A LIMNOLOGICAL INVESTIGATION OF ACID PONDS WITH PARTICULAR REFERENCE TO THE FACTORS INFLUENCING THE DISTRIBUTION AND ABUNDANCE OF THE PHYTOPLANKTON

By

Sidney R. Galler

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INTRODUCTION

In fresh water biology, just as in most other branches of biology, many of the important biological problems are concerned with the study of the balance of life especially as regards the production of life, its control and the factors closely associated with the productive cycles. However, research on the productivity of fresh waters and the associated problems of control are still relatively far behind similar investigations in other fields. (Worthington, 1939).

Welch (1935), defines limnology as that branch of science which deals with the biological productivity of inland waters and with all of the causal influences which determine it. It is interesting to note that the science of limnology has existed less than 55 years, while most of the growth in this field has been accomplished within the last 30 years, (Welch, 1935). Thus it can be seen that there still exists wide areas that must be investigated in fresh waters, especially in certain categories of fresh water environments, in relation to productivity and its associated problems. (Jewell and Brown, 1924).

Mortimer (1939) defines the productivity of a body of water as the organic matter produced by the phytoplankton. The term phytoplankton refers to the plant plankton of waters (Welch, 1935). It is probably not a completely adequate term as used in this study since some of the organisms included in the investigation are more animal than plant-like in their characteristics. For the sake of clarity, the term phytoplankton will be used in describing the organisms observed.

Birge and Juday (1911), Meloche (1938), Tressler (1931), Wiebe (1930) and a host of other investigators within the past few decades have shown that certain nutrient salts, and other chemical and physical characteristics of water are associated with phytoplankton growth. Extensive investigations of this nature have been done on marine environments as well as in fresh waters in general. Only a very small portion of this work, however, has been carried out in fresh waters that are consistently acid in character. It has been shown that most waters, fresh as well as marine, are usually neutral or alkaline in nature, in many cases with a hydrogen ion concentration ranging on the average from 6.8 or 7 to 8 and higher. Harris and Silvey (1940), Raymond (1937), Scheffer and Robinson (1939), Chandler and Allen (1927), are but a few of the workers who have made their investigations in neutral or alkaline waters, and it is in waters of this nature that most of the fundamental contributions have been made, particularly regarding the interrelationships of phytoplankton with the physical, chemical and biological factors of the environments. Whether the principles which have been formulated from studies of neutral or alkaline waters hold true for waters having acid characteristics have not as yet been fully ascertained.

The problem of acidity in the economy of a body of water was early recognized by Birge and Juday in their studies on the Wisconsin lakes (1911). Powers (1921), Shelford (1923), Jewell and Brown (1924) also made parallel studies on inland bodies of fresh water. Welsh (1936, 1938), Young (1938), and Lackey (1939), were able to demonstrate that acidity could be due to a number of chemical factors, both organic and inorganic. The results obtained by the above workers have shown that the chemical, physical and biological factors of productivity are not necessarily the same in acid waters as they are in neutral waters or alkaline waters. Their results have also shown that the magnitude of importance of these factors, according to current concepts, may undergo considerable modification in waters of an acid nature and that the characteristics of acid waters need further study.

This investigation, therefore, had as its major purpose, the determination of the general characteristics of the phytoplankton population and the relationship of the general physio-chemical and biological factors of the environment to the phytoplankton productivity.

Description of Area and Topography

The four ponds upon which the following studies were made are located within the Patuxent Research Refuge in Prince Georges and Anne Arundel Counties, Maryland. The Refuge consists of more than 2,000 acres of woodlands and fields situated entirely within the watershed of the Patuxent River. The Patuxent River within the Refuge, flows through a valley about three miles wide and 150 feet deep. The altitude of the Refuge along the river is about 80 feet above sea level, while along the west and south ends the area reaches an altitude of 220 feet. The river falls 20 to 25 feet in its course through the Refuge and is joined along this course by several brooks which arise just outside of the Refuge. Most of these brooks are small and do not maintain channels across the bottom lands but spread out on the broad flat areas. However, four of the brooks retain their integrity and have been dammed to form the ponds under study. (Hotchkiss, 1940).

Since it has been demonstrated that the type of soil present in an area directly influences many of the chemical and biological conditions of nearby waters as well as their productivity (Roelofs, 1944), an effort will be made to describe the geology and soils of the Refuge.

The Refuge is only a short distance from the inner boundary of the Atlantic Coastal Plain, which runs along a northeast-southwest line near the city of Laurel, about three miles north-northwest of the ponds. Unconsolidated sediments of Cretaceous age form the underlying strata. Most of the soils have developed from the weathered rocks of the Coastal Plain, with the exception of the Patuxent bottom land which consists of Congaree silt loam washed down from the Piedmont Plateau. About half the south tract and a small part of the west tract are covered by Tuxedo soils which are homogeneous and do not occur in layers of varied composition as do the soils covering the remainder of the Refuge. The Tuxedo soils are most subject to erosion and the least productive, agriculturally, on the Refuge.

Chemical analysis shows the soil in the area to be low in organic content. The hydrogen-ion concentration has been shown to range from neutral to strongly acid (Hotchkiss, 1940).

Aquatic Vegetation

It is interesting to note that aquatic plants are relatively rare on the Refuge but that the species found are those which are usually found in soft or acid water environments:

Potamogeton epihydrus	Polygonum hydropiperoides
P. pusillus	Polygonum sagittatum
Heteranthera reniformis	Polygonum punctatum
Podostemum ceratophyllum	Nuphar advena
Callitriche heterophylla	Ranunculus laxicaulis
Utricularia geminiscapa	Ranunculus pusillus
Isoetes engelmanni	Hypericum mutilum
Sparganium spp.	H. virgicum
Sagittaria pubescens	Viola lanceolata
Echinochloa crusgalli	Ludivigia palustris
Leersia oryzoides	Prosperpinaca palustris

Carex lupulina
C. typhina
Eleocharis obtusa
Polygonium arifolium
Lycopus spp.
Bidens connata
Juncus spp.

All of the above plants have been found either in the ponds proper, in the feeding brooks, or in the marsh areas immediately associated with the waters under investigation. (Hotchkiss, 1940).

Description of the Ponds

As already stated, the four ponds on the Patuxent Research Refuge are man-made. They were formed by excavating the brook beds and erecting dirt and stone dams to impound the waters in the excavations. All of the dams have spillways and overflow channels. Constant streams of water, reaching sizable proportions in spring and fall, pass over these channels at all times.

Cash Lake is the largest and oldest of the four ponds, having been formed in October, 1938 by impounding the waters of Cash Branch. It has an area of 53.3 acres and is surrounded by a mixed forest of oak and pine.

The next pond formed was Lake Redington. This impoundment was made in September, 1943 by building a dam across the southern boundary of Cash Lake and allowing the water of Cash Branch to back up into an area of 30.9 acres. Lake Redington is surrounded on three sides by a mixed forest of oak and pine, the southwestern boundary being exposed for a distance of about 200 feet back of the pond where trees are again present.

Blue Gill Lake was completed on August, 1944 by impounding a very small brook and backing up the water into an area of 2.1 acres. This is the smallest of the four ponds and is exposed on all four sides, grass growing almost to the edge of the water.

Snowden Pond, known also as Headquarters Lake, is the latest of the ponds to be constructed, having been completed in May, 1947. This pond occupies an area of 7.7 acres and was formed by impounding the waters of Snowden Brook, leaving a small island, .433 of an acre in area, close to the southwestern shore. The pond is sheltered by pine-oak woods on the southwestern boundary and the northern boundary, while a sudden steep rise in the terrain protects the pond along the eastern edge. It should be noted that the overflow from all four ponds pass along the original stream beds and eventually flow into the Patuxent River. (See Figure 1).

All of these impoundments were constructed for the primary purpose of studying fish propagation methods and have been stocked with fish at varying intervals. Thus, at this writing, there are fish present in all of the ponds. Bluegill sunfish (_Lepomis Macrochirus_) have been found in all of the impoundments, as have pumpkinseed sunfish (_Lepomis gibbosus_). In addition to these sunfish, Cash Lake contains bullheads or catfish (_Ameiurus nebulosus_), golden shiners (_Notemigonus crysoleucas_), Largemouth bass (_Huro salmoides_), pickerel (_Esox niger_), black crappie (_Pomoxis nigro-maculatus_), and another species of sunfish, _Lepomis microchirus_, as well as the warmouth, (_Chaenobryttus coronarius_). The American Eel and several species of minnow have also been seined from Cash Lake. Carp have been observed in the small spillway pools below Cash, and it is possible that they have entered the pond itself.

All of the aforementioned fish have also been found in Lake Redington from which they have been obtained through seining in the course of these studies. Only the species of sunfish as well as a few small bass, eels and pickerel have been seined from Blue Gill Lake. The first stocking of of fish in Snowden Pond was made on November 12, 1947, at which time 7,000 bluegill sunfish about three inches long were placed in the pond. However, a few sunfish were already reproducing in the pond where they entered by way of Snowden Brook.

Thus, it can be seen that aside from the acid character of the waters in these ponds, the study of which was the primary purpose of the investigation, the impoundments were unique in that they offered individual and varied environments for intensive limnological study in the total area of a few miles of each other and but a distance of 9 miles from the laboratory in College Park.

METHODS AND MATERIALS

Plankton samples and water for physico-chemical examinations were taken from stations so arranged as to afford an adequate coverage of each pond. Thus, 6 stations were chosen in Cash Lake, based on the possible variability of the water characteristics at these points. In Lake Redington, 2 main stations and 1 secondary station were chosen, based on the same considerations. In Bluegill Lake, 2 stations were chosen and in Snowden Pond, 4 were determined. (See Figures 1, 2 and 3).

Water samples were collected from all stations approximately once a week for as long as was practicable. This was also true for plankton collections. During the winter months it was often impossible to hold to the schedule due to increasingly inaccessable roads, particularly the road leading to Lake Redington. The formation of thin ice covers on all of the impoundments were too thick to allow the use of a boat and too thin to support the weight of a man with the necessary equipment. However, in most cases during the winter months it was possible to obtain approximately bi-weekly samples of water and plankton for examination.

The United States Fish and Wildlife Service at College Park and on the Refuge provided a truck for the transportation of field equipment and personnel in many cases, as well as boats on ponds for collecting purposes.

As the laboratory at College Park is but a relatively short distance from the ponds, only essential reagents were added to the water samples after which they were transported to the laboratory for complete analysis. During the summer months, the fresh water samples were placed in a portable ice cooler and kept at a temperature lower than the water temperature of the ponds from which they were taken, until ready for analysis.

Since preliminary analysis showed that it was unnecessary to use the Rideal-Stewert modification for the determination of dissolved Oxygen, the unmodified Winkler method as recommended by the American Public Health Association in Standard Methods of Water Analysis (1936), was employed. Free Carbon Dioxide determinations were made according to the method of Theroux, Eldridge and Mallmann (1943), as were the determination of acidity and alkalinity. For the determination of hydrogen-ion concentration a La Motte colorimetric comparator was used in most cases. However, a few readings of pH were obtained using a Coleman electrometric pH meter. Conductivity measurements were obtained in units of reciprocal megohms-per-centimeter cube through the use of the Evershed Dionic Water Tester. Silica was determined colorimetrically with the method suggested by King (1931). The soluble phosphorus was determined by Denige's method (1921), modified by the addition of Bismark brown to the standards in the presence of samples that showed a yellow tint. In some cases it was necessary to further modify the method by filtering the water samples after the proper reagents had been added and the necessary reaction completed.

Total iron content was determined by the method recommended by Theroux, Eldridge and Mallmann (1943). Ferrous iron determinations for comparison purposes were analysed by using the American Public Health Association method (1936). Ferric iron content was calculated from the formula: Parts per million total iron minus parts per million ferrous iron equals the parts per million ferric iron. Infrequent determinations of nitrate and nitrite Nitrogen were run by the methods as outlined in Theroux, Eldridge and Mallmann (1943). Transparency and the related turbidity were at first determined by a Secchi disk. Later a turbidometer was used in determining the turbidity.

Depth soundings at the stations were taken with a line measured in feet to which the Secchi disk was attached. For shallow areas a standard yard-stick was used. Temperatures, both air and surface water, were determined with a thermometer calibrated in tenths of a degree Centigrade. A few bottom temperature determinations were made with a standard reversing thermometer. An Eckman bottom dredge was used for obtaining samples of the bottom soils.

All chemical samples were placed in glass stoppered bottles. Oxygen samples were kept in small reagent bottles with an approximate capacity of 150 c.c. Carbon dioxide samples were kept in brown bottles of about a 200 c.c. capacity. The rest of the water samples for chemical analysis were placed in magnesia type bottles with lock, glass stoppers.

Phytoplankton samples were taken in large glass containers of about three and a half liter capacities. Neutral formalin was immediately added to all phytoplankton samples, after which they were transported to the laboratory and allowed to settle for at least 2 weeks and in most cases, a month. Concentration of the phytoplankton was accomplished by a siphon device developed in the laboratory.

The working parts of the instrument consisted of a vertically sliding small bore glass tube 14 inches long contained within a larger bore stationary glass tube 17 inches long. The free end of the moving tube was enlarged into an inverted funnel-like form with a diameter of 2½ inches, and was covered with 3 thicknesses of number 20 guage plankton netting, held in place over the mouth of the funnel-like opening by means of elastic bands. Although the inner tube was free moving, a washer consisting of 2 inches of close fitting rubber tubing, attached to the free end of the stationary tube through which the inner glass tube moved, kept the latter in place and maintained an effective vacuum seal between both tubes. During operation, the proper rate of flow could be maintained by means of a stopcock placed in the opposite arm of the siphon device. (See Figure 4).

A rubber tube inserted in the opposite arm of the device was used to draw up the volume of water necessary to start the siphon operating, after which the rubber tube was closed by means of a pinchcock. The siphon was started on a blank water sample in order to prevent any initial disturbance from occuring in the plankton sample. During the actual operation of the device contact was maintained between the funnel opening of the siphon and the surface of the sample by progressively lowering the moving tube into the sample as the water was drawn off. Care was exercised in maintaining a weak siphon in order to prevent the phytoplankton from being disturbed in the bottom of the container. By means of this device it became possible to concentrate a plankton sample from 3500 c.c. to between 15 and 30 c.c. in approximately 8 to 10 minutes.

Microscopic examination of the runoff water revealed that no effective part of the phytoplankton had been lost during the concentration. In a few cases it was necessary to concentrate the plankton more than could be safely accomplished by the siphon, in which cases the residue obtained by means of the instrument was allowed to settle once again and the remaining excess water was drawn off by means of a pipette.

The Sedgewick-Rafter cell was used for the determination, quantitatively, of the samples, since most of the phytoplankton had to be observed under a relatively medium power of magnification. (i.e. from X210 to X360). In making calculations, the formula of Littleford, Newcombe and Shepherd (1940) was employed.

Fish for possible corollary studies were collected by seining, using seines 10 feet long by 3 feet high and 75 feet long by 4 feet high, respectively. Insect collections were made and vegetation studies were also carried out for related investigations when necessary.

The first series of samples for this study was obtained on June 11, 1947, and the last series was taken on April 5, 1948. The following field observations and discussion are based upon a total of approximately 3,822 field determinations and water samples as well as phytoplankton samples. In many cases, several determinations were made on each sample in the laboratory in order to verify results obtained.

OBSERVATIONS

Soundings taken at all of the stations showed that station 3 on Snowden had a depth of about 15 feet as did stations 1, 3 and 6 on Cash Lake. These were the deepest points encountered during the investigations. Station 1 on Lake Redington has an approximate depth of 9 feet, while stations 2 and 3 in that pond are 4 and 3 feet deep respectively. The most shallow of the waters are located at Snowden station 4 with a depth of 1 foot, in Snowden station 1 with a depth of 2½ feet, and in Blue Gill Pond where both stations are approximately 2 to 2½ feet deep. Stations 2 and 4 in Cash Lake have depths of about 3 to 4 feet while station 5 on Cash is about 5 feet deep. The exact depths depend upon the season at which soundings are made, as the water levels in the ponds are periodically raised and lowered. This is especially true in Lake Redington and Cash Lake. Redington was lowered a total of 42 inches over a two-week period beginning June 23, 1947. Most of this overflow from Redington entered Cash which rose several feet in the same period. Beginning September 17, 1947 and extending over a two-week period the water level on Lake Redington was raised several feet with a corresponding fall in the water level of Cash Lake. The water level of Blue Gill pond was lowered about 2 feet in the latter part of April, 1948. Snowden pond has also been subject to minor fluctuations in the water level particularly at a period shortly after it was filled, at which time the dam started leaking and necessitated changes in the water level. From this it can be seen that only relatively shallow waters were encountered during this investigation.

Thermal Conditions

Thirty-six degrees Centigrade, the highest temperature recorded during any of the field studies, was obtained on June 11, 1947. It is interesting to note that the lowest temperature recorded, 2 degrees Centigrade, was registered on March 3, 1948, toward the end of the winter. Most of the period during which studies were made was notable for rapid and sometimes great variation in air temperature. On June 24, 1947, for example, the air temperature at 1:00 P.M. was 24 degrees Centigrade but jumped to 31 degrees Centigrade by 11:00 A.M. on June 26, 1947. A temperature of 35 degrees Centigrade was recorded on July 1, 1947 but fell to 27 degrees by July 3, 1947. A temperature of 3 degrees was noted at 10:30 A.M. and jumped to 14 degrees Centigrade by 3:30 P.M. of the same day. Similar temperature fluctuations were noted during the entire year.

Water temperature recordings at the stations in all of the ponds showed that generally they closely paralled the air temperatures. When the air temperature was at 27 degrees Centigrade on July 8, 1947 at 12:30 P.M., the water temperature was recorded at 26 degrees, in Snowden Pond, station 1. At 10:30 A.M. on August 13, 1947, the air temperature was recorded as 30 degrees and the water in Lake Redington at Station 1 was recorded as 30 degrees. On October 1, 1947, the air temperature at 10:00 A.M. was 16 degrees and the water at station 3 in Cash Lake was 15 degrees. Only in relatively rare instances was there more than a few degrees difference between air and water temperatures. On July 1, 1947, for instance, the air temperature was recorded at 35 degrees Centigrade while the water, at Station 2 in Cash Lake was found to have a temperature of 30 degrees. At 11:30 A.M. on February 18, 1948, the air temperature was 18.8 degrees Centigrade while the water temperature in station 2 on Cash Lake was found to be 4.8 degrees Centigrade. Some differences in water temperatures between ponds were found to occur. On July 23, 1947, the average water temperature in Cash Lake was found to be 26.5 degrees, in Blue Gill Pond it was 24 degrees, in Redington the average temperature of the water was 26 degrees, and in Snowden Pond the temperature of the water was 28 degrees. A greater difference was noted on October 1, 1947, at which time the temperature in Cash Lake was 16 degrees, in Blue Gill Pond, 20 degrees, in Lake Redington, 17 degrees and in Snowden Pond, 21.4 degrees Centigrade. Cash Lake had a temperature of 3.2 degrees, Blue Gill Pond, 5.4 degrees, Redington, 6.0 degrees and Snowden, 4.2 degrees Centigrade on December 11, 1947.

Appreciable differences in temperatures of various stations on the same ponds were noted. A difference was noted between station 6 on Cash Lake with a temperature of 28.6, on August 20, 1947, and stations 3, 4 and 5 on the same pond, with temperatures of 29 degrees Centigrade. Station 1 on Snowden Pond had a temperature of 26 degrees on July 8, 1947, while stations 2 and 3 had temperatures of 25 degrees. The minimum temperature variation between stations was noted in Blue Gill and Redington. Water temperatures varied from a maximum of 30.1 degrees Centigrade at station 2 in Redington, August 7, 1947, to a minimum of 2.8 degrees at station 1 on January 10, 1948. In Snowden Pond the maximum temperature occurred on August 20, 1947, when 31.5 degrees was noted in all stations on this pond. The minimum temperature of 3.0 degrees was obtained from stations 1 and 4 in Snowden Pond on December 17, 1947. A maximum of 35 degrees was recorded at station 1 on Cash lake, June 11, 1947. The minimum of 3.0 degrees for Cash was recorded at station 1 on January 10, 1948. Blue Gill Pond exhibited a maximum temperature of 32 degrees at both stations on August 20, 1947, and a minimum temperature of 2.0 degrees at both stations on February 18, 1948. It should be noticed that the periods of maxima and minima for water temperature between the 4 ponds did not coincide in most cases. (See Tables 1, 2, 3 and 4 and Figure 5).

Transparency and Turbidity

There is an important relationship between transparency and turbidity, so when it became apparent that the range of the Jackson turbidometer was not wide enough to give accurate turbidity readings of the pond waters, Secchi disk readings for transparency were substituted.

Maximum transparency for Cash Lake was observed on November 11, 1947 when a reading of 32 inches was obtained. The minimum transparency on Cash Lake was noted on July 1, 1947 with a reading of 6 inches. Blue Gill Pond had a maximum bottom transparency at all times. In Lake Redington, a maximum transparency of 18 inches was obtained on November 10, 1947. The minimum reading of 1 inch was recorded on July 8, 1947. Snowden Pond showed a maximum transparency of 42 inches on July 30, 1947, and a minimum reading of 17.5 inches on August 15, 1947.

The marked differences in the transparency between the ponds should be noted. The maximum transparency of all the ponds occurred in Snowden Pond, while the minimum transparency occurred in Lake Redington. Variations in transparency were noted between stations in a pond. For example, on February 23, 1948, station 2 on Cash Lake showed a transparency of 20 inches while station 4 showed a transparency of only 16.5 inches. On April 3, 1948, Cash station 1 had a transparency of 15 inches while stations 3 and 4 exhibited a transparency of 12 inches. Cash Lake showed the greatest degree of variation in transparency between stations of all of the ponds. However, all of the ponds showed at least slight station variations in transparency. With the exception of Blue Gill Pond which exhibited a bottom transparency at all times, examination of the data shows that on the whole, transparency increases toward the end of summer and through the fall while there is a rapid decrease in transparency at the end of February and into March. Snowden showed appreciable differences in the trend of transparency from the rest of the ponds in that the level of transparency was always higher than in Redington or Cash. Furthermore, Snowden did not show as marked a loss of transparency during the winter months as did Cash Lake and Lake Redington.

The raising and lowering of the water levels of Lake Redington and Cash Lake did not seem to interrupt appreciably the transparency trend during this period. As seen from the above observations, the maxima and minima of the water transparencies of the four ponds did not coincide in the same periods. (See Tables 5, 6, 7 and 8 and Figure 6).

Conductivity

A definite seasonal trend in conductivity was observed in all of the ponds. Conductivity values as shown in Figure 7 and Tables 9, 10, 11 and 12 seemed to decrease as the summer progressed. During the fall months, conductivity tended to increase towards a peak in the winter months and remain at a high level or begin once again to drop. In Snowden Pond, station 2 showed a conductivity value of 35 reciprocal megohms on July 8, 1947. On August 27, the conductivity at the same station was 32, while on December 11, 1947, the conductivity rose to 43 reciprocal megohms per centimeter cube. After this peak, the conductivity at station 2, Snowden Pond started downward to a low of 34 on March 5, 1948.

Station 1 at Blue Gill Pond had a conductivity of 28 on June 11, 1947. The conductivity values then showed a downward trend up to and including August 20, at which time the reading at the same station was 18 reciprocal megohms. Blue Gill Pond also had a fall peak, since readings taken from station 1 on October 1 gave a conductivity value of 25. However, by October 16, a minimum of 17 was shown. The rest of the trend followed more or less the trends of the other ponds in that winter peaks were noted on March 1 and March 17, 1948, with readings of 29 and 35 reciprocal megohms, respectively.

Cash Lake, station 2, was shown to have a conductivity peak on June 11, 1947, at which time a reading of 35 was taken. Conductivity then started downward to reach a minimum of 25 on October 1, 1947. An upward trend at station 2 was noted beginning on November 10, when a value of 28 was recorded and reaching a peak of 37 megohms on February 28, 1948. There was a decrease in conductivity after this date until March 17, 1948, when a reading at station 2 showed a value of 33. The conductivity values at station 1, Lake Redington remained more or less constant during the months of June and July, 1947. The readings during that period averaged approximately 30 reciprocal megohms per cubic centimeter. An upward trend was noted beginning July 30 when a value of 33 was recorded. A peak was reached on August 30, with a conductivity reading of 40. This level was maintained through October 16. A definite trend downward was observed beginning on October 26, when a value of 35 was recorded and continuing until November 19, 1947, when a conductivity reading of 32 was obtained. The next peak was recorded on December 17, when a reading of 40 was taken. This was the last peak noted, since conductivity readings showed a downward curve up to and including March 17, 1948, when the conductivity value was 30.

As can be seen from the above data, conductivity levels varied considerably between the four ponds. The conductivity levels of Lake Redington ranged between 30 and 46. In Cash Lake conductivity varied from 24 to 36, while in Snowden Pond there was a range from 34 to 50 reciprocal megohms per centimeter cube. Blue Gill Pond showed a variation from 15 to 37 reciprocal megohms. Another noteworthy observation is the that even though the levels of conductivity in the different ponds varied, the actual point difference in three of the ponds was remarkably similar. For example, Cash Lake had a variation of 12 reciprocal megohms from maximum to minimum; Lake Redington showed a 16 point variation, as did Snowden Pond. Blue Gill showed the greatest point difference between maximum and minimum, having a 22 point variation.

Noteworthy differences in conductivity between stations in the same pond were observed as well as an interesting difference between peak levels of stations. On June 17, 1947, Cash station 1 had a conductivity reading of 35, but station 2 had a reading of 32. On June 26, the reading at station 1 was 34, while the reading at station 5 showed a value of 28. Similar point differences were observed in all of the ponds. Although a maximum for station 2 in Cash Lake was recorded on February 28, 1948, the peak in station 1 was found to occur on November 20, 1947. The maximum conductivity value at station 1 on Snowden Pond was found to occur on December 17, while the peak at station 2, occured on December 11. Similar differences were noted in the rest of the impoundments.

Hydrogen Ion Concentration

The data obtained showed that in a general way, a similar trend could be observed in all of the ponds. There seemed to be a tendency for the pH to go up during the summer and fall and beginning in late fall to start downward to a winter low. Toward the following spring an upward pH trend was again observed. An early fall peak was observed in Snowden Pond on September 9, 1947, with an average pH value of 6.2. A minimum pH value of 5.8 occurred in Snowden Pond on February 28, 1948, and the early spring value of 5.9 occurred on March 17, 1948. Reding had a fall peak on November 10, 1947 and a winter low of 5.7 on January 10, 1948. The pH rose to a value of 5.9 on March 17 in Lake Redington. It should be noted that Redington also showed a summer pH maximum of 6.2 on August 13, 1947. A fall maximum pH value of 6.3 in Blue Gill Pond was recorded on December 11, 1947. A minimum value of 5.2 was found on February 28, 1948. By March 17, the pH had risen to a level of 5.9. A summer maximum was also found to occur in Blue Gill Pond when a value of 6.6 was recorded on July 28, 1947.

Cash Lake showed a summer peak on August 7, 1947, of 6.6, a fall peak of 6.5 on November 20, 1947, and a winter minimum of 5.6 on January 10, 1948, rising to a level of 6.2 on March 17, 1948. It can be seen that even though there were marked seasonal trends in all of the ponds, the points of maxima and minima in the different ponds did not correspond with one another.

The range for pH in the different ponds was noticeably different. There was a range in Cash Lake of from 5.6 to 6.6, while in Redington a variation was found from a pH of 5.4 to 6.45. The range was greatest in Blue Gill Pond with a change of pH from 5.2 to 6.6. The narrowest range was found to occur in Snowden Pond. In this impoundment the pH rose from a low of 5.7 to a high of 6.3.

Just as with the previous factors, appreciable differences between the pH values of stations in any pond were recorded. On October 15, 1947, Snowden Pond, station 1, had a pH of 6.0 while stations 2 and 3 had a pH of 5.8. In Snowden, station 1 on February 27, a pH value of 5.9 was observed while station 2 had a pH value of 5.7. In Blue Gill the variation, while measurable, was not as pronounced. On June 18, 1947, the pH at station 1 was 6.0 and at station 2 it was 6.1. On February 27, station 1 had a pH of 5.5 and station had a value of 5.4. Lake Redington showed a few more pronounced pH variations between stations. On July 23, station 1 in Lake Redington showed a pH of 6.6 but station 3 had a value of 6.4. The rest of the variations were similar to those found in Blue Gill. For example, station 1, Lake Redington showed a pH of 5.5 on October 16, 1947 and on the same date, station 3 showed a pH of 5.4. Similar differences were noted in Cash Lake. Station 1 had a value of 6.3 while station 6 gave readings of 6.1 on June 24, 1947. (See Tables 13, 14, 15 and 16 and Figure 8).

Carbon Dioxide

With one or two exceptions, it was observed that beginning in June and proceeding through the summer, the carbon dioxide content of the waters under study decreased. Towards the end of summer and through the fall and winter, this trend was reversed so that the carbon content generally increased in all of the impoundments. At the end of the winter and in the very early spring the carbon dioxide content once again showed indications of decreasing. In Cash Lake the summer downward trend began on June 11 and with an average reading for this body of water of 8.5 parts per million of carbon dioxide. With the exception of a couple of minor variations during the first part of July, the carbon dioxide diminished to a low point of 3 parts per million on August 13, 1947. The upward surge started on August 20, with a value of 4.5 and continued generally until a maximum value of 14 was obtained on February 23, 1948. The downward curve for carbon dioxide in Cash Lake started once again on March 5, 1948, with a carbon dioxide value of 11 parts per million and on March 17, the value had fallen to 9. Later data obtained outside of the scope of this paper indicates that the downward trend is continuing.

A similar situation was noted in Lake Redington where starting on June 26, 1947, when the water contained 8.5 parts per million of free or dissolved carbon dioxide (the latter term is used in this paper) and continuing through the summer, carbon dioxide content fell to a low of 3.0 on August 13. A sudden secondary peak of 7.0 occured on August 27, after which the carbon dioxide fell to a lower level of 5.0 parts per million on September 9, and again resumed the upward movement. This situation continued until a high point of 8.5 was recorded on February 18, 1948. Shortly after this date, the trend was once again reversed so that by March 17, a value of 5.0 was found in the waters of Lake Redington.

The summer cycle of carbon dioxide began on June 18 in Blue Gill Pond. On that date an average of 6 parts per million dissolved carbon dioxide was found. The level continued falling until August 20 when the water contained an average of 3 parts per million. The upward portion of the cycle started on August 27, with a recorded average value of 3.5 and took a sudden surge on September 9, when a value of 10.0 was noted. On October 16, it was noted that the carbon dioxide had returned to a level of 6.0 but that it was continuing the upward trend, so that another peak of 10 was found in

Blue Gill waters on November 19, 1947. The level dropped to 4.7 parts per million (average) on December 11, 1947, after which the upward trend started so that a winter peak of 8.3 was obtained on February 18, 1948. This peak continued at a level of 8 parts per million until March 5, 1948, when the cycle was reversed. On March 17, the carbon dioxide level had fallen to 5.5.

Snowden Pond appeared to have a similar carbon dioxide cycle. However the proportions of the Snowden cycle were noticeably different. The carbon dioxide fall started on July 8, 1947 with an average of 8.5 parts per million and ended on July 23, with an average of 4.4. On July 30, a slow but steady upward trend was noted with a starting value of 5.0. Not a single, sudden upward surge or reversal was noted throughout the summer, fall and mid-winter. The rate of increase was remarkably regular and continued until a maximum of approximately 15 parts per million carbon dioxide was recorded on February 27, 1948. Shortly after, the cycle was reversed so that a low of 5 was recorded on March 17, 1948.

There was considerable variation in the ranges between the minima and maxima among the four bodies of water, in that Snowden Pond has a range of 10.4 parts per million dissolved carbon dioxide; Blue Gill Pond a 7.2 range; Redington a range of 5.2; and Cash Lake a difference of 11.0 parts per million of dissolved carbon dioxide..

In some instances, considerable variations between the carbon dioxide content of the waters at different stations in the same lake were observed. On February 23, 1948, Cash Lake station 1 water contained an average of 14 while water from station 4 was shown to contain 10.5 parts per million. The same situation was true in Cash Lake on March 5, 1948, when station 1 contained 11.0 parts per million and water from station 2 contained an average of 5.0. Similar observations were made on Lake Redington where it was demonstrated that the variations were not as large since there were no cases where the carbon dioxide differences between stations exceeded more than a change of 1.5 parts per million. In Blue Gill Pond there was only one instance when the station variations reached a difference of 1 part per million. In all other cases on this pond the differences were confined to approximately 0.5 between stations on any given date of collection.

In comparison to the variations in Cash Lake the fluctuations between stations on Snowden Pond were relatively small, the greatest difference occurring in the latter on February 27, 1948, when a fluctuation of 2.4 parts per million carbon dioxide between stations 1 and 4 was recorded. Most of the other station differences on this impoundment were confined to 1 part per million or less. (See Tables 17, 18, 19 and 20 and Figure 9).

Alkalinity

Observations show that the cycle for alkalinity in the ponds is not nearly as clearcut as it is with some of the other physical and chemical factors. However, an examination of the data in Figure 10 and Tables 21, 22, 23 and 24, seems to indicate that alkalinity measured in parts per million calcium carbonate may remain at generally what appears to be the same level or may show some decrease during a part of the summer. The alkalinity seems to increase through the fall and the first part of winter, dropping rapidly during the last part of the winter and very early spring. As already indicated there are marked variations from this general cycle among the four waters studied.

Examination showed that the waters of Blue Gill contained 12.0 parts per million alkalinity as calcium carbonate on July 18, 1947. From this level the alkalinity fell to a low of 4.5 on July 23, where it remained until July 30. At this latter date the alkalinity rose to a level of 9.0 where it was generally maintained with the exception of one or two minor dips through the rest of the summer, fall and part of the winter. A drop in alkalinity which proved to be progressive started on February 27, 1948, with an average content of 6. The drop continued through the 17th of March when a value of 3.5 was obtained.

From 10.5 parts per million measured on July 16, the alkalinity value in Snowden fell to 8.0 on July 30, 1947. The upward trend started on August 7, and with the exception of a couple of minor reversals continued upward to a maximum alkalinity value of 13.8 (average) on December 12, 1947. A reversal started on December 17, and continued down to February 18, when a value of 5.5 was obtained. An unusually strong upward surge occured on February 27, 1948, when a value of 20 parts per million alkalinity in terms of calcium carbonate was obtained. However, the peak was short lived and on March 17, 1948, the reading in Snowden Pond was 4.5.

With the exception of two sharp peaks of brief duration in the month of July, the values for alkalinity in Lake Redington gradually diminished to a level of 6.0 both on August 20 and 27. On September 9, the upward portion of the alkalinity cycle began with a measurement of 7.5 and increased to 12.0 the 26th of October. Alkalinity continued generally at this level until November 19, (8.5 parts per million) when a definite downward trend was started continuing, with the exception of a short rise, until March 17, 1948, when a reading of 4.0 was taken from Redington.

Generally, the alkalinity level of Cash Lake remained more or less constant from June 11, 1947 to August 20, of the same year. During this period the alkalinity flustuated between 11.0 and 11.5 parts per million on the average. A drop to 9.0 was noted on August 27, but shortly afterwards the upward trend again started and continued to a peak of 18.0 on December 17. The rest of the period of this study saw the alkalinity in Cash drop to a low of 7.5 parts per million calcium carbonate on March 17, 1948. It might be of interest to note that just before this minimum was reached, a short but relatively high peak occurred on March 5, resulting in a value of 12.4.

As with other factors so far observed, the ranges of alkalinity for the different ponds varied. Cash Lake had a range of 13 from the maximum to the minimum. Lake Redington had a range of 11 from maximum to minimum. Snowden showed a 16 parts per million range and Blue Gill Pond showed a range of 8.5. (See Tables 21, 22, 23 and 24 and Figure 10).

Variations between different stations on the same body of water were observed just as was the case with previous chemical and physical factors. The smallest variability between stations occurred on Blue Gill Pond where the average difference proved to be less than 1 part per million. Snowden proved to have an average station difference of slightly more than 1, as did Lake Redington, while the greatest variability between stations was on Cash Lake, with an average value of aproximately 2 parts per million.

Total Iron

The seasonal trend for iron in the four ponds studies seems to be the least general of the factors observed. Only in the broad sense can a trend be described. On the average there seemed to be a reduction of total iron occurring during the summer particularly during the early summer. The cycle seemed to reverse itself during different periods of the summer in the different ponds and show a tendency to go up to a higher level and stay at that level until well into winter, or as it sometimes manifested itself, the iron showed another low period before it started a rise in the fall. During the winter, two kinds of conditions seemed to prevail, in some cases the iron remained at a high level throughout this season and abruptly tapered off during the last part of the winter into the early spring when it once again started upward. On the other hand, in at least one of the ponds, the iron suddenly dropped during mid-winter, recovered, and then dropped again until spring when it was seen to start the general upward trend. Blue Gill Pond illustrates the latter of the two cycles. On June 18, 1947, the iron content in this body of water was measured as 2.5 parts per million total iron. The amount of iron began to diminish on June 26, (2.0 parts per million) and continued down to July 16, when an analysis of the water showed 1.5 iron to be present. A value of 2.0 was obtained on July 23 and the level continued upward to August 13, (3.0 parts per million) when a second reversal occurred bringing the iron down to 0.50 by October 1, 1947. On October 16, the amount of total iron once again started to increase and by November 19, 2.0 was recorded in Blue Gill Pond.

At this point Blue Gill exemplifies the second set of conditions, namely, that a reversal of the cycle occurred resulting in a drop in iron present, so that by February 18, 1948, the total iron content of the waters was on the average 0.5. After this period the level rose and continued to rise into late winter so that by March 17, the total iron had reached a level of 3.0

Cash Lake illustrates the first of the two conditions previously described. Beginning with a value of 4.5 parts per million total iron on June 11, 1947, the amount of iron diminished to a low of 2.0 on July 23, when an upward trend occurred so that a value of 4.0 was attained on August 13. From this date until November 20, the iron content was at more or less the same level. The cycle reversed itself and started down beginning on December 11, 1947, reaching a winter minimum of 2.0 by February 18, 1948. On February 23, the iron content slowly started up and reached a late winter peak of 3.5 parts per million on March 5, 1948.

With the exception of a few individual variations, the cycle for Lake Redington generally seems to fall into the same category as Cash Lake, while Snowden Ponds appears closer to the type exemplified by the iron cycle of Blue Gill Pond.

Observations showed that there was a difference in the iron ranges from maximum to minimum for the different bodies of water under study. Snowden was found to have a maximum of 5.5 parts per million and a minimum of 0.75. The maximum for Blue Gill Pond was 3.0 and a minimum of 0.5, while the maxima and minima for Cash Lake and Lake Redington was found to vary from 4.5 to 1.5 and 6.0 and 1.5 respectively. As seen from the tables, variations between stations on the same impoundment occurred in all of the waters studied, just as was the case with other factors, physical and chemical. (See Tables 25, 26, 27 and 28 and Figure 11).

Silica

Silica was another chemical factor of the waters studied which did not follow a single trend but showed two separate, if related, cycles. In at least one of the impoundments, the silica was at a peak during the late spring and early summer. During the middle of summer the level slowly dropped and remained at a low point until late summer or early fall at which period the silica content of the water again increased. This level was maintained for a relatively short period at the end of summer, when the level once again was reversed in a downward movement until a comparatively low point was reached. This latter value was maintained with sporadic upward surges of short duration and low intensity until mid or late winter, at the end of which period the silica level slowly started to rise and continued the upward trend into the early spring.

The other silica cycle started at a relatively high level at the beginning of the summer and continued to go up through mid-summer into late summer or early fall. During the early autumn, the silica started to fall slightly and then leveled off, still at a comparatively high level, until late autumn. Beginning in late autumn and continuing into mid-winter, the silica content of the water slowly dropped to a minimum in late winter, at which time the trend was once again changed and the silica started to increase into the early spring.

The silica cycle in Cash Lake seemed on the whole to fluctuate in a manner similar to the first of the two cycles observed. A value of 0.50 milligrams per liter of silica was obtained on June 11, 1947. Shortly after this date the silica value started to fall until an average level of 0.25 milligrams per liter was reached on June 26. A consistent rise was first noted on July 3, and continued until the original value of 0.50 milligrams per liter of silica was reached on July 11, 1947. With the exception of one short rise, this level was maintained up to and including August 13, and continuing through August 20, the silica content of the water of Cash Lake jumped to 0.75 and then started a decline culminating with a minimum content of less than 0.12 milligrams per liter of silica or trace silica on December 11, 1947. This minimum continued through February 23, or mid-winter. Beginning March 5, 1948, the silica cycle once again started an upgrade which continued through April 3, with a value of 0.25 milligrams per liter of silica.

The silica pattern for Lake Redington apparently followed the second of the two cycles observed. A reading of this pond taken on June 26, 1947, indicated content of 0.50 milligrams per liter. On July the level rose to a level of 0.75 milligrams and continued to be increased through August 20, at which time an analysis showed a silica content of 1.0 milligrams per liter of water. On August 20, the trend was reversed and the silica started to fall from a value of 0.85 milligrams per liter on that day to a minimum of 0.12 through February 18, 1948. March 1 showed the beginning once again of an increase in the silica content of the water in Lake Redington, continuing through March 17, with a recorded value of 0.50 milligrams of silica per liter.

The silica trend of Snowden Pond on the whole, seemed to follow the pattern of silica in Lake Redington, with the exception of a very short downward tendency recorded in the former impoundment on July 16. Blue Gill Pond seemed to follow the first of the two cycles and generally appeared to be similar to Cash Lake in relation to the silica cycle. No downward movement in Blue Gill was recorded during the mid-summer period. Instead, the silica content during this period remained constant until late summer.

As with other factors, the silica ranges for the four impoundments varied. The fluctuation from maximum to minimum in Blue Gill Pond ranged through 0.75 milligrams of silica per liter of water. The same type of range in Snowden Pond showed a fluctuation of 0.88 milligrams of silica per liter of water. For Lake Redington, the value was also observed to consist of 0.88 milligrams per liter, while a range of 0.74 was found in Cash Lake.

It was also observed that the peaks for silica generally seemed to coincide among the bodies of water investigated. The silica maxima in Cash occurred on July 30 and August 13, 1947. The peaks for the other three impoundments occurred in the same general period. This apparent coincidence was not noted when dealing with the previous factors described. Silica variations between different stations on a body of water were observed in all 4 ponds. (See Tables 29, 30, 31, 32 and Figure 12.)

Soluble Phosphorus

Observations of the phosphate (soluble phosphorus) fluctuations of waters studied indicate that here again apparently more than once cycle occurred. Two of the ponds showed a low phosphate level at the beginning of the summer which slowly rose during the month of July and then suddenly dropped by the end of the month or in the early part of August. A short time later it was noted that the phosphate content of the water once again started to increase, this time very slowly and with numerous minor variations, and then dropped during the fall or early winter. From this point on into the mid-winter, phosphates remained at a low level and only started to rise, slowly, towards the end of the winter season.

In the other phosphate cycle, the level was relatively high in the early part of the summer and then started to fall during July. The phosphate content generally seemed to remain constant through the early fall.

During late fall and into early winter, the phosphates were either constant or showed a sudden and relatively short surge, after which a return to a lower level was observed. During the rest of this cycle, the value of phosphates in the water remained at a medium or low level and showed an indication of rising only towards the end of winter.

The phosphate cycle as observed in Cash Lake seemed to be of the same general pattern as the one first described in that the value determined on June 11, 1947, was found to be 0.012 milligram of soluble phosphates per liter of water. The level rose to 0.025 milligrams on July 16, and then started to fall soon after so that by the end of July, a minimum of trace phosphates had been reached. On August 13, 1947, the cycle once again started and reached a maximum of 0.075 milligrams on October 20. On November 10 the trend was reversed, with a phosphate content of 0.040 milligrams and ending with a minimum of trace phosphates on January 10. With the exception of minor variations, this minimum point was maintained until March 5, 1948, when analysis showed a capacity of 0.050 phosphates in the water of Cash Lake. Another drop was noted on April 3, but it is doubtful if this reversal was anything but a momentary fluctuation.

The phosphate cycle in Blue Gill Pond generally paralleled that of Cash Lake, except that in Blue Gill the fall and late fall minima occurred on October 1, and December 17, 1947, with values in both instances consisting of trace phosphates.

In Lake Redington the phosphate fluctuations seemed to follow the second pattern described previously. Measurements taken on June 26, 1947, indicated a phosphate content of 0.025 milligrams per liter. This level started to fall soon after so that on July 3, a low of 0.012 was reached.

A variation from the general cycle took place on July 16, 1947, when the phosphate level in the water of Lake Redington rose for a short period to 0.030 milligrams of soluble phosphates per liter of water. However, this surge was short lived and the phosphates fell to 0.020 on July 23, and continued generally at this level until August 13, 1947, at which time the phosphates dropped to 0.012 milligrams and continued a slow downward trend to October 1, 1947. On this date an absolute minimum of zero was registered colorimetrically. Although the level rose to trace phosphates soon after, this low point was maintained through the rest of the winter and into early March. On March 17, 1948, the phosphates once again started to rise, and a value of 0.025 milligrams of phosphates per liter was obtained.

Snowden also showed a phosphate cycle which evidently followed the second pattern observed. A long period of minimum phosphates varying from trace to zero was observed beginning on August 15, and continuing through October 15, 1947. Shortly after this date the level was increased to 0.020 milligrams (November 10), and remained generally at this level until January. On January 10, 1948, the trend was reversed downward in Snowden. However, this was of very short duration, since the phosphate content was back to 0.025 on February 18, and rose rapidly to 0.050 on February 27, 1948. This medium level was maintained through March 17.

In Cash Lake, soluble phosphates in milligrams per liter ranged through a fluctuation of 0.075 milligrams from maximum to minimum. The range for Blue Gill Pond was approximately 0.070 from maximum to minimum, while in Redington a comparable analysis indicated a range of 0.050 milligrams per liter. Snowden Pond showed a 0.075 milligram per liter fluctuation for soluble (dissolved) phosphates.

As in all of the previous cases observed, marked variations in the soluble phosphate content occurred at different stations on the same body of water. In Snowden Pond at station 2, the water had a level of 0.012 milligrams of soluble phosphates on December 11, 1947, while the area at station 4 contained 0.030 milligrams, on the same date. An analysis of water taken from station 1 on Lake Redington, October 1, indicated the content of phosphates was zero while water from station 3 showed 0.012 milligrams of soluble phosphates per liter of water. Similar station variations were noted both in Blue Gill Pond and Cash Lake. (See Tables 33, 34, 35 and 36 and Figure 13).

Dissolved Oxygen

Although of necessity highly generalized, the oxygen cycle seemed to be similar for all of the ponds, at least up to the winter months. The oxygen cycle started at a medium value in the beginning of the summer and remained at that general level for a part of the summer. During the mid and late summer, the oxygen content of the water apparently diminished but increased with surprising rapidity in some cases, during the fall. However, a few variations occurred during the winter. While the oxygen content never dropped to the original level of the early summer, some falling off from the autumn peak was noted. This level was continued throughout the winter, until an ice cover was produced, at which time the level started to fall. After dissolution of the ice cover, the oxygen level in some cases was raised immediately and to a high degree, while in other cases no sudden rise occurred. In one instance, the level actually fell toward the end of winter.

Snowden Pond was the impoundment showing greatest variation from the general cycle described. Dissolved oxygen content for Snowden on

July 8, 1947, was 5.03 parts per million. This general level continued to prevail throughout the summer up through October 1, 1947. On October 15, the oxygen started to show an upward trend (5.87) which continued to increase all through the winter and reached a peak on March 17, 1948.

Cash Lake showed an oxygen content of 5.81 parts per million on June 11, 1947, which increased to 7.10 on July 1, and fell rapidly to 4.92 on July 3. By July 11, the level again had reached a higher value of 6.70. With minor variations, this level was maintained until August 27, at which time the analysis showed a low point of 4.46. The trend was soon reversed and continued rising to meet an early winter maximum of 8.35 on December 17, 1947, which continued until February 18, 1948, when it was noted that a depression of the dissolved oxygen content of the water of Cash Lake resulted in a value of 6.00 parts per million. This minimum continued until March 5, 1948, when a sudden rise sent the value up to 9.25. The oxygen level continued to rise through April 3, at which time a record of 9.57 was obtained.

From an early summer maximum of 10.00 observed on June 26, 1947, the oxygen content of Lake Redington gradually fell through the summer to a minimum of 3.87 parts per million on August 27. With the exception of a couple of violent but short declines, the late fall-early winter maximum of 17.50 was reached on December 11, 1947. From December 17, with a content of 9.79, on through the winter, the oxygen continued to fluctuate between an average of 9.5 and 10.2 parts per million.

Of all ponds studied, Blue Gill appeared to follow the general pattern most closely. From a summer peak of 7.55 parts per million occurring on July 23, 1947, the dissolved oxygen content fell slowly through the summer with an approximate average value of 5.5. An autumn peak of 9.51 was recorded on November 19, 1947, after which a short drop occurred on December 11. An average value of approximately 12.0 parts per million dissolved oxygen was maintained through the winter with the exception of February which had an average oxygen content of about 8.6 parts dissolved oxygen per million parts of water. On March 17, 1948, a slight upward tendency was noted. However, the variation was so small as to constitute an insignificant indication of increase.

All of the ponds showed variations in the amount of oxygen present in the water of several stations on a single impoundment. There were also differences in the number of parts per million dissolved oxygen necessary to go from maximum to minimum in the waters studied. This figure for Blue Gill Pond was 6.30; 13.64 for Redington; 5.13 for Cash Lake; and 5.91 for Snowden Pond. (See Tables 37, 38, 39 and 40 and Figure 14).

Acidity

Of all of the physical and chemical factors so far observed, acidity seems to show the most decisive trend. Furthermore, with the exception of a few individual variations in the four ponds which were for the most part minor, the impoundments studied all seem to follow a single pattern.

The total acidity expressed in terms of calcium carbonate was observed to be at a relatively high level at the beginning of the summer in 1947. As the summer progressed, the acidity slowly but consistently, fell to lower levels until a minimum was reached in the latter part of the summer, notably in mid-August. An upward trend was shortly indicated and continued up through fall and into mid or late winter. Shortly after the winter maximum had been reached, the cycle was reversed and a lowering of acidity content of the water began which continued through the middle of March.

On June 26, Lake Redington waters were found to contain an average of 14.0 parts per million total acidity expressed in terms of calcium carbonate. The downward trend was started on July 1, when a value of 12.5 parts per million total acidity was found in Redington and continued in the same direction, with the exception of a few minor reversals through most of the summer and into late August with a minimum record of 9.9. The beginning of the upward movement was first noted on August 27, 1947, when a reading of 15.0 parts per million total acidity was obtained. This upward trend continued through January 10, 1948 at which time a level of 23.0 total acidity was observed. The pre-spring downward trend started on February 18, 1948, when a reading of 18.0 was made and continued through March 17, at which time the level had fallen to 11.0.

Cash Lake showed a similar trend. The early summer maximum of 16.50 parts per million on June 11, 1947, slowly decreased to a late summer minimum of 6.50, on August 27, 1947. The fall rise started on October 1, 1947, when a value of 10.0 was recorded and continued through the winter to reach a maximum of 25.50 on February 18, 1948. On February 23, 1948, the pre-spring decline was first noted when a value of 22.50 was reached and continued in a downward direction through March 17, when 14.0 parts per million total acidity was present in the waters of Cash Lake.

The summer peak for acidity in Snowden Pond occurred on July 7, 1947, at which time analysis of the water showed 22.0 parts per million total acidity to be present. The downward curve continued through August 20, 1947, at which time a reading of 12.0 was observed. The first indication of a consistent upward trend was observed on October 1, at which time an analysis of the waters in Snowden Pond showed an average value of approximately 17.0 total acidity. This upward cycle continued through the months of November, December and part of January and ended with a peak value on January 10, of 29.0. A decline started on February 18, with a value of 27.5 and continued through March 17, when a value of 11.5 parts per million total acidity was observed.

Blue Gill Pond also seemed to follow the general acidity pattern in that an early summer peak of 11.0 was obtained on June 18, 1947 and this level dropped to a minimum of 6.5 on August 13, 1947. The pre-winter peak began September 9, 1947, with a value of 18.0 and continued upward through November 25, 1947, when a fall maximum of 25.5 was noted. During the months of December and January, acidity showed an unusual tendency to fall so that the general average for total acidity during these two months was approximately 15.0 parts per million. A sudden upward trend during the month of February, 1948, resulted in a total acidity value of 20.0 on February 18. Shortly after this date, the acidity began to decline, finally reaching a low value of 8.50 on March 17, 1948.

There were noticeable differences in the ranges from maxima to minima among the four bodies of water studied. Snowden Pond showed a drop of 19.0 parts per million total acidity from maximum to minimum levels. Lake Redington showed a similar drop of 15.0. For Cash Lake the figure was approximately 20.0 and for Blue Gill, the drop covered a range of 19.0 parts per million total acidity in terms of calcium carbonate.

As was the case with the other chemical and physical factors observed, variations between the acidity content of water at different stations on the same body of water often occurred. In Blue Gill Pond, station 1 had a value of 21.0 parts per million on October 1, 1947, and on the same date, station 2 had a content of 17.5. Similar fluctuations took place in the other impoundments observed. On August 20, 1947, station 5 in Cash Lake had an acidity content of 8.5 parts per million while station 2 had a level of 7.0. On December 17, station 1 on Lake Redington was observed to have 20.0 parts per million while at the same time, station 3 had a level of 22.0. One of the station variations on Snowden Pond took place on July 23, 1947. At that time station 2 waters had an average of 11.5, while station 4 contained 10 parts per million. (See Tables 41, 42, 43 and 44 and Figure 15).

Phytoplankton and Nannoplankton Distribution

The following phytoplankters were found in one or more of the bodies of water under investigation and are listed by species under their respective classes.

Bacillariaceae (Diatoms)

Diatoma
Melosira
Cyclotella
Stephanodiscus
Navicula
Stauroneis
Amphora
Nitszchia
Synedra
Frafillaria
Asterionella
Tabellaria
Cymbella

<u>Cyanophyceae</u> (Blue-Green Algae)

Gloeocapsa
Chroococcus
Spirulina
Oscillatoria
Anabaena
Microcystis

<u>Chlorophyceae</u> (Green Algae)

Spirogyra
Mougeotia
Botryococcus
Kirchneriella
Ankistrodesmus
Coelastrum
Scenedesmus
Crucigenia
Ulothrix
Tribonema
Cladophora
Oedogonium
Cosmarium
Arthrodesmus
Staurastrum
Zygnema
Closterium

<u>Phytomastigophora</u>

Euglena
Trachelomonas
Phacus
Astasia
Chilomonas
Uroglena
Synura
Dinobryon
Peridinium (Tentative identification)
Glenodinium

<u>Rhizopoda</u>

Arcella
Difflugia

<u>Ciliata</u>

Vorticella
Stentor

It was observed that the phytoplankton and nannoplankton in the 4 ponds consisted of at least 52 separate genera grouped under 6 classes. Since one of the primary objectives of this study consisted of obtaining quantitative as well as qualitative data about the plankton in the impoundments, it became most convenient to use a Sedgewick Rafter cell for counting studies. Only medium magnifications could therefore be utilized with a resulting possibility that some of the very minute forms may have been overlooked. It should be reiterated that the studies are primarily concerned with the phytoplankton.

Taken as classes, only the most general cyclic observations of the phytoplankton could be made on the ponds as a whole. Numerous variations occurred between individual phytoplankters as well as in the ponds taken separately.

Most of the diatom genera seemed to show a peak during the early part of the summer as well as in mid-autumn. A relatively small number of genera in the Bacillariaceae showed indications of having secondary pulses during the late summer and early fall. Minor pulses also occurred during the early winter in a few of the genera. Generally, diatom minima seemed to appear during the middle of the summer and winter.

Considerable variation was noted in individual cycles for the various genera of blue-green algae but on the whole, many of the pulses seemed to take place toward early spring and into early summer. Relatively few peaks occurred during the middle of summer. The level for these phytoplankters rose rapidly during autumn and in some cases extended well into winter. A few genera showed an increase for a short period during August.

Apparently the general peak for the green algae took place in early summer, especially during June. The cycle then seemed to reverse itself and fall during the mid-summer period. Minor p aks were recorded during August but the important rises began in the fall and extended into early winter, in many cases. On the average, a general drop started during January, extended through February and ended with a minimum during the early portion of March. The rise started once again in April and seemed to continue into May.

A discernable general trend was observed only by grouping all of the classes of the Protozoa together. A generally high level of this type of phytoplankter prevailed during June, especially during the early part of this month. The trend was downward beginning in the last part of June and continuing from July through September but reversed itself during the months of October and November at which time the Protozoa once again reached a peak. During the winter the cycle started on the downgrade and continued through the month of March. A higher count was recorded in April and the Protozoa surged upward during the month of May at which time the last counts were made for this study. As has already been implied, many variations were found to o cur in the different genera. In some instances relatively short but intense pulses were observed during the summer, particularly during the month of August. Only those plankters present in abundance on the 4 ponds will be described individually throughout this study.

All of the diatoms studied were present in Cash Lake, however, Gloeocapsa, Anabaena, and Microcystis of the blue-green algae, although present were only seen in small numbers in this impoundment. Several of the green algae were absent from the waters observed in Cash Lake. Thus, no members of Mougeotia, Coelastrum, Cosmarium and Arthrodesmus were counted in this impoundment. All of the Phytomastigophora and Rhizopoda were present in Cash Lake and all of the Ciliata with the exception of Stentor were also observed there.

Melosira varians Agardh seemed to be one of the most abundant of the diatoms present in Cash Lake, yielding a general, all-period count of roughly 12,000 individual cells per liter of water. The count on June 11, 1947, was approximately 12,300 cells per liter of water. This level jumped to 73, 256 Melosira cells per liter of water on July 1, 1947 and then dropped to a low point of 3,708 cells on August 20, 1947. This low point was maintained until December 11, 1947, at which time a sudden pulse sent the level up to a count of 63,032 cells per liter of water. However, by January 10, the cycle had reversed itself and a count of 16,000 cells was observed. A minimum of only 103 cells per liter of water was recorded on March 17, 1948 in Cash Lake. The upward trend was first noticed on April 5, 1948, at which time the value was observed to be 8,463 cells of Melosira varians per liter of water. By May 3, the level had risen to 30,000 cells per liter of water for Cash Lake. Peaks for Melosira were recorded in early July and December, while the minima occurred during the mid-summer and mid-winter.

Another diatom commonly observed in Cash Lake was Nitzschia linearis Smith. The maximum counts were obtained on June 17, 1947 when an average record of 5,760 was obtained and October 31, when 8,622 individuals per liter of water were counted. A minor pulse was recorded on September 9, when the count was 2,113 cells of *Nitzschia* per liter of water. A summer minimum of 140 cells per liter was counted on August 7, 1948 and a winter minimum of 9 cells per liter of water on February 23, 1948. No cells of *Nitzschia* were found in the water of Cash Lake on March 5 and March 17, 1948. However, 491 cells were found on April 5, and the level increased to 1,680 individuals per liter of water on May 3, 1948.

A summer maximum of 390 cells of *Navicula* was noted in Cash Lake on July 1, 1948, while a minimum of 9 cells per liter of water occurred on August 13, 1947. The fall pulse started in November and reached a peak on December 17, when the count consisted of 912 cells of *Navicula* per liter of water. The winter period was observed to be a period of low productivity for *Navicula*, and a complete absence of this phytoplankter was found during February and March. The upward trend started in April and the count on May 3 showed 180 cells per liter of water in Cash Lake. The other diatoms were observed to be present in fewer numbers in this pond. *Tabellaria fenestra* Kutzing showed a pulse on September 9, 1947, when analysis of the water of Cash Lake showed 168 cells per liter of water and a minimum of 5 organisms per liter on August 15, 1947. *Tabellaria* was not observed during the month of February, while on May 5, 29 cells were counted in a liter of water in this impoundment, indicating a rapid rate of increase.

Synedra showed its maximum peak during the summer with a total of 613 cells per liter in Cash Lake on July 16, 1947, and its summer minimum occurred August 27, with a count of 39 cells per liter. The fall pulse took place on October 21, 1947 when a total of 890 cells were found per liter. This high level continued through the last part of December and fell rapidly during January to the minimum winter level. A few cells of Synedra were counted throughout the winter and the first recorded increase occurred on April 5, 1948 when a count of 158 cells per liter was obtained. The first spring pulse for 1948 was found on May 3 when 629 cells of Synedra per liter of water were counted in Cash Lake.

Although present, the blue-green algae were never found in considerable numbers in Cash Lake. A maximum of 47 units of 4 cells of Anabaena flos-aquae Brebisson was found to occur on June 17, 1947. This level fell rapidly to a minimum on August 27, when cells were not observed. Another peak was observed during a part of January with a count of 39 organisms per liter of water from Cash Lake on January 17, 1948. Although scarce throughout the rest of the winter, a few Anabaena were found in every winter sample with the exception of February during which month none were observed. Oedogonium showed a pulse on June 11, 1947, when 27 cells were counted, but was very rare throughout the rest of the year on Cash Lake. The only period when Spirulina major Jutzing was present in appreciable numbers was on August 27, 1947 when a count of 12 cells per liter of water was found in Cash Lake. During the rest of the year this organism was rare being entirely absent from the samples from Cash Lake from February through March 1948.

Microcystis was rare at all times in Cash Lake but two pulses were observed, one in June and the other in November. During the rest of the year, Microcystis was often completely absent, especially during the winter months, and to a lesser degree through the mid-summer.

Although green algae were present in Cash Lake with the exception of the genera cited, they were never present in relatively great abundance. Spirogyra was the most common of the green algae noted. On June 11, 1947, 249 units of 4 cells were counted, with an increase to 416 units of Spirogyra on June 17, 1947. Apparently this constituted the early summer peak, because a noticeable drop was observed shortly after to a minimum number of 7 units counted on August 7, 1947.

The fall peak occurred on December 11, 1947, when a count of 373 units of Spirogyra was observed in Cash Lake. During the winter, Spirogyra remained at a very low rate of production with a minimum of 6 units obtained on February 23, 1948. During the latter part of March, this phytoplankter again started to increase so that 460 units per liter of water was noted on May 3, 1948.

Ankistrodesmus seemed to have an abundance in Cash Lake comparable to that of Spirogyra. Although present in relative abundance throughout the early summer, a slight peak was noted on July 1, 1947, when 1,019 cells were counted. During August, especially late August, Ankistrodesmus fell rapidly to reach a low of 102 on August 27. The fall maximum occurred on November 20, when the count went to a high of 1,750 cells per liter of water. The downward curve for this green algae was considerably slower than the trend for Spirogyra, the minimum being reached March 17, 1948, when only 7 cells per liter of water were present. Just as was the case with Spirogyra and most of the other green algae present in this body of water, Ankistrodesmus started to increase into the spring of 1948, resulting in a count of 2,249 cells per liter of water on May 3, 1948.

Staurastrum was one of the more abundant of the desmids occurring in Cash Lake. An early summer peak was recorded on June 17, 1947, when the count reached 6,424 cells per litter. Staurastrum seemed to vary somewhat from the general pattern in that it was present in some abundance throughout the summer. However, a minimum of 417 cells per liter was observed on August 20, 1947. A winter maximum was recorded during the month of December and appeared to extend through the entire month. However, the greatest number observed was on December 11, 1947, when 5,400 cells per liter were noted. Although Staurastrum was present throughout the winter, a minimum was recorded on March 31, 1948, with a value of 160 cells per liter. Shortly after this minimum count, the Staurastrum cycle started upward again and on the last count of this investigation, taken on May 3, 1948, an average value of 933 organisms per liter of water was found in Cash Lake.

As previously mentioned, all of the Protozoa were observed in Cash Lake, with the exception of Stentor. Of the Phytomastigophora, Peridinium and Glenodinium were the most commonly observed genera. On July 16, 1947, a total of 623 Glenodinium pulvisculus cells was counted in Cash Lake. This apparently constituted a summer peak since Glenodinium fell to a minimum of 9 cells per liter of water on August 13, 1947, and remained low until the fall. A higher, more prolonged rise took place during the autumn, beginning on October 21, with a total of 937 cells and reaching the highest level on November 20, 1947, when the count was 2,049 cells per liter of water. During December, the Glenodinium population decreased very rapidly, becoming almost non-existent during the remainder of the winter. The first appreciable number of this Phytomastigophoran was observed on April 5, 1948, with a count of 135 cells per liter of water. Oddly, the level again fell during the May 5, 1948, since only 62 cells of Glenodenium were present per liter of water.

Peridinium reached a peak of 521 cells per liter of water in Cash Lake on June 11, 1947, and then decreased very rapidly, remaining at a minimum of less than 25 cells on an average throughout the remainder of the summer, fall and winter of 1947-48. This particular Phytomastogophoran was tentatively identified as Peridinium. However, it is possible that this organism may be another species of Glenodinium. For the sake of clarity, it shall be referred to as Peridinium in this paper. On May 5, 1948, the Peridinium population was once more increasing since a total of 167 cells per liter of Cash Lake water was observed.

Euglena was noted throughout the investigation and seemed to follow the general Protozoa pattern. Pulses of Euglena were seen during the month of June as well as during the early part of October, 1947. Another increase was observed during the last part of February and into early March, 1947, yielding a peak count of 201 cells per liter of water on April 5, 1948, in Cash Lake.

Arcella and Difflugia of the class Rhizopoda were present in Cash Lake, especially in the early spring, late fall and through the winter. They were never too abundant, however. Arcella vulgaris Ehrenberg was the more common of the two, reaching a peak of 423 cells per liter in Cash Lake on June 17, 1947, and continuing on a high level through July 16. The pulse had greatly diminished by July 30, and this organism remained at a minimum throughout August and September. Another pulse was noted on October 21, 1947, at which time 787 cells were counted per liter of water. The pulse continued on progressively lower levels through December and early January. During the rest of the winter and early spring, Arcella was only occasionally observed.

Difflugia constricta Ehrenberg was always present in small numbers. A minor peak was recorded on June 11, 1947, in Cash Lake when 88 individuals were counted. This peak was short lived and the numbers were much lower through the rest of summer and early fall. A rise to 217 cells per liter was recorded on October 21, 1947, and a maximum pulse was observed on December 17, when 467 individuals were counted in a liter of water from Cash Lake. Difflugia was present in small numbers throughout the winter and early spring, and a peak was again recorded on May 5, 1948, at which time 106 cells per liter from Cash Lake were observed.

Vorticella campanula Ehrenberg was first observed in relatively large numbers on July 16, 1947, and continued to increase in population until a peak count of 73 cells per liter of water from Cash Lake was observed on August 20, 1947. Up to July, Vorticella had been present in numbers never higher than 27 per liter of water. From August through the month of October, these organisms were observed in relative abundance. The pulse dropped during December and Vorticella was only occasionally observed during the rest of winter and through March. An increase in population was noted in April and a spring peak occurred in May, yielding 50 cells per liter of water from Cash Lake on May 5, 1948.

Lake Redington exhibited phytoplankton characteristics which were generally similar to that of Cash Lake. It is possible that aside from reproduction within Cash Lake, the latter obtained a portion of its phytoplankton population, especially quantitatively, from Lake Redington. All of the diatoms recorded in Cash Lake were also found to be present in Lake Redington, with similar pulses and peaks, particularly in Lake Redington. The general level of the diatom population seemed to be lower in Lake Redington than in Cash Lake, although a few exceptions occurred on individual counts, especially during the summer.

Fewer genera of Cyanophyceae were present in Lake Redington than in Cash Lake and all of them in the former impoundment occurred in smaller numbers. None of the blue-green algae that had been absent from the waters of Cash Lake were found in Lake Redington. Thus, of the Cyanophyceae, only Chroococcus and a few Spirulina were observed. Only one sample showed a trace of Oscillatoria and that was a tentative identification since the speciman was in very poor condition. Not as many of the Clorophyceae were present in Lake Redington as in Cash Lake. Not only were Mougeotia, Coelastrum and Arthrodesmus absent from Lake Redington and Cash Lake but Kirchneriella, Tribonema and Closterium were not observed in the former pond. On the other hand, Arthrodesmus was not observed in Cash Lake but a few cells were seen in the waters of Redington in November.

All of the Phytomastigophora were observed on Lake Redington, but in generally fewer numbers. The exceptions were Glenodinium and Peridinium. Vorticella was only occasionally seen in this pond while Stentor was absent.

Blue Gill Pond presented a rather different picture from the other two impoundments. Relatively few of the diatoms were present. Of the complete list the following genera were represented in Blue Gill: Melosira, Navicula, Synedra, Asterionella, Fragillaria, and Tabellaria. Melosira, Navicula and Synedra were found to be more abundant than in Crash Lake but Asterionella, Fragillaria and Tabellaria were less common.

A maximum of 89,769 Melosira cells per liter of water was observed on July 8, 1947, in Blue Gill Pond. For Navicula, the maximum was shown to occur on November 19, 1947, when a count of 3,123 cells per liter of water was obtained. The maximum Synedra pulse was seen to occur on August 7, 1947, when the population reached a level of 1,327 cells per liter.

On the other hand, a peak of 74 individual Asterionella cells took place on June 17, 1947, in Blue Gill Pond, while the minimum occurred shortly after this on July 1, 1947, as indicated by a total of 9 cells per liter of Blue Gill water. The figures for Fragillaria showed a peak on July 16, with a count of 143 cells per liter of water and a minimum on August 27, when 27 cells were counted in a liter of water. The maximum and minimum Tabellaria populations also occurred in July and August with 46 cells and 2 cells per liter of water respectively.

All of the genera of Cyanophyceae previously enumerated were found in Blue Gill Pond. All of them were also found in greater abundance here than in any of the other waters studied. Chroococcus and Gloeocapsa, as well as Spirulina were especially abundant.

The Chlorophyceae were also completely represented in Blue Gill Pond. Spirogyra, Ankistrodesmus, Scenedesmus and Mougeotia, as well as Staurastrum, were the most common of the green algae found in Blue Gill Pond. However, all of the genera were more numerous in this impoundment than in any of the other bodies of water observed.

Such was not the case regarding the Protozoa. Trachelmonas, Uroglena, Dinobryon and Phacus were abundant while the rest of the Mastigophora, though present, did not attain the abundance observed in Cash Lake. Both Difflugia and Arcella were present in reduced numbers in Blue Gill pond. All of the Ciliata were represented in this pond. No special effort is being made to describe the times of maxima and minima as they generally corresponded relatively closely to similar peaks in Cash Lakes. Stentor was observed to have a maximum population on July 8, 1947, at which time 37 cells per liter of water was observed. The minimum number of 4 cells per liter of water was counted on December 19, 1947.

Snowden Pond contained representative genera of all of the classes of organisms previously enumerated but only a few of the forms present in the other impoundments were observed. In the Bacillariaceae, only the following genera were found to be present: Melosira, Stephanodiscus, Navicula, Nitzschia and Synedra. Spirulina and Anabaena were the only two representatives of the blue-green algae found in Snowden waters and Ankistrodesmus, Scenedesmus, Crucigenia, Staurastrum and Ulothrix were the only Chlorophyceae genera observed to be present. On the other hand, all of the Phytomastigophora except Dinobryon and Uroglena were found in this pond. Only an occasional Difflugia population was encountered from among the Rhizopoda genera. On the whole, the individual cycles for these organisms were similar to those encountered in the other ponds, however, the populations were less abundant than in any of the other waters studied. For example, Staurastrum shows a maximum of 2,733 cells per liter on July 1, 1947, in Snowden Pond, while Blue Gill Pond was observed to contain a population of 12,309 Staurastrum on June 11, 1947.

Trachelomonas hispida Stein showed a peak in Snowden Pond on November 20, 1947, with a count of 29 cells per liter of water. In Blue Gill Pond the peak occurred on December 12, with an observed population of 1,894 cells per liter. 947 Difflugia cells were counted in Lake Redington on December 11, 1947, while the peak in Snowden Pond occurred on November 20, 1947, with a count of 31 cells per liter of water.

On the whole the following general observations could therefore be made: Cash Lake seemed to contain the greatest variety of phytoplankton especially true for the diatoms. Redington did not show quite as much variety as Cash with respect to diatoms and much less variety in other categories of phytoplankton. Blue Gill demonstrated the most complete blue-green and green algae populations and also showed some variety with respect to the Protozoans. This pond demonstrated the least versatility of diatoms. Snowden Pond showed a rather complete Phytomastigophoran population but had few of the other Protozoans in its waters. Many of the diatoms present in the other waters were not found in Snowden Pond. It was the poorest of the four ponds with respect to numbers of genera of green and blue-green algae present.

The number of different phytoplankters present in the water did not necessarily indicate the abundance of these organisms in the water. On the whole, Cash Lake seemed to have the greatest populations of any of the ponds with respect to the number of individual diatoms found in the ponds. However, Blue Gill, although it did not contain as many different phytoplankters as Cash Lake, showed the greatest abundance as well as variety of green and blue-green algae. Cash Lake also seemed to show the greatest maxima for Protozoa, especially in the case of the Phytomastigophora. Blue Gill also appeared to have large populations of a few of the Protozoa even the variety was limited. Lake Redington seemed to contain the largest populations of Rhizopoda. On the other hand, Snowden Pond, although showing a large number of different Protozoa, especially of the Phytomastigophora, had the lowest number of these organisms of any of the impoundments studied.

Another general observation that was made on all of the ponds was the differences in populations of phytoplankton in different stations on the same body of water. It was found that stations 5, 3 and 2, on Cash Lake contained the largest populations of phytoplankton in the most general sense. This was found to be particularly true for green and blue-green algae at stations 5 and 2. All of the stations on Cash Lake seemed to contain generally similar amounts of diatoms, although stations 3, 4 and 6 seemed to be the most consistent in this respect. Station 2, as well as stations 1 and 5 seemed to hold the most consistently abundant Protozoan populations. Station 5 seemed to show this characteristic best for the Phytomastigophora and the Ciliates.

In Lake Redington, the stations 1 and 2 were very much alike in respect to variations in phytoplankton populations. Station 3 sometimes showed a greater number of Protozoans, but the variation was not significantly large. This was also true for the diatom populations. Relatively, smaller populations of blue-green and green algae were noticed at times in station 2 but again, the differences from stations 1 and 3 were not significantly large. In Blue Gill Pond, stations 1 and 2 were alike in every respect except for Protozoan populations that appeared to fluctuate from one station to the other at different intervals during the investigation.

On Snowden Pond, large variation occurred between stations 1 and 3. Station 1 appeared to contain the larger amounts of most of the phytoplankton. Little difference was noted between stations 2 and 3. Station 4 also was observed to contain populations which were more closely related to station 1. However, the difference between station 1 and station 3 was not as consistently variable as that from station 1 and 3. Wherever possible, the populations of the different stations were averaged together in order to give a general figure of productivity. This was especially necessary in Snowden Pond, as well as in Cash Lake, where occasional marked differences in phytoplankton populations were noted. In all cases, when a maximum for a particular plankter was recorded at one station, a similar, although not necessarily parallel, fluctuation was noted in the other stations of a particular lake.

DISCUSSION

One of the most important problems which arose in conjunction with these limnological studies, was the question of why the 4 impoundments were acid in character. Birge and Juday (1911), and Shelford (1923), studied acid waters. They found that generally, an increase in acidity was closely correlated with a decrease in the dissolved oxygen content of the water. It was concluded that the acidity was due to a high rate of organic acid synthesis from products of decomposition. Since oxygen was a necessary part of the synthesis, it decreased as the rate of acid production increased. On the other hand, Jewell and Brown (1924), from their studies of acidity in Big Muddy River of Illinois, concluded that it was a result of the mineral acids dissolved in the water. They further noticed that there was a large amount of plant material in the streams which would suggest an abundant amount of oxygen present in the water. During their investigations on Vincent Lake, Jewell and Brown (1924), again concluded that the acidity was organic in character, arising in this case from the bog-like margins of the lake. The oxygen supply was not depleted in the lake itself, providing further evidence that the oxygen cycle does not necessarily have to be depleted during periods of high acidity.

Thus, acidity may be due to the presence of organic acids which in turn may have been synthesized in the same waters from products of decomposition present in the surface layers or on the bottom. It also follows that the organic acids may originate around the margins of the body of water. (Welch, 1930). Aquatic plants and animals may produce slight conditions of acidity as noted by Jewell and Brown (1924). However, it is doubtful if this last source plays an important part in increasing the acidity of a body of water studied, since the aquatic vegetation is not abundant. Acid environments may also be produced by the presence of mineral acids in the waters. Mineral acids may enter the water from mine shafts, excavations, or acid water wells via streams feeding the body of water. (Lackey, 1938).

None of the above conditions seemed to explain satisfactorily the acid characteristics of the 4 impoundments studied on the Patuxent Research Refuge. It is true that the above area contains an underlying stratum of Cretacious material which seems to be acid in character. However, the source is not adequate enough to explain the generally characteristic fluctuations in acidity that were observed in these ponds. Acidity produced as a result of runoff also would not show as much of a seasonal variability as occurred in Cash, Redington, Snowdon and Blue Gill ponds. (Lindeman, 1941). Undoubtedly all three of the above sources contributed in some degree to the acid content of these bodies of water.

An examination of the other physical and chemical factors of these waters seems to afford another possible explanation of their acid characteristics. All 4 of the ponds are relatively shallow impoundments that appear to exhibit no thermal or chemical stratification, being similar in that respect to the bodies of water investigated by Chandler (1940). It was also observed that the conductivity was relatively low in all 4 of these ponds as was the alkalinity. On the other hand, the free carbon dioxide and acidity as well as the dissolved oxygen was relatively high. Finally, all 4 ponds were found to have a very low calcium and magnesium content, indicating the waters to be soft. (Tressler and Bere, 1934).

An examination of the seasonal variations of the above factors showed, with the exception of a short spring and fall period of fluctuation, free carbon dioxide and acidity reached their peeks during the winter and were at their minimum during the summer. This was also true for oxygen. Conductivity was at a relative maximum during the summer and at a minimum during the winter but showed short peaks during the spring and fall. Correlation of these factors seemed to offer a plausible explanation for the characteristic acid conditions of the ponds. (See Figures 17 and 18).

An excess of free carbon dioxide was found to be present in the waters. During the hot summer months the amount of carbon dioxide present was naturally at a minimum (Juday and Birge, 1935), while the reverse was true during the winter months.

When free or excess carbon dioxide combined with water it formed carbonic acid. (Welch, 1935). If there are appreciable amounts of calcium or magnesium carbonates (mono-carbonates) present in the water, the carbonic acid combines with the unsoluble mono-carbonates to yield soluble bicarbonates. In the ponds studied we find a minimum amount of carbonates as indicated by the low alkalinity as well as quantitative tests which were run at one period. Thus the carbon dioxide content continues to accumulate within temperature limiations until there is a rather high concentration of carbonic acid. Thus there is a direct correlation between carbon dioxide and acidity. As the acidity increases the alkalinity seems to decrease to some extent, possibly indicating that the small amounts of carbonates that are present have been charged to the soluble bicarbonates. This possible explanation seems to fit the chemical and physical data as well as the season variations in acidity observed in the ponds. From the observations it can be stated that all four ponds followed the same trend, discounting individual variations.

Another problem concerned the extent of the relationship between pH and the total acidity. It was noted that as acidity rose, the pH fell and conversely, when the pH rose the acidity fell. Again, a correlation of the available data seemed to offer a satisfactory explanation.

Cheatum, Longnecker and Metler (1942) showed that although the acidity content of a body of water might be relatively high, the pH did not necessarily have to be low. These authors showed that the organic materials derived from decaying basic peaty vegetation held the pH to a rather high level. It should be noted that when monocarbonates are present in natural waters, they may act as buffers because the carbonic acid combines with the monocarbonates to form soluble bicarbonates. When some of the carbon dioxide is withdrawn during photosynthesis, (Wiebe, 1930) the insoluble carbonate and carbonic acid are again formed. Later, if more carbon dioxide is added it combines once again to form soluble bicarbonates. This reaction is known as the buffer effect and prevents extreme variations in the hydrogen ion concentration. (Welch, 1935).

In all of the ponds on the Patuxent Research Refuge soft water conditions prevailed. This of course, implies a minimum amount of available monocarbonates. In the absence of these substances with their buffer actions, complete ionization can be brought about with a resulting lowering of the pH value. During the winter when the water was able to retain a greater amount of free carbon dioxide, more carbonic acid formation results in a closely correlated lowering of the pH value. In the summer the carbonic acid content of the water fell with a consequent increase of the pH level. (Juday and Birge, 1935).

Still another problem concerned the possible roles of pH and acidity in connection with other general physical and chemical characteristics of the four impoundments.

Do acidity and pH directly influence the other physical and chemical conditions or are they merely indicative of other conditions? Juday and Birge (1935), indicate that pH activity is to be regarded as an index of other underlying conditions which have a more direct relationship with lake biota. Juday, Birge, Kammer and Robinson, (1928) claimed that there was no correlation between the amount of phosphorous and the carbon dioxide in the water.

It was observed that all of the ponds (Cash, Redington, Blue Gill and Snowden), were of the soft water type. The conductivity was relatively low at all times, particularly during winter. Alkalinity was also observed to be low during the period of investigation. Transparency was observed to increase through the fall and into winter with the exception of a short period during fall when a drop was noted.

Tressler and Bere (1934), found that soft water was not as productive as hard water lakes. They also found that generally, dammed streams were productively poor. Juday (1942) also found the productivity of soft waters low. He found that the dissolved organic matter are much lower in soft waters than in hard waters. Welch (1936) notes that the rate of conductivity is closely related to the amount of dissolved organic materials contained in the water. The greater the amount of dissolved organic substances, the greater the amount of electrolytes in the water, with a consequent increase in the conductivity level. There is also a close association between the amount of dissolved organic material and the amount of carbonates in the water. When there is an increase in dissolved organic material there also seems to be an increase in the level of the carbonates. An increase in turbidity is usually associated with an increase in the amount of dissolved organic substance present in the water. Thus, the conductivity, and to a smaller extent, turbidity, may be a general indication of the level of dissolved organic substances. Lack of carbonates may also be an indication in the impoundments that were studied.

Thus, if we correlate all of these factors, some indication of the importance and relationships of acidity to other chemical and physical factors may be noted. The four soft water ponds contained very small amounts of dissolved organic material. This was shown by the low conductivity rate and the lack of carbonates. Increases were noticed in the turbidity level during the summer. This observation, plus the observed lack of turbidity during the winter was another indication that the dissolved organic materials were low. This was associated with a minimum buffer effect as well as a lack of the monocarbonates with which to utilize the amounts of carbonic acids which were being found. Hence, there was increase in acidity as well as a decrease in pH level when the dissolved organic materials on the water decreased.

Precipitation, water movement and temperature can also be correlated with acidity and pH. Although no precipitation tables are provided, it was observed that the heaviest and most prolonged periods of rainfall took place in the spring and in the fall of 1947. During these periods it was also seen that the acidity dropped for short periods and the pH level was raised at the same time. Apparently the pond water containing the acidity is diluted by the rain falling directly on the impoundments as well as by the resulting increased flow of water into ponds via the streams. Increased runoff as well as the sources just cited would serve to bring in a greater amount of dissolved organic matter thus increasing the amount of buffer materials in the waters and decreasing the acidity as well as raising the pH in another fashion. Increased currents during this period also serve to keep the acidity at a low level. Water agitation, especially during moderate and warm days seems to drive off a portion of the excess carbon dioxide in the water and prevents large accumulations of carbonic acid.

The lowered transparency during these periods showed that waters were more turbid, another indication of increased organic material entering the water of the four ponds. However, an excess turbidity in a sense, defeats its purpose. Sediment can gradually cause part of the covering being buried under the silt brought in by the streams. (Irwin, 1945). Roelofs (1944), points out that land runoff can substantially influence the chemical characteristics of a body of water. During the periods of increased water flow, the acidity dropped as has been mentioned. This might be another indication that organic acids were not entering the water in large enough quantities to cause appreciable difference in the acidity. It may also be possible that part of any acid material entering the pond through runoff were being buffered by chemical substances contained in the same runoff. It is therefore felt that this further indicates that only a small part of the acidity was due to materials derived from the land soils. It is possible that this source contributed more to a future acid condition through sedimentation and consequent loss of available buffer and other necessary constituents of the water. The abundancy of oxygen which would not always be present when acidity was due to organic acids as a result of decomposition products of the soil being placed in the water, did not contribute to the total acidity of the ponds to any substantial degree.

Probably the most important problem which arose during the investigation was the relationship between acidity and pH to phytoplankton distribution and productivity.

Was the phytoplankton influenced directly or indirectly by the acid environment, or was acidity and the pH levels merely and indication of other factors which influence the biological metabolism of the ponds?

Lackey (1938), believes that an abundant but narrow group of organisms may be supported in highly acid waters. Suspended forms in acid waters from mine runs and acid wells were rare (Lackey, 1939). Welch, (1936) found a diversity of phytoplankton in the acid waters which he studied. However, quantitatively, they were low. Scheffer and Robinson (1939), found poor populations of phytoplankton in their studies of slightly acid waters. Rawson (1939) points out that organisms can withstand a wide range of pH. Welch (1938), found more phytoplankton in the waters than zooplankton and claimed that the level of productivity was low. Jewell and Brown (1924) noted the absence of fresh water mussels from the acid waters which they studied.

The distribution of phytoplankton in the four impoundments was not as great as has been found in neutral alkaline waters. Chandler (1940), found 86 algal forms, including 40 Chlorophyceae. It is possible that there is a direct relationship between the low biological productivity of acid waters and the low organic content of soft waters. Phosphorus was present but never abundant. Nitrites and nitrates from occasional analysis proved to be very low. Calcium and magnesium were very low. Silica at times was present in large quantities as was iron.

On the whole, the periods of maxima for the above chemical materials seemed to occur during spring or early summer and also in autumn. This was also true for oxygen, conductivity, alkalinity and turbidity. On the whole, the largest number of maximum peaks in the greatest number of phytoplankton genera also occurred during similar periods. It seems logical to assume that barring adverse physical conditions and other special considerations, phytoplankton in the ponds studied, reached a maximum population at the same time or shortly before or after periods of abundance of nutrient materials. Meloche, et al, (1938), noted that at one time diatoms increased at the same time that silica decreased. At another time diatom increases occurred while the silica was still abundant. Domogalla and Fred (1926), said that an increase in phytoplankton caused a decrease in phosphorus.

Although periods were observed when there seemed to be an increase of phytoplankton taking place coincident with a decreased but still abundant silica and phosphates, there were also periods of phytoplankton when the nutrient materials had not yet reached their maxima but were abundant, nevertheless. During the hot summer months, as well as during the midwinter period, both phytoplankton and nutrient materials such as silica and phosphates were at a minimum. This was also true for iron.

There is a possibility that the turbidity may have interfered with the maximum peaks of phytoplankton in some instances. Chandler (1942), expounds the theory that a high turbidity content just before or during a phytoplankton pulse might interfere with the maximum production of the pulse. Rice (1917), claims that a limited phytoplankton population may reach a medium state of abundancy in spite of a very small amount of nitrates and nitrite. Riley (1940), also seems to feel that some degree of productivity will occur even though nitrates are almost absent and the phosphates reduced.

Hutchinson (1941) suggests that ferric and ferrous iron in suspended state may be a source of iron for the phytoplankton. Pearsall and C. H. Mortimer (1939), claim that an excess of iron may take the

the necessary oxygen out of the water. Apparently this did not occur in any of the ponds observed. Einsele (1936), takes the view that iron may precipitate the phosphates and cause them to be lost to the organisms. This may take place in acid waters, however, there is no evidence to state definitely that it took place in the four ponds of the Patuxent Research Refuge. It is therefore possible that the index of phytoplankton productivity in Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond may be acidity and pH.

A recapitulation of the probable events that take place in these ponds may serve to clarify the relationship between the plankton and acidity. There is a basis for stating that phytoplankton abundance depends upon the abundance of nutrient materials in the water especially dissolved organic materials. It has been shown that the dissolved organic material may contain not only nutrient materials but also chemical substances which serve to buffer the water and prevent a change of pH. It has also been explained that the substances which serve as buffers also combine with carbon dioxide to prevent an accumulation of carbonic acid. The presence of organic material may be demonstrated by measurement of the electrolytes in the water as well as by examination of the turbidity of the water.

If the dissolved organic material is lacking it is assumed that the abundance of phytoplankton will be limited. At the same time the absence of buffers and substances combining with carbon dioxide will allow the latter to accumulate and combine with the water to form carbonic acid. Other mineral and organic acids may also be present. Since there may not be any buffers present in the absence of dissolved nutrients the acids will ionize and the hydrogen ion concentration will change, giving us acidity of a high intensity or low pH. Alkalinity will also decrease. Lowered temperatures may result in increased acidity and lower pH by allowing a greater amount of carbon dioxide to accumulate and thereby combine with the water to form carbonic acid. Thus, we can say that acidity, together with a closely fluctuating pH may serve as an index of the amount of dissolved organic nutrient material in the water which in turn infers that the acidity together with the pH may serve as indicators of the phytoplankton abundance.

Jewell and Brown (1924) noted that molluscs were absent from some acid waters because of the harmful effect the acidity may have upon the shells. They further pointed out that the sunfish Lepomis gibbosus can tolerate a wide range of pH. It has already been pointed out by numerous investigators that some abundance of phytoplankton may occur but that number of different organisms are relatively limited. This was noticed in the four bodies of water on the Patuxent Research Refuge. However, it is questionable if the acidity and pH alone act as a limiting factor for a number of different kinds of organisms simply because these organisms cannot withstand a wide range of pH. It is more likely that the waters cannot support a limited amount of phytoplankton due to the low content of nutrients. This, along with acidity and pH and other factors such as high turbidity and low temperature, may serve as a continued limiting factor for some of the less hardy organisms.

It seems therefore, quite likely that acidity of a relative high intensity (low pH) may serve primarily as an index of other chemical conditions of the water as well as an index of the abundance of phytoplankton. The acidity may serve secondarily as a limiting factor, probably together with several other chemical and physical factors of the waters studied.

Through careful examination of the tables and graphs, it can be seen that on the whole, the abundance and distribution of the phytoplankton in the ponds depended upon a consistent supply, principally, of nutrients and other favorable physical and chemical conditions rather than upon the acidity by itself.

SUMMARY AND CONCLUSIONS

A limnological investigation with especial regard to the distribution and abundance of phytoplankton in acid waters, was carried out on four artificial impoundments. The four impoundments had been constructed over a period of ten years by excavating brook beds and putting up dams. These ponds ranged in size from 53.3 acres in area to 2.1 acres and all gave characteristic soft water acid reaction when tested.

The studies were carried out over a period of eleven months, beginning June 1947 and includes examination of the physical, chemical and biological characteristics of the water

Physical examination included studies of the air and water temperatures, transparency, depth, turbidity and conductivity. Chemical examination included studies of the acidity, hydrogen ion concentration, alkalinity, carbon dioxide, oxygen, iron, phosphorus, silica and periodic tests of the calcium, magnesium, nitrite and nitrates of the waters.

The phytoplankton was collected and examined by the Sedgewick rafter method. Calculations were according to Littleford Newcomb and Shepherd modification.

Simultaneous investigations were also carried out on the zooplankton, insect, fish and plant populations of the area. It was observed that the physical, chemical, and biological factors undergo seasonal as well as other fluctuations such as fluctuations due to water movement. Approximately 50 different genera of phytoplankton in varying degrees of seasonal abundance were observed.

A total of 3,822 separate samples were obtained during this investigation. The data obtained were correlated and are the basis for the following conclusions:

1. It was concluded that the four ponds studied were of the soft water type and showed distinct acid characteristics.

2. The amount of nutrients present in the water was low in comparison with medium or hard waters.

3. There was a limited distribution of phytoplankton present in these waters. Although the phytoplankton showed characteristic peaks, the abundance was not as high as in neutral or alkaline waters.

4. The acidity and pH of these ponds seemed to serve as indicators of the other chemical and physical conditions occurring in the waters.

5. The intensity of the acid in the water was probably due to a lack of buffer and nutrients present in the waters studied as well as an excess of carbon dioxide in the water. There is evidence that other acids, probably organic, as well as chemical in nature, contributed to the total acidity of the impoundments.

6. It was concluded that the acidity and pH served primarily as an index of the phytoplankton abundance. The intensity of the acidity (pH) along with other agents in the water may act as a limiting factor of phytoplankton. There is no conclusive evidence to substantiate this theory, however.

TABLE 1.

SNOWDEN POND
WATER TEMPERATURE IN DEGREES CENTIGRADE

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	26.0	25.0	25.0	25.5
7/16	31.0	31.0	31.0	-
7/23	28.0	27.0	26.0	27.0
7/30	28.0	28.0	28.0	28.0
8/7	29.50	29.50	29.50	29.10
8/15	31.0	30.0	30.0	30.0
8/20	31.50	31.50	31.50	31.50
8/27	28.50	28.50	28.50	28.0
9/9	26.0	26.0	26.0	26.0
10/1	21.40	21.40	21.40	21.20
10/15	19.20	19.20	19.20	19.10
11/10	11.0	11.0	11.0	11.9
11/19	6.0	6.0	6.0	6.0
12/11	4.20	4.20	4.20	4.10
12/17	3.0	-	-	3.0
1/10	4.0	-	-	4.0
2/18	3.20	-	-	3.10
2/27	5.0	5.0	4.50	4.50
3/5	8.30	8.30	8.30	8.10
3/17	11.40	10.20	11.0	10.50

TABLE 2.

BLUE GILL POND
WATER TEMPERATURE IN DEGREES CENTIGRADE

Date	Blue Gill I	Blue Gill II
6/18	24.0	24.0
6/26	25.2	25.2
7/8	26.6	26.6
7/16	32.0	32.0
7/23	24.0	24.0
7/30	26.4	26.2
8/7	30.2	30.0
8/13	30.0	30.0
8/20	32.0	32.0
8/27	30.5	30.8
9/9	27.0	27.2
10/1	20.0	20.0
10/16	17.0	17.0
10/26	14.8	14.8
11/10	12.0	12.0
11/19	7.0	7.0
12/11	5.4	5.5
12/17	4.0	4.1
1/10	4.6	4.6
2/18	2.0	2.0
2/27	4.2	4.3
3/1	6.6	6.6
3/5	9.0	9.0
3/17	14.0	14.0

TABLE 3.

LAKE REDINGTON
WATER TEMPERATURE IN DEGREES CENTIGRADE

Date	Redington I	Redington II	Redington III
6/26	25.0	25.1	-
7/1	31.0	31.0	-
7/3	27.0	27.2	-
7/8	26.0	26.0	-
7/16	30.0	30.0	-
7/23	26.0	26.2	26.0
7/30	28.0	28.1	28.0
8/7	30.0	30.0	30.1
8/13	30.0	30.0	30.0
8/20	27.0	27.0	-
8/27	25.0	25.0	-
9/9	24.0	24.0	-
10/1	17.0	17.2	17.0
10/16	18.0	18.1	18.0
10/26	9.0	9.0	8.9
11/10	8.5	8.6	8.4
11/19	4.0	4.0	4.2
12/11	6.0	6.0	6.1
12/17	4.0	-	-
1/10	2.8	-	-
2/18	5.0	5.0	-
3/1	8.0	8.2	-
3/17	11.0	11.4	-

TABLE 4.

CASH LAKE
WATER TEMPERATURE IN DEGREES CENTIGRADE

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	35.0	35.5	-	-	-	-
6/17	25.0	24.0	-	-	-	-
6/24	26.0	26.0	26.0	26.0	26.2	26.0
6/26	25.0	25.0	25.0	24.8	25.0	25.0
7/1	30.0	30.0	30.0	30.0	30.2	30.0
7/3	27.0	27.0	27.0	26.8	28.0	27.0
7/11	30.2	30.0	30.4	30.4	29.8	30.0
7/16	29.0	28.0	28.0	28.2	28.6	28.0
7/23	26.5	27.0	27.2	27.2	27.2	27.0
7/30	27.0	27.0	27.0	27.0	27.2	27.0
8/7	29.0	29.0	29.0	29.0	28.8	29.0
8/13	30.0	30.0	30.0	30.0	30.0	30.0
8/20	28.8	28.6	29.0	29.0	29.0	28.6
8/27	27.2	27.0	27.0	27.2	27.2	27.0
9/9	23.5	23.6	23.0	23.0	23.8	23.6
10/1	16.0	16.0	16.0	16.4	16.6	16.0
10/20	12.5	12.4	12.6	12.4	12.6	12.4
11/10	9.0	9.0	9.2	9.2	9.4	9.0
11/20	6.5	6.6	6.8	6.8	6.8	6.6
12/11	3.2	3.2	3.2	3.2	3.2	3.2
12/17	4.5	-	-	-	-	-
1/10	3.0	-	-	-	-	-
2/18	-	-	-	-	-	-
2/23	3.8	3.6	4.2	4.2	3.6	3.8
3/5	6.0	6.0	6.0	6.0	5.8	6.0
3/17	12.4	12.0	12.4	12.4	12.4	12.2
3/31	15.0	15.0	15.0	15.0	15.4	15.0
4/3	14.2	14.3	14.2	14.2	14.4	14.4

TABLE 5.

CASH LAKE
INCHES OF TRANSPARENCY (SECCHI DISK)

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	12.0	12.0	-	-	-	-
6/17	12.0	12.0	-	-	-	-
6/24	10.0	10.0	8.0	8.0	11.0	10.0
6/26	8.0	7.0	7.0	7.0	10.0	7.0
7/1	7.0	7.0	6.0	6.0	7.0	7.0
7/3	9.0	11.0	10.0	10.0	10.0	11.0
7/11	10.0	14.0	13.0	13.0	10.0	14.0
7/16	15.0	16.0	15.0	14.0	15.0	15.0
7/23	17.5	18.0	17.	15.0	18.0	18.0
7/30	18.0	18.0	18.0	18.0	18.0	18.0
8/7	19.0	19.0	18.0	18.0	19.0	19.0
8/13	19.5	18.0	17.0	17.0	20.0	18.0
8/20	22.0	21.0	20.0	19.5	22.0	21.0
8/27	25.0	25.0	23.0	23.0	25.0	25.0
9/9	29.0	28.0	26.0	25.5	30.0	29.0
10/1	31.0	31.0	30.0	30.0	30.0	31.0
10/20	30.0	30.0	30.5	30.0	30.0	30.0
11/10	32.0	32.0	30.0	30.0	32.0	32.0
11/20	30.5	30.0	38.0	39.0	31.0	30.0
12/11	26.0	27.0	26.0	26.0	28.0	27.0
12/17	-	-	-	-	-	-
1/10	-	-	-	-	-	-
2/18	-	-	-	-	-	-
2/23	-	20.0	17.0	16.5	-	19.0
3/5	15.0	18.0	16.0	16.0	18.0	18.0
3/17	16.0	18.0	15.5	15.0	18.0	17.5
3/31	15.5	15.5	15.5	15.0	15.5	15.5
4/3	15.0	13.0	12.0	12.0	15.0	14.5

TABLE 6.

LAKE REDINGTON
INCHES OF TRANSPARENCY (SECCHI DISK)

Date	Redington I	Redington II	Redington III
6/26	7.0	9.0	No data
7/1	4.0	3.0	
7/3	4.0	4.0	
7/8	1.0	2.0	
7/16	4.5	5.0	
7/23	6.0	5.0	
7/30	7.0	6.0	
8/13	7.0	8.0	
8/20	8.0	7.0	
8/27	10.0	9.0	
9/9	14.0	14.0	
10/16	17.0	15.0	
10/26	17.0	17.0	
11/19	16.0	16.0	
12/17	-	-	
1/10	-	-	
2/18	-	-	
3/1	6.0	5.0	
3/17	4.0	2.0	

TABLE 8.

SNOWDEN POND
TRANSPARENCY IN INCHES (SECCHI DISK)

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	38.0	34.0	34.5	bottom
7/16	32.0	32.0	34.0	"
7/23	35.0	36.0	35.0	"
7/30	39.0	40.0	40.0	"
8/7	33.0	35.0	36.0	"
8/15	17.5	25.5	30.0	"
8/20	13.0	18.0	22.0	"
8/27	9.5	12.0	14.0	"
9/9	25.0	28.0	30.0	"
10/1	14.0	16.0	16.0	"
10/15	17.0	18.0	21.0	"
11/10	23.5	27.0	27.0	"
11/19	28.0	29.0	30.0	"
12/11	32.5	35.0	34.0	"
12/17	32.5	35.0	34.0	"
1/10	-	-	-	-
2/18	-	-	-	-
2/27	bottom	29.0	35.0	-
3/5	27.0	26.0	29.0	bottom
3/17	18.0	18.0	20.0	"

TABLE 9.

CASH LAKE
CONDUCTIVITY IN RECIPROCAL MEGOHMS

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	34	35	-	-	-	-
6/17	35	32	-	-	-	-
6/24	32	34	32	34	32	36
6/26	34	30	30	30	28	32
7/1	31	29	29	29	30	31
7/3	25	26	25	25	27	25
7/11	28	30	28	29	29	30
7/16	29	29	28	29	29	28
7/23	30	29	30	31	31	29
7/30	29	28	28	28	29	29
8/7	28	29	28	29	29	28
8/13	32	30	32	32	34	32
8/20	25	28	25	27	29	27
8/27	27	27	27	29	26	27
9/9	25	26	25	25	26	26
10/1	24	25	25	26	23	24
10/20	28	26	27	27	29	27
11/10	31	28	30	30	32	30
11/20	36	33	35	36	32	32
12/11	35	34	35	35	36	35
12/17	32	35	32	31	30	32
1/10	33	35	-	-	-	-
2/18	35	37	-	-	-	-
2/23	32	34	-	-	-	-
3/5	33	33	33	33	35	32
3/17	36	33	35	35	32	36

TABLE 10.

LAKE REDINGTON
CONDUCTIVITY IN RECIPROCAL MEGOHMS

Date	Redington I	Redington II	Redington III
6/26	30	30	-
7/1	32	34	-
7/3	30	32	-
7/8	29	30	-
7/16	30	30	-
7/23	30	32	38
7/30	33	35	40
8/7	35	38	40
8/13	35	40	-
8/20	38	40	-
8/27	40	44	-
9/9	38	42	44
10/1	40	40	42
10/16	39	42	46
10/26	35	36	40
11/10	34	34	36
11/19	32	30	32
12/11	35	35	36
12/17	40	-	-
1/10	36	-	-
2/18	35	38	-
3/1	33	35	-
3/17	30	32	-

TABLE 11.

BLUE GILL POND
CONDUCTIVITY IN RECIPROCAL MEGOHMS

Date	Blue Gill I	Blue Gill II
6/18	28	27
6/26	24	26
7/8	19	19
7/16	18	17
7/23	20	20
7/30	19	19
8/7	21	23
8/13	20	21
8/20	18	21
8/20	18	21
8/27	20	19
9/9	21	21
10/1	25	26
10/16	17	17
10/26	18	19
11/10	19	20
11/19	15	17
12/11	25	26
12/17	25	25
1/10	25	22
2/18	20	22
2/27	25	26
3/1	29	30
3/5	30	29
3/17	35	37

TABLE 12.

SNOWDEN POND
CONDUCTIVITY IN RECIPROCAL MEGOHMS

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	35	35	35	38
7/15	33	35	35	36
7/23	35	35	35	35
7/30	36	36	42	40
8/7	35	37	37	36
8/15	34	35	38	40
8/20	33	35	35	35
8/27	-	32	36	34
9/9	35	35	35	38
10/1	37	38	38	40
10/15	38	37	37	40
11/10	42	41	40	44
11/19	40	42	38	40
12/11	45	43	43	47
12/17	50	-	-	50
1/10	35	-	-	38
2/18	37	-	-	39
2/27	40	35	35	38
3/5	36	33	34	39
3/17	40	35	35	40

TABLE 13.

SNOWDEN POND
HYDROGEN ION CONCENTRATION

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	5.90	5.90	5.80	5.80
7/16	5.90	5.90	5.90	5.80
7/23	5.80	5.80	5.80	5.90
7/30	5.90	5.90	5.90	5.90
8/7	5.90	5.90	5.80	5.80
8/15	5.0	5.10	5.0	5.10
8/20	6.10	6.10	6.1	6.30
8/27	6.0	5.90	5.90	6.0
9/9	6.20	6.20	6.20	6.30
10/1	6.0	6.0	6.0	5.90
10/15	6.0	5.80	5.80	6.0
11/10	5.90	6.0	6.0	6.0
11/19	5.90	6.0	5.90	6.0
12/11	5.90	6.0	5.90	6.10
12/17	5.80	-	-	6.0
12/10	5.80	-	-	6.0
2/13	5.80	-	-	5.80
2/27	5.90	5.70	5.80	5.90
3/5	5.90	5.80	5.80	6.10
3/17	5.90	6.0	6.10	6.10

TABLE 14.

BLUE GILL POND
HYDROGEN ION CONCENTRATION

Date	Blue Gill I	Blue Gill II
6/18	6.0	6.1
6/26	6.1	6.1
7/8	6.2	6.2
7/16	6.4	6.4
7/23	6.6	6.6
7/30	6.4	6.3
8/7	6.3	6.3
8/13	6.2	6.2
8/20	6.2	6.3
8/27	6.1	6.1
9/9	6.0	6.0
10/1	6.1	6.1
10/16	5.9	6.0
10/26	5.9	5.9
11/10	6.0	6.0
11/19	6.0	6.0
12/11	6.3	6.3
12/17	6.0	6.1
1/10	5.8	5.8
2/18	5.2	5.2
2/27	5.5	5.4
3/1	5.7	5.7
3/8	5.9	5.9
3/17	5.9	5.9

TABLE 15.

LAKE REDINGTON
HYDROGEN ION CONCENTRATION

Date	Redington I	Redington II	Redington III
6/26	6.13	6.18	-
7/1	6.35	6.40	-
7/3	6.45	6.45	-
7/8	6.26	6.29	-
7/16	6.20	6.20	-
7/23	6.6	6.6	6.4
7/30	6.4	6.4	6.3
8/7	6.3	6.3	6.3
8/13	6.2	6.1	-
8/20	6.0	6.0	-
8/27	5.8	5.8	-
9/9	5.7	5.6	5.6
10/1	5.5	5.4	5.4
10/16	5.5	5.5	5.4
10/26	5.8	5.8	5.8
11/10	6.0	6.0	5.9
11/19	6.0	6.1	6.0
12/11	6.2	6.2	6.2
12/17	6.3	-	-
1/10	5.7	-	-
2/18	5.6	5.6	-
3/1	5.6	5.5	-
3/17	5.9	5.9	-

TABLE 16.

CASH LAKE
HYDROGEN ION CONCENTRATION

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	6.2	6.2	-	-	-	-
6/17	6.1	6.2	-	-	-	-
6/24	6.3	6.3	6.2	6.2	6.3	6.1
6/26	6.2	6.3	6.3	6.3	6.2	6.3
7/1	6.3	6.4	6.4	6.3	6.2	6.3
7/3	6.5	6.5	6.5	6.4	6.4	6.3
7/11	6.5	6.5	6.4	6.4	6.5	6.5
7/16	6.4	6.3	6.2	6.3	6.4	6.5
7/23	6.5	6.6	6.6	6.5	6.5	6.4
7/30	6.6	6.6	6.5	6.5	6.5	6.5
8/7	6.5	6.6	6.4	6.4	6.5	6.5
8/13	6.5	6.5	6.5	6.5	6.5	6.5
8/20	6.5	6.5	6.4	6.3	6.4	6.5
8/27	6.3	6.3	6.3	6.3	6.3	6.3
9/9	6.4	6.5	6.5	6.5	6.3	6.5
10/1	6.3	6.3	6.1	6.1	6.3	6.2
10/20	6.2	6.2	6.2	6.2	6.2	6.2
11/10	6.0	6.1	6.0	6.0	6.0	6.0
11/20	6.3	6.5	6.3	6.2	6.2	6.3
12/11	6.0	6.1	6.0	6.0	6.0	6.0
12/17	5.9	5.9	-	-	-	-
1/10	5.6	5.8	-	-	-	-
2/18	5.7	5.6	-	-	-	-
2/23	5.7	5.6	5.6	5.7	5.6	5.7
3/5	6.1	6.2	6.2	6.1	6.1	6.1
3/17	6.2	6.1	6.1	6.1	6.2	6.2

TABLE 17.

CASH LAKE
CARBON DIOXIDE IN PARTS PER MILLION

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	8.50	8.50	-	-	-	-
6/17	8.0	7.0	-	-	-	-
6/24	7.0	6.50	7.0	7.50	8.0	7.50
6/26	6.0	6.50	6.50	8.0	8.0	7.0
7/1	6.50	7.0	7.0	8.0	8.0	7.0
7/3	6.50	6.0	6.0	6.50	7.50	6.50
7/11	6.0	6.0	6.0	5.50	7.0	6.0
7/16	6.0	5.0	5.5	5.50	6.0	5.0
7/23	5.0	4.0	4.50	5.0	5.50	4.50
7/30	4.5	4.0	4.50	4.50	5.50	4.0
8/7	4.0	3.5	3.50	3.50	4.50	4.0
8/13	3.0	3.0	3.0	3.50	5.0	3.0
8/20	4.50	3.0	3.50	4.0	4.50	3.5
8/27	5.50	4.5	4.0	5.0	5.0	4.5
9/9	5.0	3.0	3.0	5.0	6.0	4.5
10/1	5.5	4.0	4.5	4.5	6.50	5.0
10/20	6.0	5.0	5.5	5.5	6.50	5.0
11/10	6.50	5.0	6.0	6.0	6.50	6.0
11/20	6.50	6.0	6.0	6.0	8.0	6.50
12/11	6.50	6.0	6.0	6.5	11.5	8.0
12/17	7.0	7.0	-	-	-	-
1/10	8.0	9.0	-	-	-	-
2/18	13.0	11.50	-	-	-	-
2/23	14.0	12.0	11.0	10.50	13.0	12.5
3/5	11.0	5.0	9.0	8.50	11.0	9.50
3/17	9.0	6.0	6.50	7.0	10.0	8.50
4/3	-	-	-	-	-	-

TABLE 18.

LAKE REDINGTON
CARBON DIOXIDE IN PARTS PER MILLION

Date	Redington I	Redington II	Redington III
6/26	8.5	8.5	-
7/1	8.0	8.5	-
7/3	6.0	5.5	-
7/8	5.0	5.0	-
7/16	6.0	5.5	-
7/23	6.0	6.0	5.5
7/30	5.0	5.0	5.0
8/7	3.5	3.0	3.0
8/13	3.0	3.0	-
8/20	5.0	4.5	-
8/27	7.0	7.0	7.0
9/9	5.0	5.0	4.5
10/1	6.0	6.0	5.5
10/16	6.0	6.5	6.0
10/26	6.5	6.5	6.0
11/10	7.0	7.0	7.0
11/19	6.0	6.5	7.5
12/11	6.5	6.5	7.0
12/17	7.0	-	-
1/10	8.0	-	-
2/18	8.5	8.5	-
3/1	8.0	8.5	-
3/17	5.0	5.5	-

TABLE 19.

BLUE GILL POND
CARBON DIOXIDE IN PARTS PER MILLION

Date	Blue Gill I	Blue Gill II
6/18	6.0	6.0
6/26	4.0	5.0
7/8	3.0	3.5
7/16	4.0	4.0
7/23	4.5	4.0
7/30	4.0	4.5
8/7	3.5	3.5
8/13	3.5	3.5
8/20	3.0	3.0
8/27	3.5	3.5
9/9	10.0	10.5
10/1	-	-
10/16	5.0	5.5
10/26	6.5	6.0
11/10	7.5	7.5
11/19	10.0	10.0
12/11	4.5	5.0
12/17	5.0	5.0
1/10	6.0	6.0
2/18	8.5	8.0
2/27	8.0	8.5
3/1	8.0	8.0
3/5	7.5	8.0
3/17	5.5	6.0

TABLE 20

SNOWDEN POND
CARBON DIOXIDE IN PARTS PER MILLION

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	8.50	8.0	8.0	9.0
7/16	5.0	7.0	5.50	6.0
7/23	4.50	4.50	4.50	3.0
7/30	5.0	5.0	4.50	5.0
8/7	5.50	5.50	5.50	5.50
8/15	6.0	6.0	5.30	5.0
8/20	6.50	6.50	7.0	7.0
8/27	6.50	6.50	6.50	7.0
9/9	5.50	5.0	6.50	5.0
10/1	7.0	7.0	7.0	7.50
10/15	8.50	8.50	8.50	8.0
11/10	9.0	9.0	9.0	9.5
11/19	10.0	10.0	10.0	9.50
12/11	10.50	11.0	11.0	11.0
12/17	11.0	-	-	12.50
1/10	11.50	-	-	11.50
2/18	12.20	-	-	11.0
2/27	13.4	13.0	12.5	11.0
3/6	10.60	10.50	10.50	10.80
3/17	5.0	5.0	5.0	5.0

TABLE 21.

SNOWDEN POND
ALKALINITY IN PARTS PER MILLION

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	-	-	-	-
7/16	10.50	10.0	11.0	10.0
7/23	9.50	10.0	10.0	10.0
7/30	8.0	7.50	10.5	8.50
8/7	9.5	10.0	10.0	10.50
8/15	10.0	10.0	10.0	10.50
8/20	9.50	9.50	9.0	10.50
8/27	10.50	10.0	10.0	10.0
9/9	11.0	11.0	11.0	11.5
10/1	11.0	10.5	10.5	11.5
10/15	10.5	12.5	10.5	10.5
11/10	12.0	12.0	12.0	12.5
11/19	10.0	10.0	9.50	10.0
12/11	14.0	13.0	13.5	13.5
12/17	10.0	-	-	11.0
1/10	6.0	-	-	6.0
2/18	5.50	-	-	5.50
2/27	20.0	20.0	20.0	20.5
3/5	5.0	4.50	4.50	5.0
3/17	4.50	6.50	7.0	5.0

TABLE 22.

BLUE GILL POND
ALKALINITY IN PARTS PER MILLION

Date	Blue Gill I	Blue Gill II
6/18	12.0	12.0
6/26	10.0	10.5
7/8	9.5	10.0
7/16	8.0	8.0
7/23	4.5	5.0
7/30	9.0	9.0
8/7	8.5	9.0
8/13	9.0	9.0
8/20	8.5	8.5
8/27	8.0	8.5
9/9	7.5	8.0
10/1	6.0	6.0
10/16	7.0	7.0
10/26	8.0	8.0
11/10	7.5	7.5
11/19	8.0	8.5
12/11	8.0	8.0
12/17	8.0	8.0
1/10	7.0	7.0
2/18	7.5	8.0
2/27	6.05	6.5
3/1	6.0	6.0
3/6	5.0	5.0
3/17	3.5	3.5

TABLE 25.

LAKE REDINGTON
ALKALINITY IN PARTS PER MILLION

Date	Redington I	Redington II	Redington III
6/26	7.0	-	-
7/1	6.0	6.0	-
7/3	10.0	10.5	-
7/8	8.0	8.0	-
7/16	15.0	13.5	-
7/23	8.5	8.5	8.5
7/30	8.0	8.5	8.0
8/7	7.5	7.0	7.0
8/13	7.0	7.0	-
8/20	6.0	6.0	-
8/27	6.0	7.0	7.5
9/9	8.5	10.0	9.5
10/1	9.5	9.5	9.0
10/16	10.5	10.5	10.0
10/26	11.5	12.0	11.5
11/10	10.5	10.0	10.0
11/19	8.5	9.0	8.5
12/11	8.0	8.0	8.0
12/17	9.0	-	-
1/10	6.5	-	-
2/18	6.0	6.0	-
3/1	4.0	4.0	-
3/17	4.0	4.5	-

TABLE 24.

CASH LAKE
ALKALINITY IN PARTS PER MILLION

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	11.5	12.0	-	-	-	-
6/17	10.0	10.0	-	-	-	-
6/24	9.0	9.5	9.0	9.5	9.5	9.0
6/26	10.0	10.0	10.5	10.5	10.0	9.5
7/1	10.5	10.0	10.0	10.0	10.0	10.0
7/3	10.0	10.0	10.5	10.5	11.0	10.5
7/11	10.5	10.0	10.5	10.5	10.0	10.0
7/16	11.0	10.5	11.0	11.0	10.5	10.5
7/23	9.5	10.0	9.5	9.5	10.5	9.5
7/30	11.0	10.0	9.5	10.0	9.5	10.0
8/7	10.5	10.5	10.5	10.5	11.0	10.5
8/13	10.0	10.0	10.0	10.0	10.0	10.0
8/20	11.0	10.0	11.5	11.5	11.0	11.0
8/27	9.0	10.5	9.0	9.0	9.5	9.5
9/9	11.5	11.0	11.0	11.5	10.5	11.0
10/1	12.5	14.0	13.0	13.0	12.0	13.0
10/20	15.0	14.5	14.5	14.5	15.0	14.0
11/10	14.0	15.0	16.0	15.0	15.5	14.0
11/20	15.0	15.0	15.5	15.5	14.5	15.0
12/11	16.0	19.0	17.6	17.5	17.0	17.5
12/17	18.0	17.0	17.5	17.0	16.0	15.5
1/10	5.0	6.5	-	-	-	-
2/18	8.0	7.5	-	-	-	-
2/23	7.5	7.5	-	-	-	-
3/5	12.4	13.0	12.5	13.0	13.0	12.0
3/17	7.5	5.0	7.0	7.0	7.0	7.0

TABLE 25.

CASH LAKE
TOTAL IRON IN PARTS PER MILLION

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	4.5	4.5	-	-	-	-
6/17	4.0	4.0	-	-	-	-
6/24	3.0	3.5	3.5	3.0	3.0	3.5
6/26	2.0	2.5	2.5	2.5	2.0	3.0
7/1	2.5	2.5	2.5	2.0	2.5	2.5
7/3	2.0	2.5	2.5	2.5	2.0	2.0
7/11	2.0	2.0	2.0	2.0	2.0	2.0
7/16	2.5	2.0	2.0	2.0	2.0	2.0
7/23	2.0	2.5	2.5	2.5	2.5	2.5
7/30	2.5	2.5	2.0	2.0	2.5	2.0
8/7	3.0	3.0	2.5	3.0	3.0	2.5
8/13	4.0	4.0	4.0	4.0	4.5	4.0
8/20	3.5	4.0	4.0	4.0	4.0	3.5
8/27	3.0	4.0	3.5	4.0	4.0	3.0
9/9	3.0	3.5	3.0	4.0	4.0	3.5
10/1	3.0	3.5	3.0	3.0	3.5	3.0
10/20	-	-	3.0	3.5	3.5	3.5
11/10	3.5	3.5	3.0	3.5	3.5	3.0
11/20	4.0	3.5	4.0	4.0	3.5	3.5
12/11	3.0	3.0	3.0	3.0	3.5	3.5
12/17	3.5	3.0	-	-	-	-
1/10	2.0	2.5	-	-	-	-
2/18	2.0	1.5	-	-	-	-
2/23	3.0	3.0	3.0	3.0	3.5	3.0
3/5	3.5	3.0	3.0	3.0	3.0	3.0
3/17	3.0	3.5	3.0	4.0	4.0	3.5

TABLE 26.

LAKE REDINGTON
TOTAL IRON IN PARTS PER MILLION

Date	Redington I	Redington II	Redington III
6/26	4.0	4.0	-
7/1	3.5	3.0	-
7/3	3.0	3.0	-
7/8	3.0	3.0	-
7/16	3.0	3.0	-
7/23	2.5	3.0	-
7/30	2.5	2.5	2.5
8/7	1.5	2.5	2.0
8/13	6.0	5.5	5.0
8/20	5.5	5.5	-
8/27	5.0	5.0	-
9/9	5.5	5.5	-
10/1	5.5	5.0	5.0
10/16	5.0	5.0	5.5
10/26	5.0	5.5	5.5
11/10	4.5	4.5	4.0
11/19	5.0	4.5	5.0
12/11	4.5	5.0	-
12/17	4.0	-	-
1/10	2.5	-	-
2/18	2.0	2.0	-
3/1	1.5	2.0	-
3/17	4.0	4.0	-

TABLE 27.

BLUE GILL POND
TOTAL IRON IN PARTS PER MILLION

Date	Blue Gill I	Blue Gill II
6/18	2.5	2.5
6/26	2.0	2.5
7/8	1.5	1.5
7/16	1.5	1.5
7/23	2.0	2.0
7/30	2.5	3.0
8/7	2.5	2.5
8/13	3.0	2.5
8/20	2.5	2.5
8/27	2.5	2.5
9/9	2.0	2.5
10/1	0.50	1.5
10/16	1.0	1.0
10/26	1.5	1.50
11/10	2.0	1.5
11/19	2.0	2.0
12/11	1.0	1.0
12/17	1.0	1.0
1/10	1.0	1.0
2/18	0.5	0.50
2/27	1.5	1.0
3/1	1.5	1.50
3/5	2.0	2.0
3/17	3.0	3.0

TABLE 28.

SNOWDEN POND
TOTAL IRON IN PARTS PER MILLION

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	1.50	1.50	1.50	1.50
7/16	1.50	1.50	1.50	1.50
7/23	2.0	2.0	2.0	1.50
7/30	2.0	2.0	2.0	2.0
8/7	3.0	2.50	2.50	2.50
8/15	1.50	2.0	1.50	1.50
8/20	1.0	0.750	0.750	1.0
8/27	1.0	1.0	1.0	1.0
9/9	2.0	1.50	1.50	2.50
10/1	3.50	3.50	3.50	3.50
10/15	5.0	5.0	5.50	5.0
11/10	4.50	4.50	4.0	4.50
11/19	3.0	4.0	4.0	5.0
12/11	4.0	3.50	3.50	4.0
12/17	3.0	-	-	3.50
1/10	2.50	-	-	2.0
2/18	1.50	-	-	2.0
2/27	1.50	1.0	1.0	1.0
3/5	2.0	2.0	2.0	2.0
3/17	3.0	3.0	3.0	3.5

TABLE 29.

SNOWDEN POND
SILICA IN MILLIGRAMS PER LITER

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	0.50	0.50	0.50	0.50
7/16	0.250	0.250	0.250	0.250
7/23	0.50	0.50	0.50	0.50
7/30	0.750	0.750	0.750	0.750
8/7	0.750	0.50	0.50	0.750
8/15	1.0	1.0	1.0	1.0
8/20	0.750	0.750	0.750	0.750
8/27	0.750	0.50	0.50	0.750
9/9	0.50	0.50	0.50	0.50
10/1	0.50	0.50	0.50	0.750
10/15	0.50	0.50	0.50	0.50
11/10	0.750	0.750	0.750	1.0
11/19	0.750	0.750	0.750	0.50
12/11	1.0	0.750	0.750	0.750
12/17	0.750	-	-	0.750
1/10	0.50	-	-	0.50
2/18	0.250	-	-	0.250
2/27	0.150	0.150	0.120	0.250
3/5	0.150	0.1250	0.1250	0.150
3/17	0.250	0.40	0.40	0.250

TABLE 30.

BLUE GILL POND
SILICA IN MILLIGRAMS PER LITER

Date	Blue Gill I	Blue Gill II
6/18	.50	.50
6/26	.50	.50
7/8	.50	.75
7/16	.50	.50
7/23	.50	.75
7/30	.75	.75
8/7	.75	.75
8/13	.50	.50
8/20	.50	.50
8/27	.40	.50
9/9	.40	.40
10/1	.35	.40
10/16	.30	.50
10/26	.25	.25
11/10	.25	.25
11/19	.12	.12
12/11	Trace	.12
12/17	0	0
1/10	Trace	Trace
2/18	.25	.25
2/27	.12	.12
3/1	.12	.12
3/5	.25	.25
3/17	.25	.30

TABLE 31.

LAKE REDINGTON
SILICA IN MILLIGRAMS PER LITER

Date	Redington I	Redington II	Redington III
6/26	0.50	0.50	-
7/1	0.50	0.50	-
7/3	0.75	0.50	-
7/8	0.75	0.50	-
7/16	0.75	0.75	-
7/23	1.0	0.75	0.75
7/30	0.75	1.0	0.50
8/7	1.0	1.0	0.50
8/13	1.0	0.75	1.0
8/20	1.0	1.0	-
8/27	0.85	0.75	-
9/9	0.50	0.50	-
10/1	0.50	0.50	0.50
10/16	0.50	0.250	0.50
10/26	0.250	0.250	0.250
11/10	0.250	0.50	0.50
11/19	0.250	0.250	0.250
12/11	0.250	0.250	0.250
12/17	0.250	-	-
1/10	0.120	-	-
2/18	0.120	0.120	-
3/1	0.250	0.120	-
3/17	0.50	0.30	-

TABLE 32.

CASH LAKE
SILICA IN MILLIGRAMS PER LITER

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	0.50	0.40	-	-	-	-
6/17	0.40	0.50	-	-	-	-
6/24	0.50	0.50	0.50	0.50	0.50	0.50
6/26	0.25	0.50	0.25	0.50	0.50	0.25
7/1	0.40	0.50	0.50	0.50	0.40	0.40
7/3	0.40	0.50	0.30	0.30	0.50	0.30
7/11	0.50	0.50	0.50	0.50	0.40	0.40
7/16	0.50	0.55	0.50	0.50	0.50	0.30
7/23	0.50	0.75	0.50	0.75	0.75	0.50+
7/30	0.75	0.75	0.75	0.75	0.75	0.75
8/7	0.50+	0.75	0.50	0.50	0.75	0.50
8/13	0.75	0.75	0.75	0.75+	1.0	0.50
8/20	0.75	0.55	0.50	0.50	0.50	0.50
8/27	0.40	0.50	0.50	0.50	0.55+	0.40
9/9	0.40	0.40	0.30	0.30	0.40	0.30
10/1	0.25	0.25	0.25	0.40	0.40	0.40
10/20	0.40	0.25	0.25	0.40	0.40	0.25
11/10	0.25	0.25	0.25	0.25	0.50	0.25
12/11	Trace	Trace	0.0	0.0	0.0	0.0
12/17	0.12	-	-	-	-	-
1/10	Trace	0.12	-	-	-	-
2/18	0.12	0.25	-	-	-	-
2/23	0.12	0.12	Trace	0.12	Trace	Trace
3/5	0.20	0.12	0.20	0.12	0.25	0.20
3/17	0.25	0.25	0.25	0.25	0.25	0.25
4/3	0.25	0.35	0.25	0.50	0.50	0.25

TABLE 33.

CASH LAKE
SOLUBLE PHOSPHORUS IN MILLIGRAMS PER LITER

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	0.012	0.015	-	-	-	-
6/17	0.025	0.040	-	-	-	-
6/24	0.025	0.025	0.025	0.025	0.025	0.025
6/26	0.025	0.025	0.012	0.012	0.025	0.012
7/1	0.012	0.025	0.025	0.025	0.025	0.050
7/3	0.025	0.025	0.012	0.012	0.025	0.012
7/11	0.025	0.040	0.025	0.025	0.050	0.040
7/16	0.025	0.030	0.025	0.025	0.025	0.025
7/23	0.012	0.025	0.012	Trace	0.025	0.120
7/30	Trace	0.025	0.012	0.025	0.012	0.012
8/7	0.0150+	0.012	Trace	Trace	0.012+	Trace
8/13	0.0250	0.040	0.030	0.030	0.030	0.025
8/20	0.0250	0.025	0.025	0.030	0.030	0.025
8/27	0.0125	0.0120	Trace	0.0120	0.0250	0.0250
9/9	0.0250	0.0250	0.0250	0.0250	0.0250+	0.0250
10/1	0.030	0.050	0.0250	0.050	0.050	0.050
10/20	0.0750	0.0750	0.050+	0.075	0.050	0.050
11/10	0.040+	0.050	0.050-	0.075	0.075	0.050
11/20	0.040	0.040	0.040	0.040	0.040	0.040
12/11	0.012	0.025	0.0	0.0	0.012-	0.012-
12/17	010250	0.0250	-	-	-	-
1/10	Trace	-	-	-	-	-
2/18	0.0150+	0.0250	-	-	-	-
2/23	0.0120+	0.0120	0.0120	0.0120	0.0120	0.0150-
3/5	0.050	0.050	0.050	0.025	0.040	0.0250
3/17	0.050	0.050	0.050	0.050	0.050	0.050
4/3	0.0250	0.0250	0.0120	0.0120	0.0250	0.0120

TABLE 34.

LAKE REDINGTON
SOLUBLE PHOSPHORUS IN MILLIGRAMS PER LITER

Date	Redington	Redington II	Redington III
6/26	0.025	0.025	-
7/1	0.012	0.050	-
7/3	0.012	0.120	-
7/8	0.025	0.250	-
7/16	0.050	0.025	-
7/23	0.020	0.025	0.020
7/30	0.020	0.025	0.025
8/7	0.020	0.012	0.012
8/13	0.012	0.020	-
8/20	0.012	0.020	-
8/27	0.0	0.0	-
9/9	0.012	0.012	0.015
10/1	0.0	0.012	0.012
10/16	Trace	Trace	Trace
10/26	Trace	Trace	Trace
11/10	0.012	Trace	0.012
11/19	Trace	0.012	Trace
12/11	0.012	-	-
12/17	Trace	-	-
1/10	0.0	-	-
2/18	0.012	0.012	-
3/1	0.012	0.025	-
3/17	0.025	0.025	-

TABLE 35.

BLUE GILL POND
SOLUBLE PHOSPHORUS IN MILLIGRAMS PER LITER

Date	Blue Gill I	Blue Gill II
6/18	0.015	.015
6/26	0.025	.025
7/8	0.025	.030
7/16	0.025	.025
7/23	0.012	.025
7/30	0.012	.012
8/7	0.025	.050
8/13	0.050	.050
8/20	0.075	.075
8/27	0.075	.075
9/9	0.025	0.025
10/1	Trace	0.120
10/16	0.025	0.025
10/26	0.050	0.050
11/10	0.075	.075
11/19	0.050	0.050
12/11	0.050	0.050
12/17	Trace	Trace
1/10	Trace	Trace
2/18	0.012	0.012
2/27	Trace	Trace
3/1	0.025	0.025
3/5	0.025	0.025
3/17	0.050	0.050

TABLE 36.

SNOWDEN POND
SOLUBLE PHOSPHORUS IN MILLIGRAMS PER LITER

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	0.050	0.050	0.050	0.050
7/16	0.030	0.030	0.030	0.030
7/23	0.0120	0.0750	0.0250	0.050
7/30	0.0120	0.0120	Trace	0.0120
8/7	0.0120	Trace	Trace	0.0120
8/15	Trace	Trace	Trace	Trace
8/20	0	0	0	0
8/27	0	0	0	0
9/9	0	0	0	0
10/1	Trace	Trace	Trace	0.0120
10/15	Trace	Trace	Trace	Trace
11/10	0.0250	0.0120	Trace	0.0120
11/19	0.0250	0.050	0.0250	0.050
12/11	0.0250	0.0120	0.0250	0.030
12/17	0.0120	-	-	0.0250
1/10	Trace	-	-	0.120
2/18	0.0250	-	-	0.0120
2/27	0.050	0.0250	0.0120	0.050
3/5	0.050	0.0250	0.050	0.050
3/17	0.050	0.050	0.050	0.050

TABLE 37.

SNOWDEN POND
DISSOLVED OXYGEN IN PARTS PER MILLION

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	5.03	4.89	5.03	5.03
7/16	6.15	6.00	5.54	5.60
7/23	5.59	5.65	5.50	5.31
7/30	5.87	5.79	5.87	5.87
8/7	5.59	5.50	5.45	5.50
8/15	5.31	5.45	5.20	5.03
8/20	5.31	5.31	5.20	5.25
8/27	5.20	5.26	5.26	5.20
9/9	5.26	5.40	5.15	5.26
10/1	5.03	5.00	4.85	5.03
10/15	5.87	5.26	5.20	5.80
11/10	6.71	6.90	6.15	6.89
11/19	7.27	7.20	6.85	7.85
12/11	8.39	7.95	7.93	8.39
12/17	9.79	9.55	9.51	9.81
1/10	9.85	9,85	9.79	9.85
2/27	9.79	7.85	6.55	9.90
3/17	10.1	10.1	9.92	10.8

TABLE 38.

BLUE GILL POND
DISSOLVED OXYGEN IN PARTS PER MILLION

Date	Blue Gill I	Blue Gill II
6/18	5.70	5.70
6/26	6.04	6.43
7/8	6.43	6.43
7/16	7.16	7.16
7/23	7.55	7.16
7/30	6.15	6.15
8/7	5.87	5.87
8/13	5.93	5.59
8/20	5.59	5.59
8/27	5.87	5.59
9/9	5.59	7.55
10/1	8.06	8.06
10/16	8.30	8.60
10/26	8.67	8.39
11/10	8.95	9.02
11/19	9.81	8.90
12/11	7.27	7.27
12/17	10.1	10.0
1/10	8.62	8.60
2/18	9.96	9.96
2/27	12.0	12.0
3/1	10.10	11.0
3/5	12.30	12.30
3/17	12.40	12.50

TABLE 39.

LAKE REDINGTON
DISSOLVED OXYGEN IN PARTS PER MILLION

Date	Redington I	Redington II	Redington III
6/26	10.00	10.00	-
7/1	10.00	10.00	-
7/3	10.50	10.50	-
7/8	5.98	6.00	-
7/16	5.70	5.75	-
7/23	7.61	7.58	7.53
7/30	6.82	6.91	6.91
8/7	6.43	6.46	6.46
8/13	5.98	6.05	-
8/20	4.64	4.70	-
8/27	3.86	3.90	3.90
9/9	4.42	4.82	4.47
10/1	8.70	8.82	8.94
10/16	8.39	8.45	8.45
10/26	9.05	9.10	9.22
11/10	16.80	17.05	17.82
11/19	9.50	10.00+	9.50
12/11	17.50	17.50	17.50
12/17	9.79	-	-
1/10	10.05	-	-
2/18	10.20	10.20	-
3/1	9.55	9.55	-
3/17	9.40	9.40	-

TABLE 40.

CASH LAKE
DISSOLVED OXYGEN IN PARTS PER MILLION

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	5.81	5.70	5.85	5.85	5.80	5.80
6/17	6.45	6.43	6.45	6.45	6.40	6.45
6/24	6.75	6.72	6.75	6.75	6.70	6.75
6/26	5.70	5.70	5.70	5.75	5.70	5.70
7/1	7.10	7.10	7.20	7.20	7.10	7.20
7/3	4.92	4.90	4.90	5.00	4.90	4.93
7/11	6.70	6.71	6.70	6.70	6.70	6.70
7/16	5.58	5.59	5.60	5.60	5.56	5.60
7/23	6.10	6.15	6.10	6.10	6.10	6.12
7/30	6.41	6.43	6.45	6.50	6.40	6.40
8/7	6.15	6.15	6.15	6.20	6.15	6.15
8/13	6.00	6.10	6.10	6.17	6.03	6.10
8/20	5.00	5.03	5.00	5.07	5.00	5.00
8/27	4.46	4.64	4.66	4.75	4.46	4.70
9/9	4.45	4.47	4.50	4.50	4.40	4.50
10/1	6.57	6.71	6.70	6.70	6.63	6.70
10/20	6.89	6.99	7.00	7.03	6.91	6.80
11/10	7.80	7.83	7.85	7.85	7.80	7.80
11/20	8.40	8.39	8.40	8.43	8.40	8.40
12/11	8.30	8.28	8.31	8.35	8.30	8.35
12/17	8.35	8.39	-	-	-	-
1/10	8.00	8.00	-	-	-	-
2/18	6.00	6.04	-	-	-	-
2/23	6.70	6.71	6.71	6.70	6.70	6.73
3/5	9.25	9.23	9.29	9.27	9.25	9.33
3/17	9.30	9.29	9.33	9.35	9.25	9.30
3/31	9.40	9.43	9.40	9.43	9.40	9.43
4/3	9.57	9.57	9.59	9.60	9.57	9.60

TABLE 41.

CASH LAKE
TOTAL ACIDITY IN PARTS PER MILLION

Date	Cash I	Cash II	Cash III	Cash IV	Cash V	Cash VI
6/11	16.50	16.50	-	-	-	-
6/17	16.0	16.0	-	-	-	-
6/24	15.50	15.0	15.0	15.0	16.0	15.0
6/26	14.50	14.50	15.0	15.0	15.0	15.0
7/1	16.50	16.0	16.0	16.0	16.50	16.0
7/3	14.0	14.0	14.50	14.50	14.50	14.50
7/11	13.0	13.50	14.0	14.50	14.0	14.0
7/16	11.50	11.0	11.0	11.0	11.50	11.0
7/23	9.0	9.0	9.50	9.50	9.50	9.50
7/30	9.50	9.50	9.50	9.50	10.0	9.50
8/7	9.50	9.0	9.0	9.0	9.50	9.50
8/13	8.50	8.50	8.50	8.50	8.50	8.50
8/20	8.0	7.0	7.0	7.50	8.50	8.0
8/27	6.50	6.0	6.0	6.0	7.0	6.50
9/9	7.50	7.50	7.50	7.50	7.50	7.50
10/1	10.0	9.50	9.50	9.50	10.0	9.50
10/20	13.0	12.0	12.50	12.50	13.50	12.50
11/10	13.50	13.50	13.50	13.50	13.50	13.50
11/20	13.0	13.0	13.0	13.50	13.50	13.0
12/11	12.0	11.50	11.50	11.50	12.0	11.50
12/17	16.0	16.0	-	-	-	-
1/10	17.50	17.50	-	-	-	-
2/18	25.50	26.0	-	-	-	-
2/23	22.50	22.50	22.50	22.0	23.0	22.50
3/5	14.0	14.0	14.50	14.50	16.0	14.0
3/17	14.0	12.0	12.0	12.0	15.0	12.50

TABLE 42.

LAKE REDINGTON
TOTAL ACIDITY IN PARTS PER MILLION

Date	Redington I	Redington II	Redington III
6/26	14.0	14.0	-
7/1	12.50	12.50	-
7/3	14.0	14.50	-
7/8	13.50	12.50	-
7/16	12.0	12.50	-
7/23	10.50	10.50	10.50
7/30	10.0	10.50	10.50
8/7	8.0	8.0	8.0
8/13	8.0	8.0	-
8/20	9.0	9.0	-
8/27	15.0	16.0	16.0
9/9	13.50	15.00	15.00
10/1	15.0	16.50	16.00
10/16	15.50	15.50	15.50
10/26	16.0	16.00	16.00
11/10	16.0	16.50	16.00
11/19	16.50	17.50	17.50
12/11	18.50	18.00	19.00
12/17	20.0	-	22.00
1/10	23.0	-	-
2/18	18.0	21.00	-
3/1	15.0	16.00	-
3/17	11.0	11.5	-

TABLE 43.

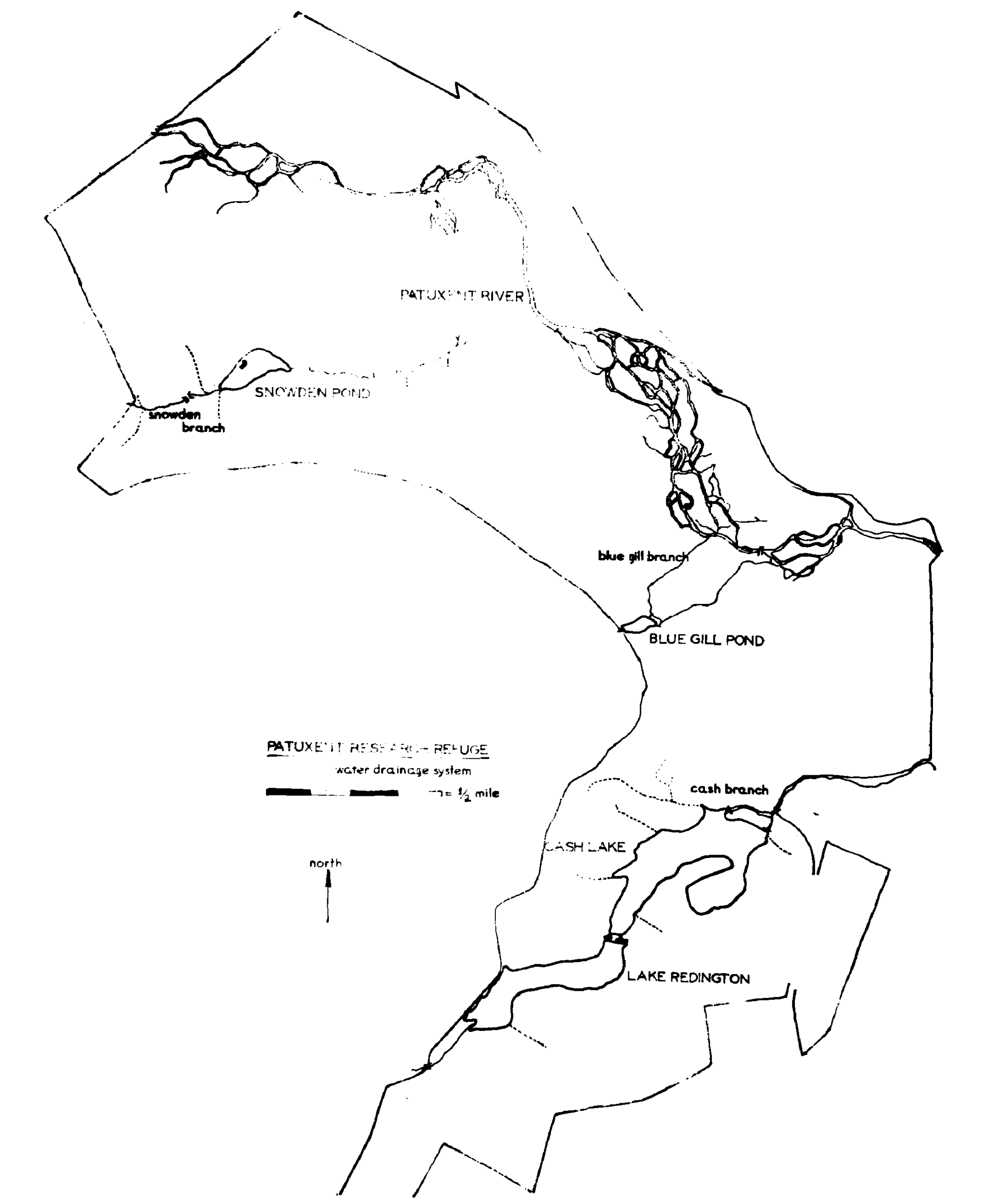
BLUE GILL POND
TOTAL ACIDITY IN PARTS PER MILLION

Date	Blue Gill I	Blue Gill II
6/18	11.0	11.0
6/26	9.50	10.0
7/8	9.0	9.5
7/16	9.0	9.0
7/23	9.50	10.0
7/30	8.0	8.5
8/7	7.0	7.0
8/13	6.50	7.0
8/20	7.50	8.0
8/27	7.0	7.0
9/9	16.0	18.0
10/1	21.0	17.5
10/16	14.0	14.0
10/26	18.0	19.0
11/10	18.5	18.0
11/19	25.5	25.0
12/11	15.5	15.5
12/17	15.0	15.5
1/10	14.0	14.0
2/18	20.0	18.5
2/27	18.5	17.5
3/1	15.0	15.0
3/5	13.5	14.0
3/17	8.50	9.00

TABLE 44.

SNOWDEN POND
TOTAL ACIDITY IN PARTS PER MILLION

Date	Snowden I	Snowden II	Snowden III	Snowden IV
7/8	22.0	22.0	22.0	22.0
7/16	15.0	15.5	15.5	14.0
7/23	10.5	11.5	11.0	10.0
7/30	11.5	11.5	12.0	11.0
8/7	13.0	13.0	14.0	12.5
8/15	15.0	15.0	15.5	15.0
8/20	12.0	13.0	13.0	11.5
8/27	15.0	15.0	15.0	15.0
9/9	12.5	12.0	14.0	12.0
10/1	16.5	17.5	18.0	16.5
10/15	17.0	17.0	17.5	17.0
11/10	20.0	20.0	21.5	20.0
11/19	23.0	23.0	24.0	22.0
12/11	24.0	24.0	24.0	24.0
12/17	22.0	-	-	23.0
1/10	29.0	-	-	29.5
2/18	27.5	-	-	28.0
2/27	27.0	27.0	27.5	27.0
3/5	18.0	18.0	18.5	18.0
3/17	11.5	11.5	12.0	11.0



FIGURES 1 AND 2

A map of the Patuxent Research Refuge showing the location of the four impoundments in relation to the Patuxent River drainage system as well as showing relationship between Lake Redington and Cash Lake.

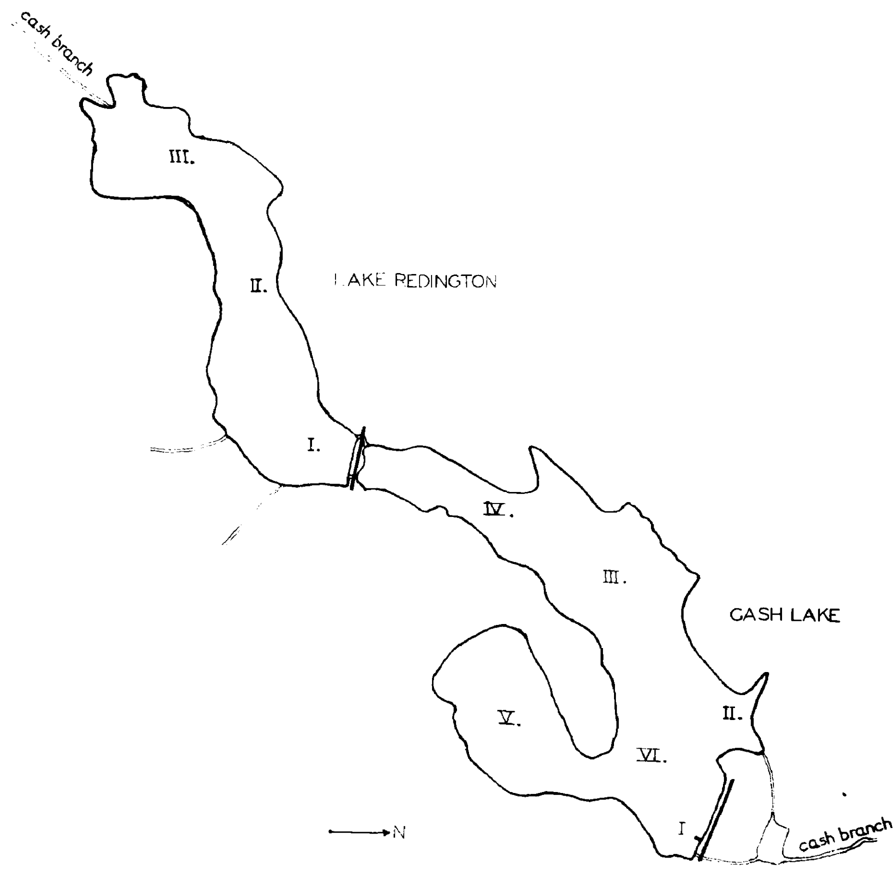


Figure 2a

An enlarged view showing the locations of the stations on Cash Lake and Lake Redington.

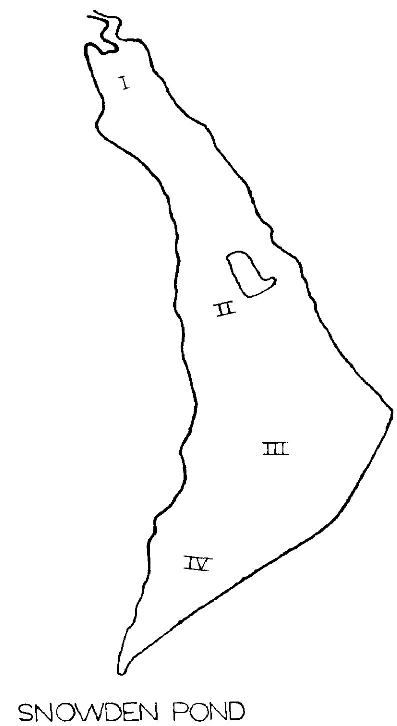


Figure 3

A map showing the contours and location of the stations on Snowden Pond.

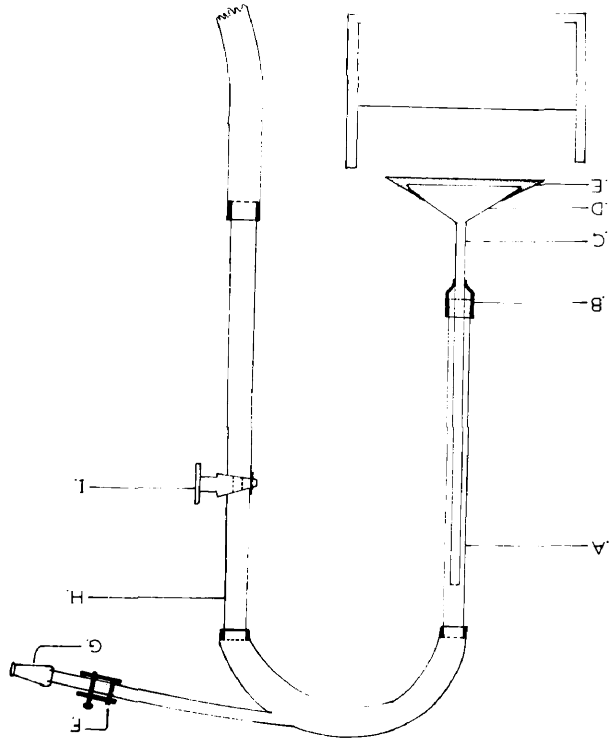


FIGURE 4

A diagram of siphon apparatus for concentrating phytoplankton samples. A. indicates the outer fixed tube through which C. the inner tube moves. B. consists of rubber tubing used to seal the tubes. D. represents the inverted funnel that actually moves into the water. E. indicates 3 thicknesses of No. 20 gauge plankton netting, stretched across mouth of funnel. F. represents pinch clamp sealing off starting tube G during operation. I is stopcock regulating flow of water through H.

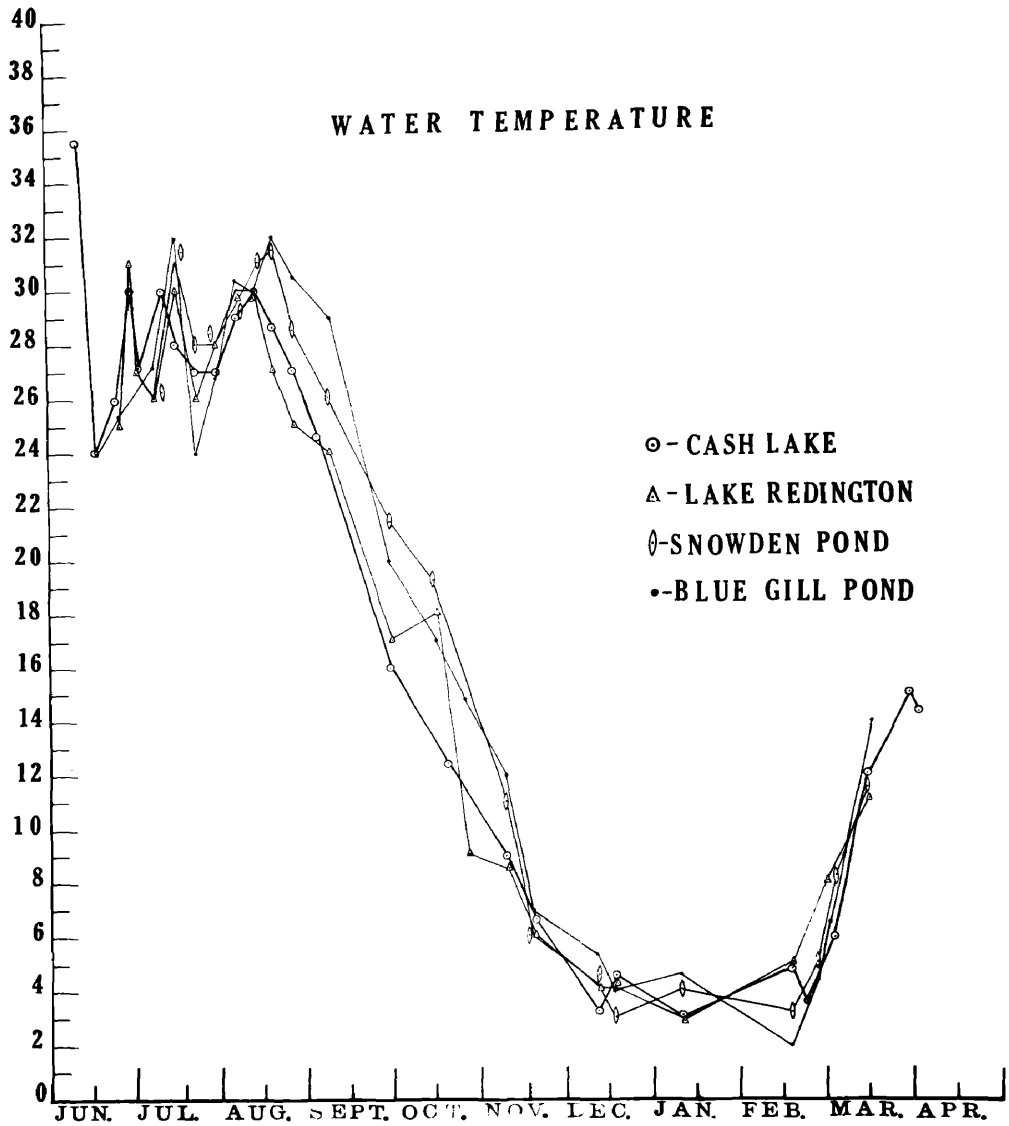


FIGURE 5.

Seasonal variation of water temperature in degrees Centigrade in Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond.

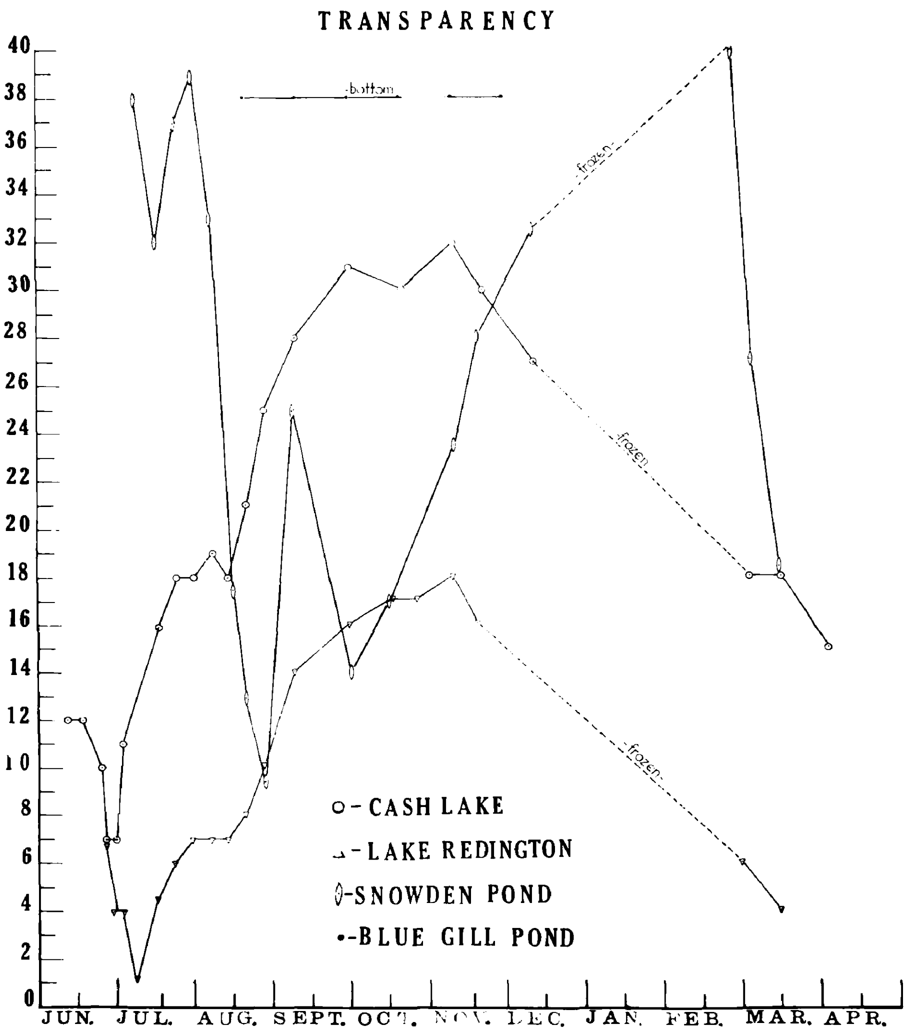


FIGURE 6

Seasonal variations in transparency in inches for Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond.

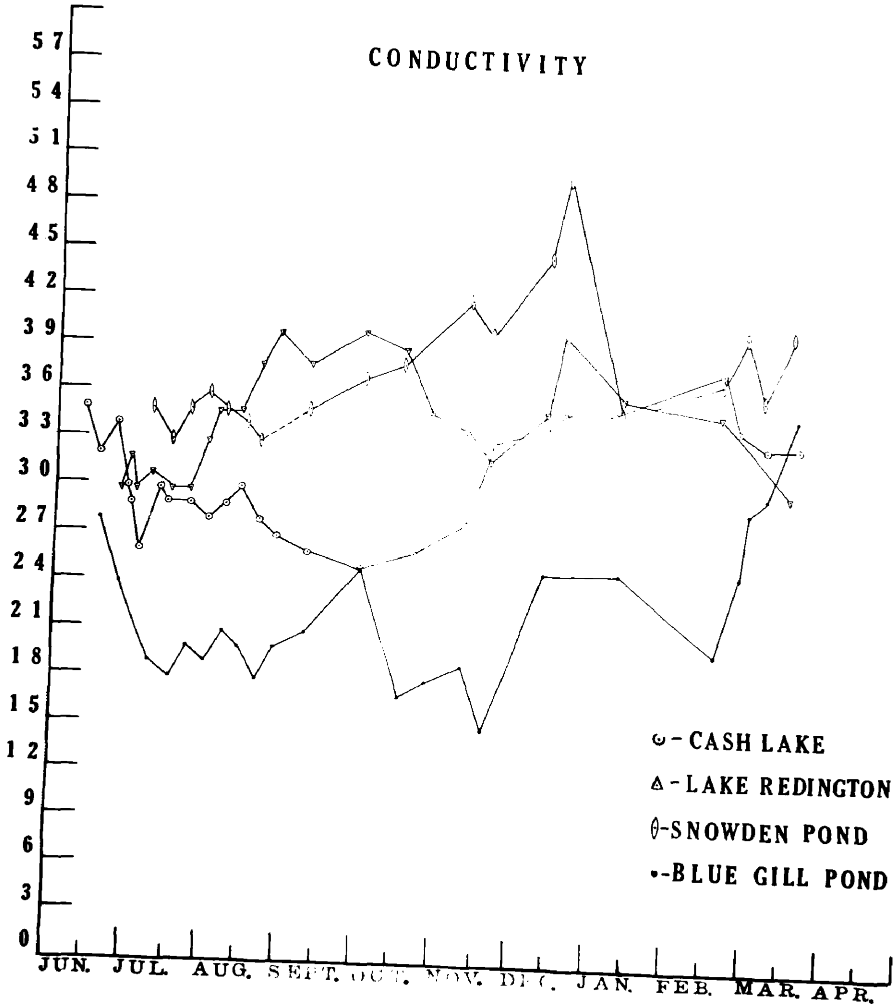


FIGURE 7

Seasonal variations of conductivity in reciprocal megohms per cubic centimeter for Cash Lake, Lake Redington, Blue Gill Pond, and Snowden Pond.

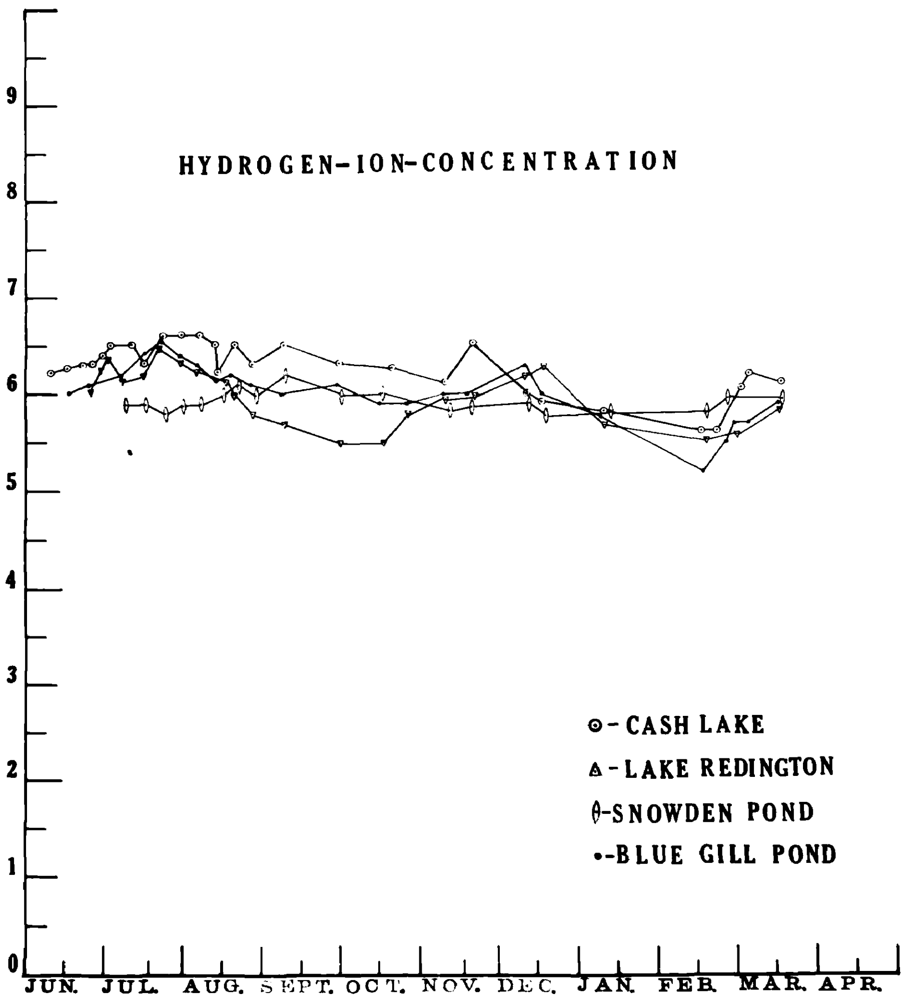


FIGURE 8

The seasonal fluctuation of hydrogen ion concentration for Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond.

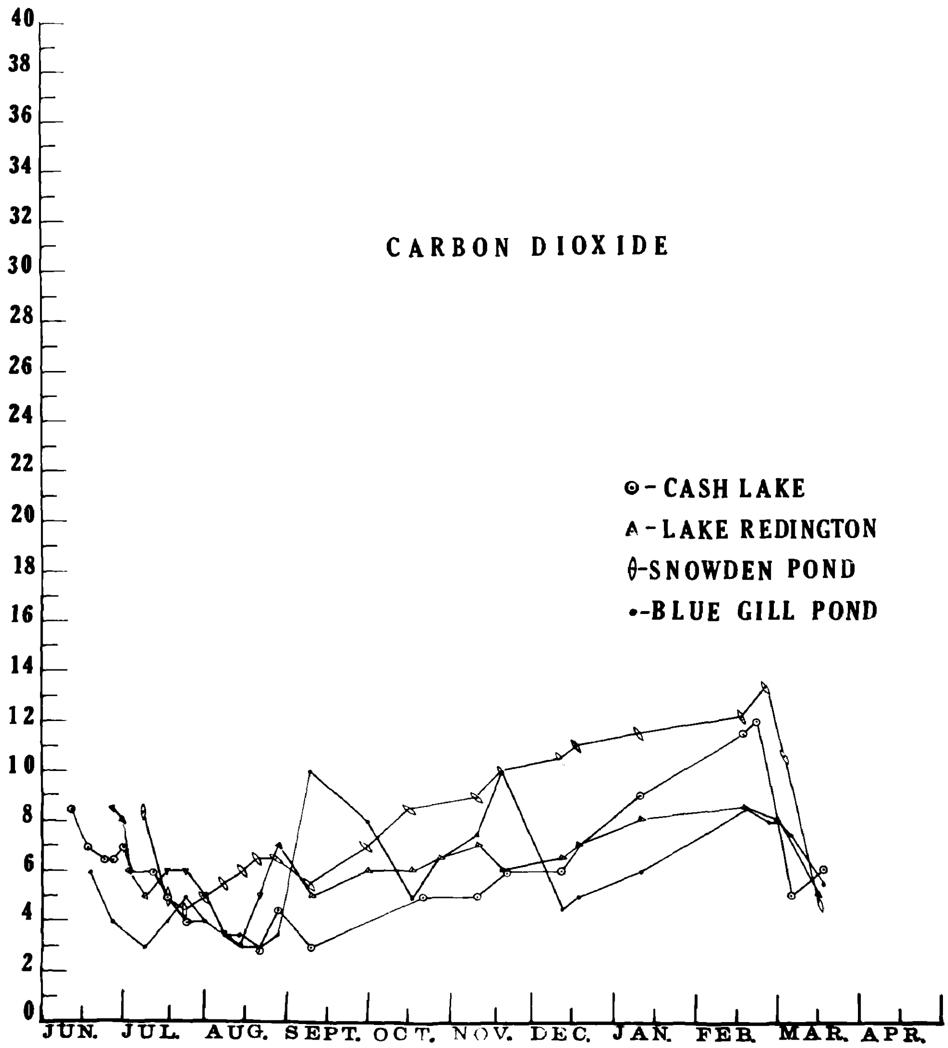


FIGURE 9

Seasonal variations of free carbon dioxide for Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond.

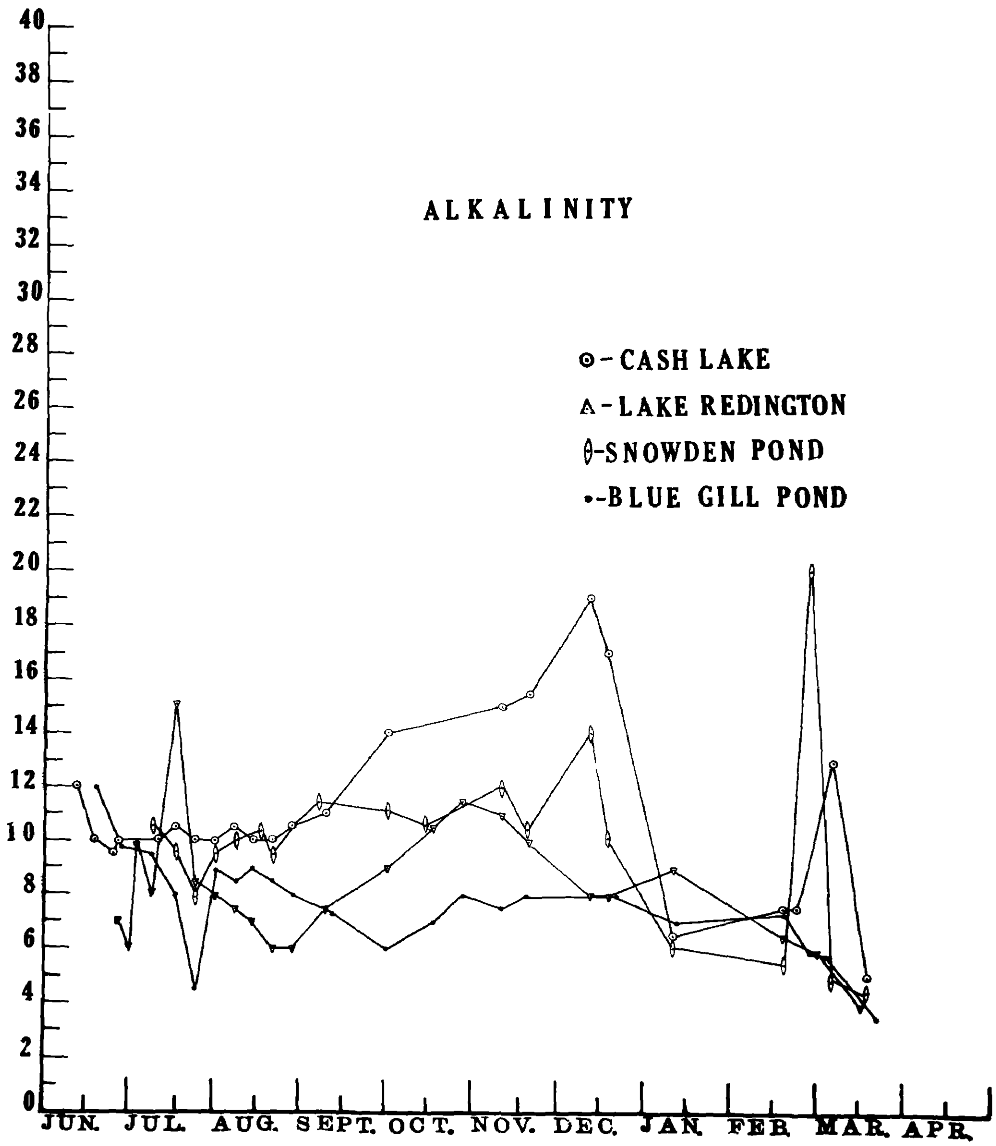


FIGURE 10

Seasonal fluctuations of alkalinity for Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond.

TOTAL IRON

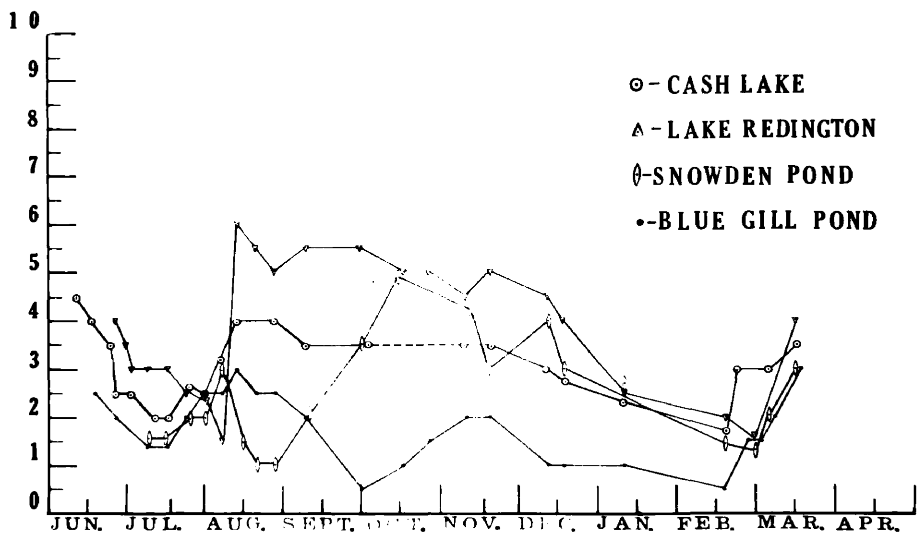


FIGURE 11

Seasonal variations of total iron for Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond.

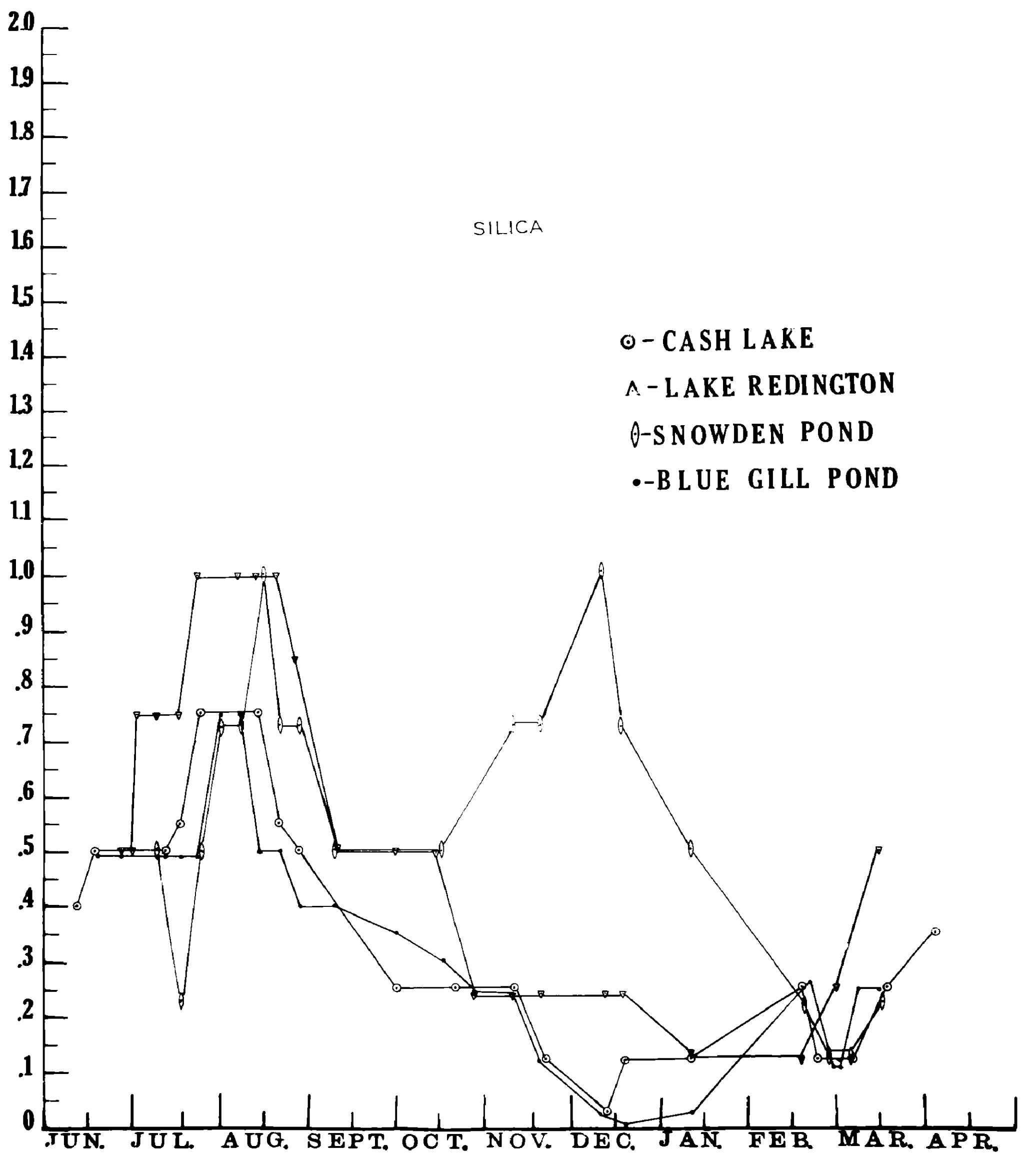


FIGURE 12

Seasonal fluctuations of silica for Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond.

PHOSPHATES

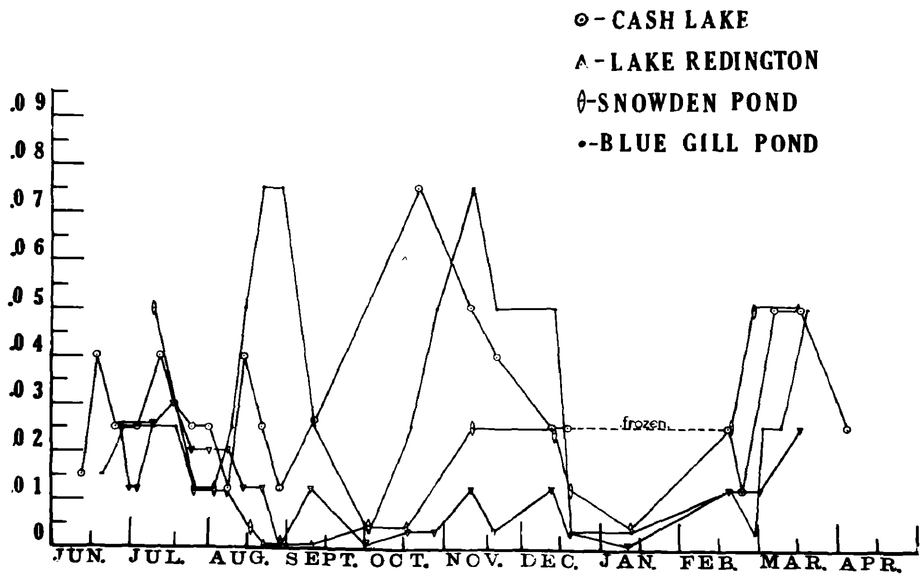


FIGURE 13

Seasonal variation of soluble phosphorus for Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond.

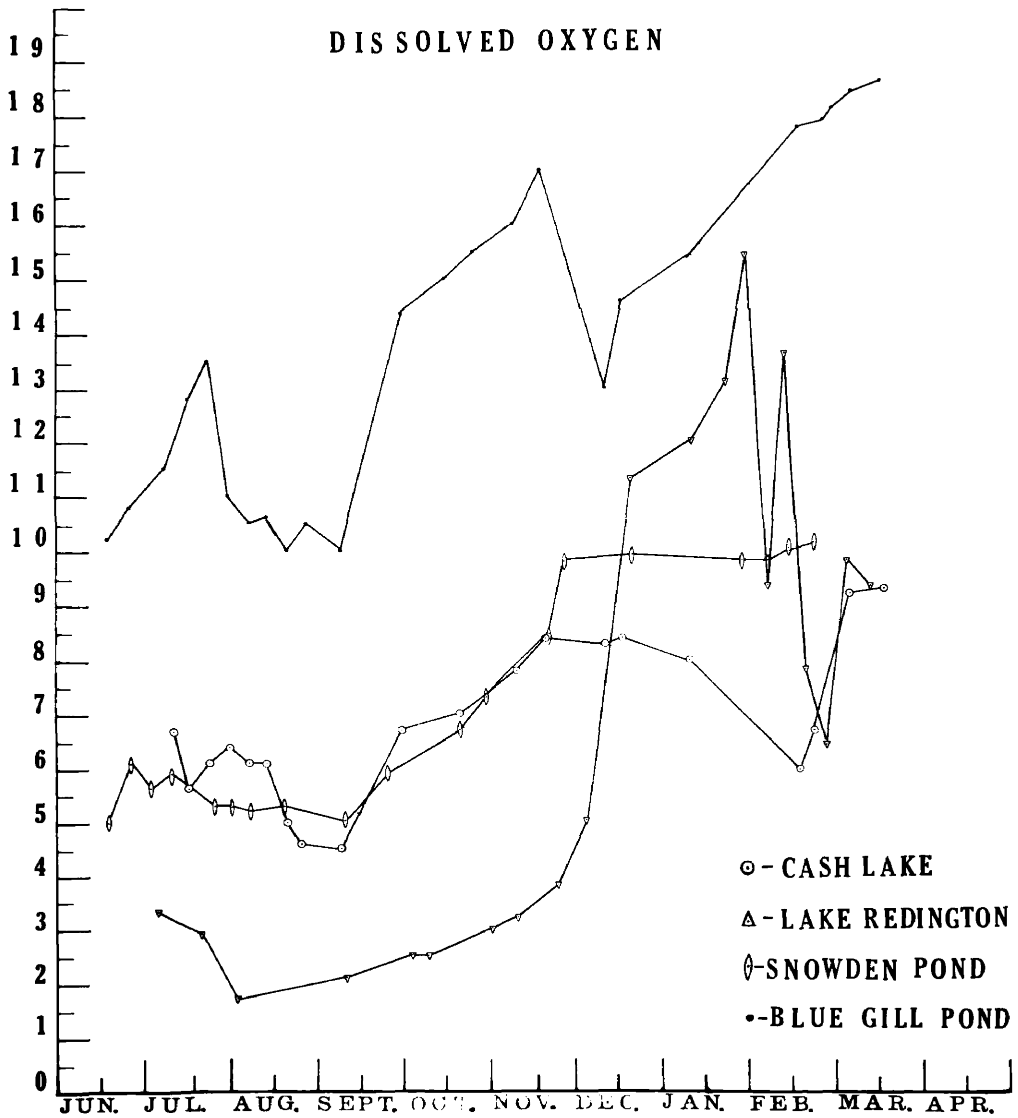


FIGURE 14

Seasonal variations of dissolved oxygen in Cash Lake, Lake Redington, Blue Gill Pond and Snowden Pond.

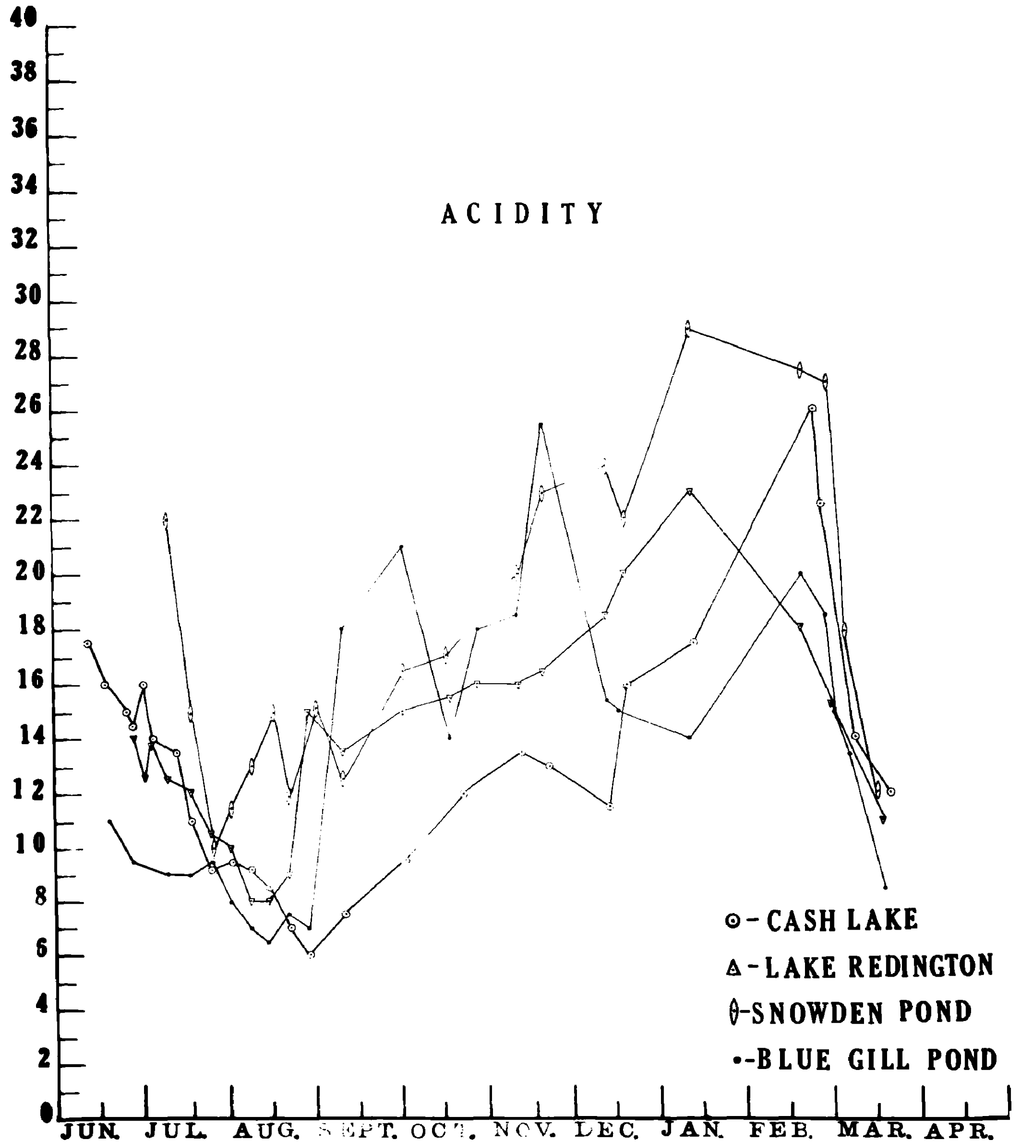


FIGURE 15

Seasonal variations in total acidity for Cash Lake, Lake Redington, Blue Gill Pond and Snowden.

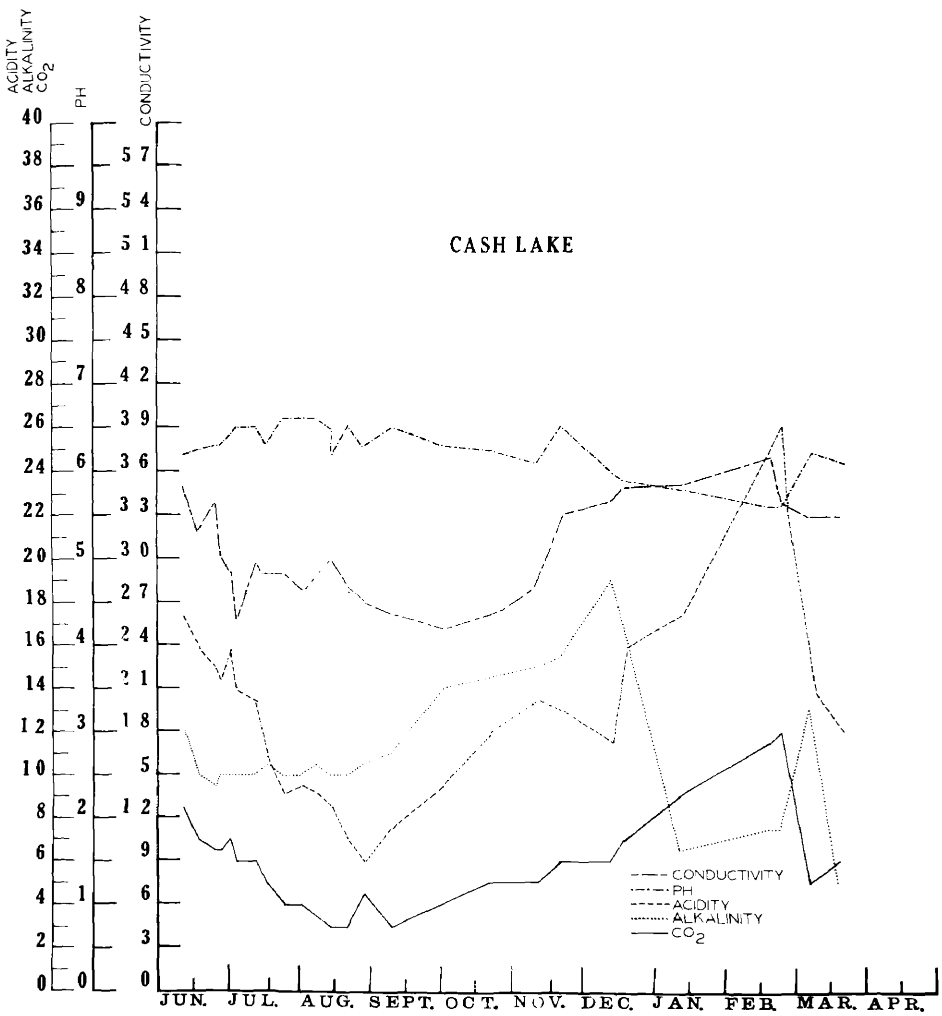


FIGURE 16

A graph indicating relationship between seasonal variations of carbon dioxide, alkalinity, acidity, hydrogen ion concentration and conductivity in Cash Lake.

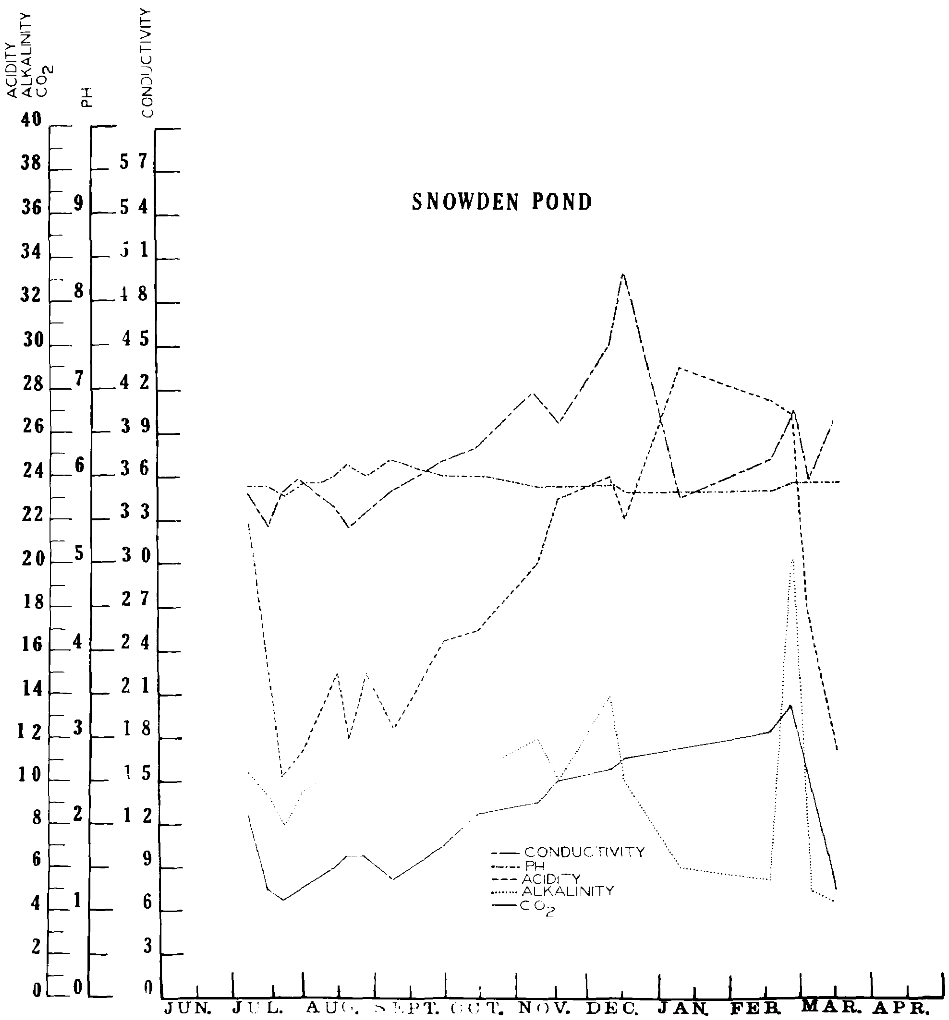


FIGURE 17

A graph indicating relationship between seasonal variations of carbon dioxide, alkalinity, acidity, hydrogen ion concentration and conductivity in Snowden Pond.

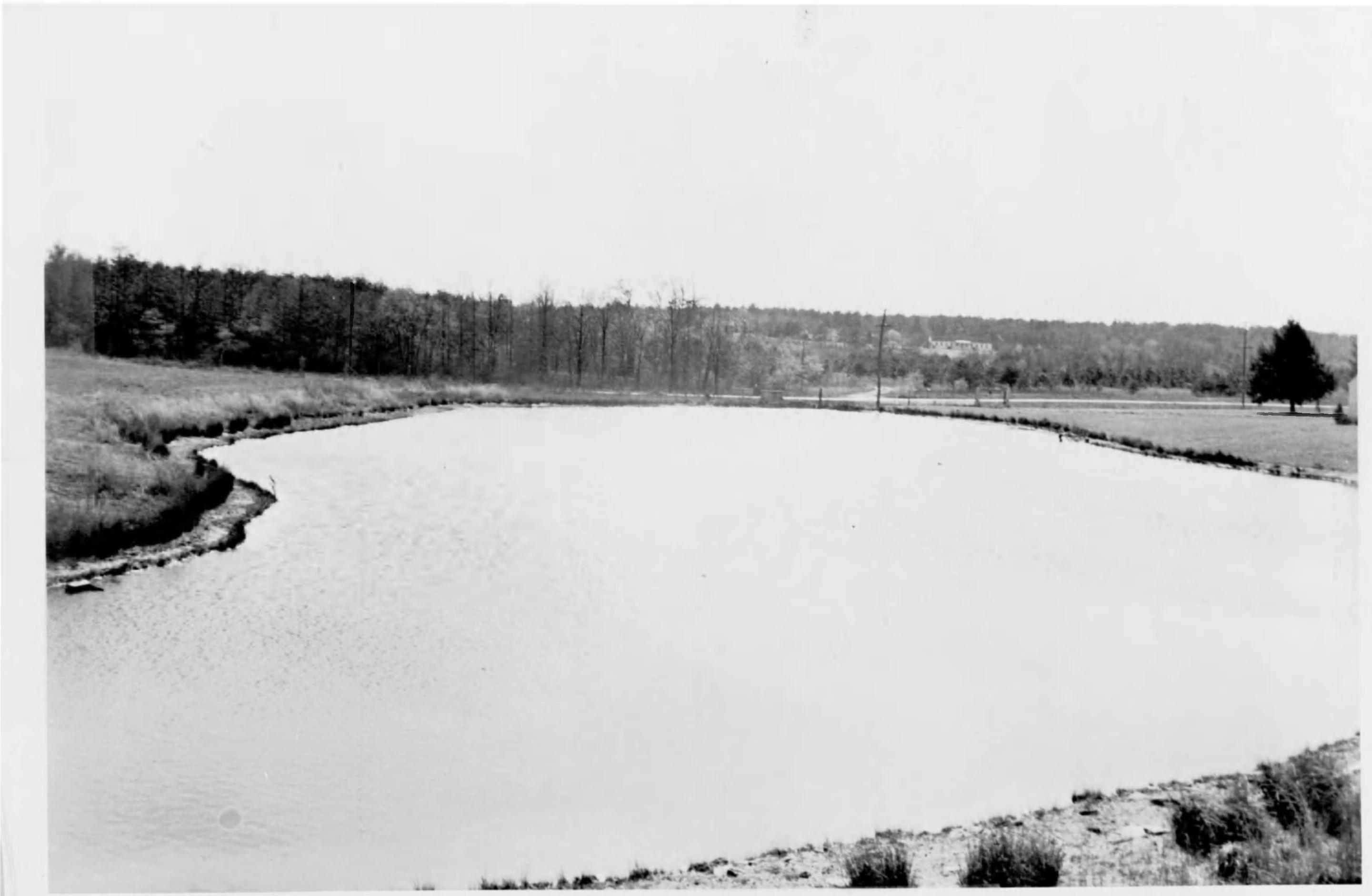


PLATE 1

Facing West on Blue Gill Pond. Station 1 is in right foreground.

PLATE 2

Facing east on Blue Gill Pond. Station 2 is in left foreground.

PLATE 3

Facing northwest on Snowden Pond. Station 4 is in left foreground. Station 3 is in middle of pond. Note island in left background.

PLATE 4

Facing southeast on Snowden Pond. Island is hidden by dense vegetation slightly to left in plate. Station 2 in the impoundment is located slightly to right of center.

PLATE 6

Facing southwest on Cash Lake. Station 2 appears in left foreground off point just showing in extreme left of plate. Station 3 is located approximately in center and Station 4 is in upper right region of pond as shown in plate.

PLATE 6

Facing due south on Cash Lake. Station 5 is located in upper left region, while Station 3 is in upper right of plate. Station 6 is in center of plate. Station 1 is in lower left area of lake, just outside of scope of plate.

PLATE 7

Pointing northeast on Cash Lake. In this plate, Station 4 is seen in lower half of center. Station 3 is in background, right of center.

PLATE 8

Lake Redington, facing southwest. Station 1 is shown in lower right region of plate. Station 2 is in middle and Station 3 is indicated in upper center of plate.

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