	u	u
Gem-I	23 Sep 85	0.1	1.63	1.20	0.35	0.19	u	0.01
Piute-1	25 Sep 85	0.2	1.10	0.28	0.22	0.12	0.01	u
Piute-1	25 Sep 85	4.0	0.99	0.29	0.21	0.40	0.01	0.02
Piute-2	25 Sep 85	0.2	1.10	0.62	0.24	0.12	0.01	0.01
Piute-2	25 Sep 85	9.0	0.98	0.33	0.21	0.10	0.01	0.01
Piute-I	25 Sep 85	0.1	0.98	0.63	0.56	0.48	0.02	0.02

TABLE 19 (cont.)

Lake/Station	Date	Sample Depth	Aluminum Total	Aluminum Total Dissolved	Iron Total	Iron Total Dissolved	Manganese Total	Manganese Total Dissolved
Emerson-1	25 Sep 85	0.2	0.57	0.40	0.16	0.07	u	u
Emerson-1	25 Sep 85	9.0	0.54	u	0.21	0.09	u	u
Emerson-2	25 Sep 85	0.2	0.51	0.37	0.15	0.07	u	u
Emerson-2	25 Sep 85	9.0	0.46	0.34	0.16	0.07	u	u
Golden Trout-1	26 Sep 85	0.2	0.49	0.26	0.12	0.02	u	u
Golden Trout-1	26 Sep 85	8.0	0.45	0.33	0.12	0.01	0.01	u
Golden Trout-2	26 Sep 85	0.2	0.40	0.50	0.12	0.13	0.01	0.01
Golden Trout-2	26 Sep 85	6.0	0.50	0.26	0.13	0.01	0.01	0.01
Unnamed-1	26 Sep 85	0.2	0.27	0.23	0.40	0.02	0.03	0.01
Unnamed-1	26 Sep 85	9.0	0.21	0.28	0.41	0.03	0.03	0.01
Unnamed-2	26 Sep 85	0.2	0.23	0.19	0.36	0.01	0.03	0.01
Unnamed-2	26 Sep 85	9.0	0.14	0.20	0.40	0.01	0.03	u
Heather-1	5 Sep 85	0.2	1.15	0.80	1.29	0.33	0.13	0.13
Heather-1	5 Sep 85	5.0	1.12	0.40	1.19	0.05	0.13	0.13
Pear-1	6 Sep 85	0.2	0.41	0.26	0.39	0.04	0.07	0.06
Pear-1	6 Sep 85	5.0	0.36	0.33	0.38	0.04	0.07	0.06
Pear-2	14 Oct 85	1.0	0.30	0.19	0.88	0.20	0.08	0.06
Pear-2	14 Oct 85	9.5	0.56	0.10	0.77	0.16	0.07	0.07
Pear-3	14 Oct 85	1.0	0.38	0.41	0.95	0.16	0.09	0.08
Pear-3	14 Oct 85	9.0	0.24	0.21	0.90	0.25	0.08	0.07
Pear-I	14 Oct 85	0.1	0.80	0.44	0.12	0.12	0.02	0.03
Oriole-1	28 Oct 85	0.2	0.25	0.38	0.41	0.32	0.06	0.13
Oriole-1	28 Oct 85	4.0	0.24	0.23	0.43	0.26	0.08	0.11
Oriole-2	28 Oct 85	0.2	0.19	0.15	0.40	0.17	0.07	0.05
Oriole-2	28 Oct 85	4.0	0.21	0.15	0.44	0.13	0.07	0.06
Up. Mosquito-1	29 Oct 85	0.2	1.03	0.74	0.18	0.11	u	0.02
Up. Mosquito-1	29 Oct 85	6.5	1.07	0.67	0.17	0.10	0.02	u
Up. Mosquito-2	29 Oct 85	0.2	1.10	0.78	0.16	0.10	u	u
Up. Mosquito-2	29 Oct 85	3.5	1.00	0.69	0.17	0.07	0.02	0.02
Crystal (M.K.)-1	29 Oct 85	0.2	0.77	0.49	0.44	0.08	u	0.02
Crystal (M.K.)-1	29 Oct 85	9.0	0.73	0.40	0.40	0.07	0.02	u
Crystal (M.K.)-2	29 Oct 85	0.2	0.72	0.56	0.43	0.08	u	0.02
Crystal (M.K.)-2	29 Oct 85	9.0	0.74	0.51	0.39	0.06	0.02	0.02

TABLE 20: Levels of trace metals (Al, Fe, Mn) in lakes sampled during spring and summer 1986. All concentrations are in micromolar, undetectable levels are designated u. Sample depths are in meters. Dash indicates no data.

			Aluminum		Iron		Manganese	
Lake/Station	Date	Sample Depth	Total	Total Dissolved	Total	Total Dissolved	Total	Total Dissolved
Up. Gaylor-2	30 Jul 86	0.2	2.37	2.63	1.33	0.45	0.03	u
Up. Gaylor-2	30 Jul 86	4.0	2.38	1.77	1.32	0.68	0.03	0.05
Up. Gaylor-I	30 Jul 86	-	2.37	2.04	0.14	0.06	u	u
Up. Granite-2	30 Jul 86	0.2	2.32	0.69	0.34	0.13	u	u
Up. Granite-2	30 Jul 86	8.0	2.00	1.54	1.55	0.53	0.03	u
McCloud-1	14 May 86	1.8	2.36	0.98	0.46	0.21	0.02	0.02
McCloud-1	14 May 86	6.0	0.93	0.63	1.44	0.11	0.34	0.34
Crystal-2	14 May 86	1.7	1.98	2.01	0.62	0.24	0.02	0.03
Crystal-2	14 May 86	7.5	1.69	1.82	0.48	0.14	0.04	0.04
Ruby-2	15 May 86	2.0	1.09	1.13	0.37	0.14	u	0.01
Ruby-2	15 May 86	12.5	0.86	1.06	0.49	0.03	0.01	u
Up. Treas-1	15 May 86	2.8	1.96	0.90	0.92	0.14	0.11	0.10
Up. Treas-1	15 May 86	3.2	3.10	1.90	0.97	0.20	0.16	0.14
Gem-1	15 May 86	2.8	1.55	1.70	0.13	0.13	u	0.03
Gem-1	15 May 86	5.8	1.28	0.62	0.46	0.06	0.18	0.13
Piute-2	16 May 86	2.0	3.28	1.47	0.92	0.10	0.07	0.07
Piute-2	16 May 86	7.5	-	1.68	-	0.22	-	0.51
Emerson-2	16 May 86	2.4	0.77	0.86	0.09	0.11	u	u
Emerson-2	16 May 86	9.5	0.94	0.76	0.21	0.05	0.09	0.08
Golden Trout-1	31 Jul 86	0.2	1.96	0.69	0.27	0.03	u	u
Golden Trout-1	31 Jul 86	10.0	1.85	0.69	0.13	0.06	u	u
Unnamed-1	31 Jul 86	0.2	-	1.15	-	5.70	-	0.01
Unnamed-1	31 Jul 86	11.0	-	2.35	-	8.40	-	0.01
Heather-2	15 Apr 86	2.5	2.65	2.22	2.60	0.84	0.25	0.23
Heather-2	15 Apr 86	5.0	2.83	2.21	7.10	0.64	0.49	0.32
Pear-4	15 Apr 86	3.5	1.95	2.46	6.30	0.61	0.14	0.16
Pear-4	15 Apr 86	14.0	1.58	0.24	2.80	0.28	0.33	0.30
Up. Mosquito-2	10 Aug 86	0.2	0.86	0.70	0.11	0.17	u	0.02
Up. Mosquito-2	10 Aug 86	5.0	0.83	0.55	0.08	0.21	0.01	u
Up. Mosquito-I	10 Aug 86	-	1.58	0.65	0.53	1.41	0.07	u
Crystal (M.K.)-2	10 Aug 86	0.2	0.98	0.54	0.35	0.09	0.02	0.02
Crystal (M.K.)-2	10 Aug 86	16.5	0.91	0.98	0.43	0.11	0.03	0.05
Crystal (M.K.)-I	10 Aug 86	-	1.62	1.27	0.26	0.11	u	u

TABLE 21. Mean values of two stations and two depths for pH and acid neutralizing capacity (ANC) in each lake during autumn (Sept.-Oct.) 1985 and during spring (May) or summer (July-Aug.) 1986. Lakes which were ice-covered during spring are coded (i). The amount of change from autumn to spring or summer is designated Δ; units of ANC are microequivalents per liter.

Lake	Season	pH	ΔpH	ANC	ΔANC
Up. Gaylor	autumn	6.96	-0.7	123	-32
Up. Gaylor	summer	6.27		92	
Up. Granite	autumn	6.99	-0.9	83	-17
Up. Granite	summer	6.11		66	
McCloud	autumn	6.54	-0.6	39	+7
McCloud	spring (i)	5.91		46	
Crystal	autumn	6.41	-0.3	85	-13
Crystal	spring (i)	6.13		72	
Ruby	autumn	6.78	-0.6	55	+4
Ruby	spring (i)	6.14		59	
Up. Treasure	autumn	6.65	-0.8	33	+9
Up. Treasure	spring (i)	5.82		42	
Gem	autumn	7.07	-0.6	106	+101
Gem	spring (i)	6.50		207	
Piute	autumn	6.79	-1.0	47	+24
Piute	spring (i)	5.78		71	
Emerson	autumn	7.01	-1.0	57	-12
Emerson	spring (i)	6.01		45	

TABLE 21 (cont.)

Lake	Season	pH	ΔpH	ANC	ΔANC
Golden Trout	autumn	7.48	-1.0	329	-19
Golden Trout	summer	6.49		310	
Unnamed	autumn	7.06	-0.8	76	+5
Unnamed	summer	6.29		81	
Heather	autumn	6.19	-0.3	51	+13
Heather	spring (i)	5.90		64	
Pear	autumn	6.33	-0.5	25	+2
Pear	spring (i)	5.86		27	
Up. Mosquito	autumn	6.83	-0.2	60	-15
Up. Mosquito	summer	6.61		45	
Crystal (M.K.)	autumn	6.71	-0.4	51	-8
Crystal (M.K.)	summer	6.31		43	

Table 22. Summer-autumn (July-Oct.) values of pH (top) and ANC (bottom) for high altitude Sierra Nevada lakes sampled from 1981 through 1984 by Melack et al. 1985, and Melack (unpublished), in 1985 by Holmes and Stoddard (unpublished), in Sept. 1985 by the California Department of Fish and Game (McCleneghan et al. 1985), and from Sept. 1985-Aug. 1986 by Melack and Setaro. Lake samples are surface water (0.2-1.0 meter) or from just below the ice layer. Alkalinity is in microequivalents per liter. Dashes indicate no data.

Lake Name	1981	1982	1983	1984	1985	1985 (DFG)	Sept.- Oct. 85	May 86	July- Aug 86
Up. Gaylor	7.08	-	-	6.46	7.27	-	6.96	-	6.31
Up. Gaylor	89	-	-	81	102	-	123	-	91
Up. Granite	7.32	5.99	-	6.48	-	-	6.99	-	5.98
Up. Granite	69	53	-	62	-	-	82	-	66
McCloud	-	-	-	-	-	6.75	6.71	5.98	-
McCloud	-	-	-	-	-	26	39	37	-
Ruby	5.90	6.54	-	6.14	6.95	-	6.80	6.19	-
Ruby	-	53	-	41	47	-	54	61	-
Up. Treasure	6.42	-	6.64	6.06	6.45	-	6.65	5.82	-
Up. Treasure	11	-	54	24	27	-	33	41	-
Gem	-	6.80	6.30	6.40	-	-	7.11	6.60	-
Gem	-	46	39	39	-	-	107	226	-
Piute	-	-	-	-	-	6.88	6.81	5.76	-
Piute	-	-	-	-	-	30	45	61	-
Golden Trout	-	-	-	-	-	8.04	7.51	-	6.49
Golden Trout	-	-	-	-	-	283	330	-	347
Heather	6.50	-	6.34	6.35	-	-	6.07	5.92	-
Heather	47	-	45	46	-	-	52	56	-
Pear	6.39	-	6.20	6.37	-	6.26	6.43	5.94	-
Pear	18	-	13	32	-	28	25	56	-
Up. Mosquito	6.53	-	6.70	-	6.42	-	6.86	-	6.60
Up. Mosquito	69	-	54	-	53	-	62	-	46
Crystal (M.K.)	-	6.97	-	-	-	-	6.62	-	6.34
Crystal (M.K.)	-	50	-	-	-	-	50	-	40

TABLE 23. Mean and standard error (top), and range (bottom) for midsummer-early autumn values of chemical constituents in high altitude Sierra Nevada lakes over a 2-5 year period; sampling within years are below lake name. Individual values are of a single sampling each year. All values (except pH) are in microequivalents per liter. Lake order in the table corresponds to geographic location from North to South. Data is from Melack (unpublished), Holmes and Stoddard (unpublished), Melack et al. 1985 and Melack and Setaro (this report).

Lake Name	NO_3	SO_4	Cl	Ca	Mg	Na	K
Upper Angora	-	6.4±4.7	5.6±0.6	36±6	11±2	35±1	6.7±0.9
81, 85	-	1.7-11	5.0-6.2	30-42	9-12	34-36	5.8-7.5
Twin East	-	85±7	6.9±1.2	387±29	59±1	82±11	14±0
81, 85	u	78-91	5.7-8.0	358-415	58-60	71-93	14
Twin West	-	60±8	9.0±5.0	315±7	44±2	66±14	15±5
81, 85	u	52-68	4-14	308-322	42-45	52-80	10-19
Upper Frog	2.1±1.2	317±70	7.5±4.6	554±122	26±5	53±17	12±5
81, 85	0.9-3.3	247-386	2.9-12	432-675	21-30	36-70	7-16
Lundy	-	191±16	5.4±1.7	402±21	29±1	60±16	18±3
81, 85	u-0.2	175-207	3.7-7.0	381-423	28-30	44-75	15-20
Upper Granite	2.2±1.4	4.9±1.9	7.5±4.0	44±5	5.1±1.1	18±3	6.7±2.5
81, 82, 84, 85, 86	u-3.6	1.0-11	2.3-19	34-58	1.1-7.3	12-28	3.6-17
Upper Gaylor	-	23±3	7.9±6.5	101±7	5.4±0.3	12±3	8.7±5.8
81, 84, 85, 86	u	17-33	1.1-34	85-118	4.8-6.0	8.8-22	1.6-32
Dana	8.1±1.0	57±5	3.7±2.4	61±4	8.0±0.6	11±3	3.3±1.3
81, 85	7.0-9.1	52-62	1.3-6.0	57-64	7.4-8.5	7.4-14	2.0-4.6
Parker Pass	7.4±1.0	127±21	63±59	100±13	19±1	19±6	53±47
81, 85	6.4-8.3	106-148	4.2-122	87-112	18-19	13-24	5.7-100
Kuna	3.8±0.5	8.6±4.4	7.4±5.6	15±1	3.6±0.3	6.7±0.5	6.6±3.4
81, 85	3.3-4.2	4.2-13	1.8-13	14-16	3.3-3.8	6.2-7.2	3.2-10
Convict	-	237±5	18±16	1237±3	35±1	57±6	31±15
81, 85	u-0.1	232-242	1.9-34	1234-1240	34-35	51-63	16-45
Bright Dot	-	70±3	7.0±5.0	744±45	24±2	29±18	11±5
81, 85	u	67-72	2-12	699-788	22-25	11-46	6-16
Dorothy	0.4±0.3	87±4	14±11	192±1	17±5	25±7	17±9
81, 85	.06-0.7	83-91	3-24	190-193	12-21	18-31	8-25

TABLE 23 (cont.)

Lake Name	NO$_3$	SO$_4$	Cl	Ca	Mg	Na	K
Constance	1.3±0.8	104±6.0	12±10	341±4.5	13±1.0	14±5.4	18±10
81, 85	.48-2.1	98-110	1.9-21	336-345	12-14	8.3-19	7.6-29
Barney	0.5±0.1	168±11	12±5	547±50	9.4±0.7	96±15	10±5.0
81, 85	0.4-0.6	157-178	6.7-17	497-597	8.7-10	81-111	5.0-15
Fairy Shrimp	2.4±1.4	9.1±4.9	4.9±3.1	16±0	2.8±0.8	5.8±1.5	3.2±0.9
81, 85	1.0-3.8	4.2-14	1.8-8.0	16	2.0-3.5	4.3-7.2	2.3-4.0
Summit	-	6.7±1.9	6.8±2.8	14±2	2.6±0.4	8.4±2.8	4.7±1.2
81, 82, 84, 85	u	3.2-11	1.1-14	9.0-19	1.6-3.4	5.4-17	2.6-8.1
Eastern Brook	-	6.9±0.7	4.9±0.2	88±11	14±2	31±2	10±1
82, 85	u	6.2-7.6	4.7-5.1	77-99	12-15	29-32	9.0-10
Ruby	1.8±0.4	7.6±0.8	3.2±0.7	40±3	3.3±0.2	11±2	3.7±0.5
81, 82, 84, 85	0.9-2.9	6.3-10	1.6-4.8	35-46	3.0-3.6	8.0-15	2.4-5.8
Gem	6.9±0.8	11±3	2.4±0.7	44±8	2.4±0.2	22±5	2.7±0.2
82, 83, 84, 85	u-8.3	5.9-20	1.3-5.0	29-72	2.2-3.0	12-42	2.3-3.1
Up. Treasure	4.3±1.5	7.0±1.6	1.8±0.3	27±2	2.4±0.1	5.8±0.3	3.5±1.0
81, 83, 84, 85	2.8-6.2	4.4-13	1.1-3.0	23-33	2.1-2.6	5.0-6.4	1.8-6.5
Dade	5.9±0.1	6.4±0.7	4.0±2.0	28±2	2.6±0.2	7.9±2.4	4.1±1.4
81, 82, 83, 84, 85	5.6-6.1	4.5-9.0	0.9-12	23-32	2.3-3.0	4.8-15	2.0-8.1
Granite	-	22±17	21±19	36±14	36±31	15±2	35±31
81, 85	u	5.0-38	1.3-40	22-50	4.4-67	13-16	4.7-66
Tablemeadow	-	3.5±0.5	3.0±1.0	21±7	3.0±0.6	9.3±3.7	2.7±0.5
81, 85	u-0.8	3.0-3.9	2.0-4.0	11-30	2.4-3.5	5.6-13	2.2-3.2
Pear	0.3±0.2	4.4±1.4	6.1±3.8	17±1	2.8±0.2	6.3±0.3	4.7±2.8
81, 83, 84, 85	u-0.7	1.3-8.0	1.5-18	14-19	2.4-3.0	5.7-7.0	1.3-13
Heather	0.5±0.2	5.4±0.8	3.2±0.7	29±3	6.0±0.5	17±2	5.8±1.0
81, 83, 84, 85	u-0.6	3.7-7.0	1.6-4.8	23-33	5.2-7.4	12-18	3.8-8.2
Emerald	2.8±0.8	8.9±1.7	3.4±1.5	19±2	3.8±0.3	11±1	2.7±0.3
82, 83, 84, 85	1.0-4.6	5.8-11	0.6-7.5	14-20	3.0-4.6	6.9-13	2.0-3.5

TABLE 23 (cont.)

Lake Name	NO_3	SO_4	Cl	Ca	Mg	Na	K
Lower Monarch	1.6±0.7	14±6	10±5	44±4	4.8±0.6	18±3	5.8±1.1
81, 83, 84	0.3-2.4	5.5-26	5-20	38-50	4.0-6.0	15-24	4.4-8.0
Upper Monarch	0.1±0.0	19±10	7.5±3.4	50±17	4.7±1.3	22±4	6.2±0.8
81, 83, 84	u-0.1	3.1-37	1.0-12	33-83	3.2-7.3	14-29	5.4-7.8
Crystal (M.K.)	-	7.6±4.4	3.2±1.9	47±5	5.1±1.1	18±3	5.0±1.7
82, 86	5.6	3.2-12	1.3-5.1	42-51	4.0-6.2	15-20	3.3-6.7
Mosquito 1	0.4±0.1	8.6±1.6	5.0±1.8	64±6	9.5±1.1	20±3	3.3±0.3
81, 83, 84, 85	u-0.6	5.5-13	1.9-8.0	55-81	7.1-12	15-27	2.8-4.2
Mosquito 3	2.3±1.6	12±3	6.0±3.0	48±2	5.3±0.4	10±1	2.6±0.7
81, 83, 84, 85	0.5-5.5	5.2-20	2.2-12	45-52	4.1-6.0	7.5-11	0.6-3.4
Mosquito 5	1.7±0.4	15±3	2.3±0.7	51±4	4.2±0.6	14±1	3.2±0.5
81, 83, 85, 86	0.5-2.3	8.1-21	0.9-3.8	43-61	2.5-5.2	12-17	1.9-4.0

TABLE 24. Mean, standard error (top), and range (bottom) for midsummer-early autumn values of pH and ANC (acid neutralizing capacity, microequivalents per liter) in high altitude Sierra Nevada lakes over a 2-5 year period; sampling years are below lake name. Individual values are of a single sampling within each year. Lake order in the table corresponds to geographic location from North to South. Data is from Melack (unpublished), Holmes and Stoddard (unpublished), Melack et al. 1985, and Melack and Setaro (this report).

Lake Name	pH	HCO_3
Upper Angora	7.60±0.62	76±12
81, 85	6.98-8.21	64-89
Twin East	8.59±0.45	403±19
81, 85	8.14-9.04	384-422
Twin West	8.11±0.15	348±24
81, 85	7.96-8.25	324-372
Upper Frog	8.02±0.17	326±68
81, 85	7.85-8.18	258-393
Lundy	7.72±0.12	281±20
81, 85	7.60-7.83	261-301
Upper Granite	6.76±0.40	71±5
81, 82, 84, 85, 86	5.98-7.32	65-80
Upper Gaylor	6.94±0.22	101±7
81, 84, 85, 86	6.31-7.37	89-121
Dana	6.60±0.05	12±7
81, 85	6.55-6.65	5-19
Parker Pass	6.19±0.55	4.0±1.0
81, 85	5.64-6.73	3.0-5.0
Kuna	6.85±0.17	17±2
81, 85	6.68-7.02	15-19
Convict	8.46±0.06	1094±43
81, 85	8.40-8.52	1051-1137
Bright Dot	8.87±0.21	692±65
81, 85	8.66-9.07	627-756
Dorothy	7.45±0.01	144±5
81, 85	7.44-7.46	139-149

TABLE 24 (cont.)

Lake Name	pH	HCO$_3$
Constance	8.02±0.07	265±7
81, 85	7.95-8.08	258-272
Barney	9.15±0.38	417±25
81, 85	8.77-9.53	392-442
Fairy Shrimp	6.29±0.63	15±0
81, 85	5.66-6.92	15
Summit	6.38±0.25	20±4
81, 82, 84, 85	6.01-7.10	10-25
Eastern Brook	7.14±0.22	111±21
82, 85	6.92-7.35	90-132
Ruby	6.35±0.20	49±3
81, 82, 84, 85	5.90-6.80	40-53
Gem	6.58±0.13	55±12
82, 83, 84, 85	6.30-6.82	39-104
Up. Treasure	6.44±0.24	34±7
81, 83, 84, 85	6.06-6.65	19-54
Dade	6.22±0.15	27±6
81, 82, 83, 84, 85	5.94-6.80	16-50
Granite	6.91±0.0	48±20
81, 85	6.90-6.91	28-67
Tablemeadow	6.48±0.13	27±14
81, 85	6.35-6.60	13-41
Pear	6.27±0.07	20±4
81, 83, 84, 85	6.10-6.39	13-32
Heather	6.32±0.09	47±2
81, 83, 84, 85	6.07-6.50	37-52
Emerald	6.11±0.25	21±4
82, 83, 84, 85	5.38-6.45	11-31

TABLE 24 (cont.)

Lake Name	pH	HCO_3
Lower Monarch	6.75±0.26	57±8
81, 83, 84	6.45-7.26	29-67
Upper Monarch	6.90±0.31	47±6
81, 83, 84	6.53-7.51	39-58
Crystal (M.K.)	6.66±0.32	45±5
82, 86	6.34-6.97	40-50
Mosquito 1	6.79±0.07	74±4
81, 83, 84, 85	6.70-6.99	67-82
Mosquito 3	6.55±0.07	44±4
81, 83, 84, 85	6.44-6.74	36-52
Mosquito 5	6.81±0.10	53±3
81, 83, 85, 86	6.60-7.08	50-62

TABLE 25. Acid neutralizing capacity (ANC), pH, sum of base cations, and ratio of ANC to sum of base cations for high altitude Sierra Nevada lakes sampled during 1985-1986. ANC and sum of base cations are in $\mu eq \cdot l^{-1}$ and pH is in pH units.

Lake	Season	pH	ANC	Sum of base cations	ANC/Sum of base cations
Up. Gaylor	autumn	6.96	123	134	0.9
Up. Gaylor	summer	6.27	92	101	0.9
Up. Granite	autumn	6.99	83	81	1.0
Up. Granite	summer	6.11	66	66	1.0
McCloud	autumn	6.54	39	51	0.8
Crystal	autumn	6.41	85	75	1.1
Ruby	autumn	6.78	55	57	1.0
Up. Treas.	autumn	6.65	33	42	0.8
Gem	autumn	7.07	106	121	0.9
Piute	autumn	6.79	47	60	0.8
Emerson	autumn	7.01	57	66	0.9
Unnamed	autumn	7.06	76	79	1.0
Unnamed	summer	6.29	81	85	1.0
Heather	autumn	6.19	51	54	0.9
Pear	autumn	6.33	25	28	0.9
Up. Mosquito	autumn	6.83	60	78	0.8
Up. Mosquito	summer	6.61	45	61	0.7
Crystal (MK)	autumn	6.71	51	77	0.7
Crystal (MK)	summer	6.31	43	71	0.6

TABLE 26: Molar ratios of total nitrogen to total phosphorus (TN/TP), total dissolved nitrogen to total dissolved phosphorus (TDN/TDP) and dissolved inorganic nitrogen to total dissolved phosphorus (DIN/TDP) for lakes sampled in autumn 1985. Nitrogen and phosphorus were determined as nitrate and phosphate, respectively. DIN is the sum of dissolved ammonium plus dissolved nitrate.

Lake/Station	Date	Sample Depth	TN/TP	TDN/TDP	DIN/TDP
Up. Gaylor-1	24 Sep 85	0.2	19	13	16
Up. Gaylor-1	24 Sep 85	4.0	18	10	8
Up. Gaylor-2	24 Sep 85	0.2	8	14	-
Up. Gaylor-2	24 Sep 85	4.0	7	11	-
Up. Granite-1	24 Sep 85	0.2	4	16	2
Up. Granite-1	24 Sep 85	8.0	6	9	6
Up. Granite-2	24 Sep 85	0.2	5	9	1
Up. Granite-2	24 Sep 85	4.0	17	9	8
McCloud-1	22 Sep 85	0.2	19	11	1
McCloud-1	22 Sep 85	4.0	15	12	-
McCloud-2	22 Sep 85	0.2	12	7	-
McCloud-2	22 Sep 85	4.0	12	13	13
Crystal-1	22 Sep 85	0.2	13	18	15
Crystal-1	22 Sep 85	4.5	21	9	10
Crystal-2	22 Sep 85	0.2	24	5	16
Crystal-2	22 Sep 85	4.5	10	12	5
Ruby-1	23 Sep 85	0.2	-	-	-
Ruby-1	23 Sep 85	4.0	-	-	-
Ruby-2	23 Sep 85	0.2	-	-	-
Ruby-2	23 Sep 85	4.0	-	-	-
Up. Treas-1	23 Sep 85	0.2	53	-	-
Up. Treas-1	23 Sep 85	1.5	74	-	-
Up. Treas-2	23 Sep 85	0.2	64	-	-
Up. Treas-2	23 Sep 85	3.0	64	69	68
Gem-1	23 Sep 85	0.2	-	-	-
Gem-1	23 Sep 85	4.0	-	-	83
Gem-2	23 Sep 85	0.2	55	-	85
Gem-2	23 Sep 85	4.0	77	-	115
Gem-I	23 Sep 85	0.1	61	-	120
Piute-1	25 Sep 85	0.2	8	-	33
Piute-1	25 Sep 85	4.0	9	-	54
Piute-2	25 Sep 85	0.2	20	-	49
Piute-2	25 Sep 85	9.0	7	-	26
Piute-I	25 Sep 85	0.1	16	31	72

TABLE 26 (cont.)

Lake/Station	Date	Sample Depth	TN/TP	TDN/TDP	DIN/TDP
Emerson-1	25 Sep 85	0.2	32	68	86
Emerson-1	25 Sep 85	9.0	22	25	36
Emerson-2	25 Sep 85	0.2	11	29	39
Emerson-2	25 Sep 85	9.0	18	30	37
Golden Trout-1	26 Sep 85	0.2	-	-	-
Golden Trout-1	26 Sep 85	8.0	-	-	-
Golden Trout-2	26 Sep 85	0.2	-	-	-
Golden Trout-2	26 Sep 85	6.0	-	-	-
Unnamed-1	26 Sep 85	0.2	-	-	-
Unnamed-1	26 Sep 85	9.0	19	19	-
Unnamed-2	26 Sep 85	0.2	-	-	-
Unnamed-2	26 Sep 85	9.0	23	25	2
Hume-1	9 Sep 85	0.2	20	24	-
Hume-1	9 Sep 85	3.0	23	26	-
Hume-I_1	9 Sep 85	0.1	-	-	-
Hume-I_2	9 Sep 85	0.1	-	-	-
Heather-1	5 Sep 85	0.2	74	25	3
Heather-1	5 Sep 85	5.0	45	30	7
Pear-1	6 Sep 85	0.2	15	30	3
Pear-1	6 Sep 85	5.0	26	12	4
Pear-2	14 Oct 85	1.0	20	41	13
Pear-2	14 Oct 85	9.5	17	38	12
Pear-3	14 Oct 85	1.0	22	33	15
Pear-3	14 Oct 85	9.0	24	17	8
Pear-I	14 Oct 85	0.1	-	-	-
Oriole-1	28 Oct 85	0.2	29	43	-
Oriole-1	28 Oct 85	4.0	19	73	-
Oriole-2	28 Oct 85	0.2	20	23	-
Oriole-2	28 Oct 85	4.0	19	26	-
Up. Mosquito-1	29 Oct 85	0.2	52	40	25
Up. Mosquito-1	29 Oct 85	6.5	51	42	41
Up. Mosquito-2	29 Oct 85	0.2	52	36	38
Up. Mosquito-2	29 Oct 85	3.5	25	44	30
Crystal (M.K.)-1	29 Oct 85	0.2	15	-	-
Crystal (M.K.)-1	29 Oct 85	9.0	21	-	-
Crystal (M.K.)-2	29 Oct 85	0.2	14	-	-
Crystal (M.K.)-2	29 Oct 85	9.0	19	-	-

TABLE 26 (cont.)

Lake/Station	Date	Sample Depth	TN/TP	TDN/TDP	DIN/TDP
Black-1	6 Nov 85	0.2	10	8	0.4
Black-2	6 Nov 85	0.2	10	9	0.5
Up. Twin-1	6 Nov 85	0.2	8	8	7
Zaca-1	9 Oct 85	0.2	17	18	2
Zaca-1	9 Oct 85	9.0	245	248	273
Zaca-2	9 Oct 85	0.2	20	20	0.8
Zaca-2	9 Oct 85	9.0	-	-	-

Appendix 1

pH Comparisons

Introduction

Shortcomings in the determination of pH in dilute waters has prompted various solutions (Galloway, J.N. et al. 1979; Herczeg, A.L. et al. 1985; McQuaker, N.R. et al. 1983). While certain modifications such as low ionic strength electrodes may alleviate dilute water effects, measurement technique is equally important under these conditions (Melack et al. 1982).

We compared pH determination employing a recent modification (Orion Pure Water Test Kit) versus an established protocol used in Melack's laboratory. We also compared the newer Ross with two other electrodes used in prior studies.

Materials and Methods

The Orion SA 250 meter with automatic temperature compensation was used for all measurements. The electrodes evaluated were: Ross 8104 (Orion), GamRad PHE-52539, and Sargent Welsh S-30072-15. Low ionic strength buffers and sample pH adjustor were components of Orion's Pure Water Test Kit (no. 700001). Reference buffer solutions were purchased from American Scientific Products.

A single, pooled sample of Emerald Lake water stored in plastic buckets containing Emerald Lake sediment was used throughout; this water had been maintained at 4°C for 4 months and had a conductance of 13 $\mu S \cdot cm^{-1}$ at 25°C.

All pH determinations were made on quiescent samples within 15 minutes of a two buffer calibration. After each calibration, each electrode was placed in 100 ml of deionized water and stirred for 2 minutes; this rinse was repeated two more times. Then pH was measured on a freshly prepared 10^{-4} N HCl solution. This was followed by a rinse with deionized water and with sample. Then the pH of a fresh sample was measured at 0, 2, 5, and 10 minutes. A final buffer check with 10^{-4} N HCl and then with reference buffer completed the procedure. Performance of the electrodes and results obtained with the low ionic strength buffers are expressed in Table 27.

Results

The data indicates that an initial pH reading is erroneous and a minimum of 5 minutes should be allowed for stabilization. Employing standard buffer calibration, day to day variation in pH value (10 minute reading) was minimal with the Ross 8104 electrode (range: 0.06 pH units), maximal with the Sargent-Welsh electrode (range: 0.24 pH units); and intermediate with the GamRad electrode (range: 0.11 pH units). Standardization with Orion's low ionic strength (L.I.S.) buffer and addition of pHix adjustor to sample decreased Sargent-Welsh electrode (range: 0.15 pH units) but increased GamRad electrode (range: 0.22 pH units) variability. Performance of the Ross electrode was similar with either buffer calibration procedure.

Employing standard buffer calibration the Ross was most precise (standard deviation (SD) = 0.04 pH units) and the Sargent-Welsh was least precise with a SD of 0.12 pH units. The mean pH values for the same pooled sample over the three day period were 6.03, 5.76, 6.12 for Ross, GamRad, and Sargent-Welsh electrodes, respectively. The same pattern was observed with a 10^{-4} N HCl solution: mean pH values for Ross, GamRad, and Sargent-Welsh were 4.05, 3.94, and 4.13, respectively. Calibration with low ionic strength buffers and pHix-adjustment of samples brought mean pH values of all electrodes closer together (5.96, 5.90, 6.08 for Ross, GamRad, and Sargent-Welsh, respectively). The L.I.S. procedure affected the three electrodes inconsistently. While lower mean pH values for Ross and Sargent-Welsh were obtained, a higher mean pH was recorded with the GamRad electrode.

Based on the data obtained with natural water having a conductance of 13 $\mu S \cdot cm^{-1}$ at 25°C, the Ross is the electrode of choice for pH measurements of dilute waters and Orion's low ionic strength buffer protocol offers no additional advantage when appropriate measurement technique (Melack et al. 1982) is adhered to. The Orion protocol may be important for snow which is more dilute than samples investigated here.

TABLE 27: Comparisons of three pH electrodes using an Orion SA 250 meter. A single pool of Emerald Lake water (cond = 13 $\mu S \cdot cm^{-1}$, 25°C) was used for all measurements. Each electrode was calibrated with two buffers prior to determination of sample pH; all measurements were made on quiescent solutions. The Orion low ionic strength (L.I.S.) buffer protocol includes an addition of "pHix adjustor" to the sample. On 4 and 5 March, calibration was followed by the 3-beaker rinse technique (see text); on 3 March the electrode was rinsed thoroughly with deionized water from a wash bottle.

	Ross 8104						GAMRAD						Sargent-Welsh					
	Standard Buffer			Orion L.I.S. Buffer			Standard Buffer			Orion L.I.S. Buffer			Standard Buffer			Orion L.I.S. Buffer		
Date, 1986	3 Mar	4 Mar	5 Mar	3 Mar	4 Mar	5 Mar	3 Mar	4 Mar	5 Mar	3 Mar	4 Mar	5 Mar	3 Mar	4 Mar	5 Mar	3 Mar	4 Mar	5 Mar
T, °C	21.8	22.0	21.8	21.8	22.4	22.0	21.8	22.0	21.8	21.8	22.4	22.0	21.8	22.0	21.8	21.8	22.4	22.0
HCl, 10^{-4}N	-	4.05	4.05	-	3.94	3.92	-	3.92	3.95	-	3.91	3.93	-	4.13	4.12	-	4.03	3.99
pH, initial	5.75	5.70	5.66	5.69	5.56	5.57	5.70	5.82	5.68	5.89	5.92	5.87	6.63	6.02	6.32	5.88	5.50	5.67
2 min.	5.96	5.91	5.91	5.82	5.78	5.87	5.70	5.83	5.78	5.95	5.97	6.07	6.26	6.06	6.13	6.11	5.96	5.98
5 min.	6.02	5.98	5.96	5.88	5.86	5.92	5.67	5.77	5.76	5.80	5.92	6.02	6.25	6.04	6.13	6.13	6.02	6.00
10 min.	6.07	6.01	6.01	5.94	5.94	5.99	5.70	5.81	5.76	5.79	5.90	6.01	6.24	6.00	6.11	6.16	6.06	6.01
HCl, 10^{-4}N	-	4.05	4.03	-	3.94	3.93	-	3.99	4.00	-	3.96	3.95	-	4.10	4.09	-	4.04	4.04
Buffer 7.00 Recheck	7.02	7.02	7.00	-	-	-	7.01	7.03	7.06	-	-	-	6.97	6.97	6.97	-	-	-
Buffer 6.97 Recheck	-	-	-	6.96	6.95	6.99	-	-	-	7.02	6.99	6.98	-	-	-	6.97	6.92	6.92