

A COMPARATIVE LIMNOLOGICAL STUDY OF TWO NORTHERN COLORADO MONTANE LAKES

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A comparative limnological study of two northern Colorado lakes was begun during the summer of 1951. The investigation was undertaken in an attempt to determine the relative productivity of the two lakes and to ascertain what factors were contributing to it.

These lakes are located in the northwestern part of Larimer County at an elevation of about 8200 feet and are in the region known as the Red Feather Lakes area. These two lakes, Parvin and Creedmore, were selected for the study because their sources of water are different, although they lie within the same geological formation. Parvin Lake is about 60 surface acres in extent and is fed by a brook, whereas Creedmore Lake contains 14.2 surface acres and receives its water supply from run-off and from seepages on the bottom of its basin. The latter lake has neither inlet nor outlet.

METHODS AND PROCEDURES

All physical, chemical, and biological samples were taken once each week. Temperatures were taken by means of the Foxboro resistance thermometer. Limit of visibility was measured with the Secchi disk.

Chemical analyses for phosphorus, calcium, magnesium, ammonia, nitrogen, and chlorides were done in the laboratory. Dissolved oxygen and hydrogen ion concentration determinations, however, were made in the field.

Biological sampling consisted of quantitative and qualitative determinations of bottom organisms and plankton. Bottom sampling was done by using the Ekman dredge. Plankton collection was accomplished by using the Wisconsin plankton net in conjunction with the Kemmerer-Juday water sampling bottle.

PARVIN LAKE

Physical Factors

Physiography and general description. Parvin Lake was impounded in 1927 by the Colorado Game and Fish Department. The lake is elongate and is classified as a single basin lake. There are several slight depressions within the main basin but none of these was large enough to show any individuality as described by Welch (1928). The shore line is, for the most part, gently sloping, and undoubtedly this factor contributes to the high productivity of the lake. Coves, bays, and numerous smaller indentations are prevalent along the western and northwestern shores. The depth of the lake is variable. The western inlet end is the shallowest portion, whereas, as would be expected, the deepest portion (30-34 feet) is about 50 yards from the dyke on the northeastern shore.

The bottom type is predominantly muck, but the bottom material in the deep portion of the basin is pulpy-peat. The heaviest deposit of muck is in the area of the inlet. This is apparently an accumulation of the sedimentary load from the stream. The volume of flow of the inlet stream varied between 5 and 30 second feet (exclusive of initial spring run-off and floods). Therefore, there was sufficient current to carry the suspended load of the stream for a considerable distance into the lake before deposition occurred. No attempt was made to determine

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the rate or amount of muck deposit but it is believed that considerable material has been brought in since the lake was impounded.

Water temperature. The pattern of temperature fluctuation can be seen in figure 1. Thermal stratification occurred about August 7. Although the thermocline that appeared in Parvin Lake was a typical stratification, it was only 5 feet thick and lasted only 10 days. Its disappearance was attributed to a series of high winds that apparently brought about the mixing of the column of water. The effect of the thermocline formation seemed to be reflected in the catch of trout, that is, as the layering of the water became complete, the catch of fish

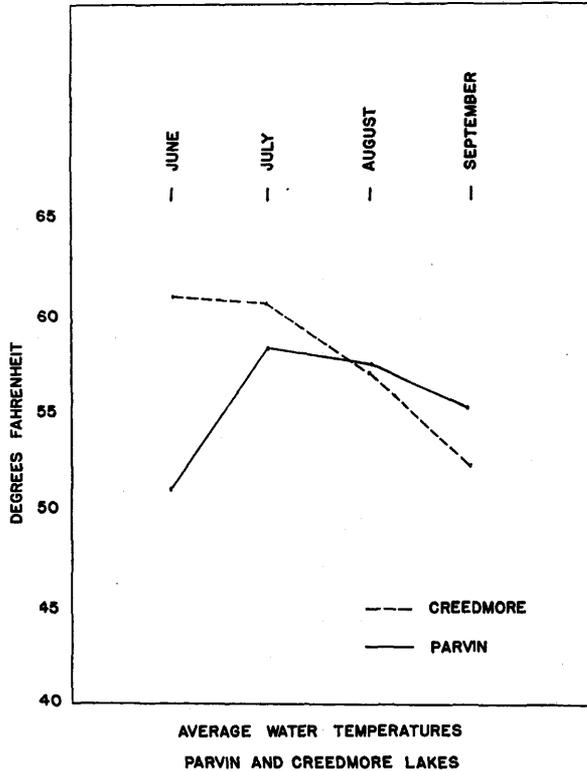


FIGURE 1. Average water temperatures Parvin and Creedmore Lakes.

increased. This was probably due to the fact that oxygen depletion in the hypolimnion had forced the fish into the epilimnion where most of their feeding was accomplished.

Water transparency. Secchi disk readings showed considerable fluctuation in transparency of the water. It is difficult to interpret the effect of these changes upon the organisms within the environment. Usually an increase in water temperature accompanied a decrease in water transparency. In this instance, therefore, it is impossible to determine whether plankters, for example, changed their level of concentration because of temperature factors or light factors. During periods of heavy algal "blooms" the Secchi disk reading was reduced to only 18 inches. The maximum reading at the same sampling station was 10 feet.

Chemical Factors

As has been suggested, Parvin Lake is highly productive. Undoubtedly this productivity is the result of a complex that is related to the basic chemical

constituents within this lake plus the replacement of various elements by run-off and agricultural drainage. The total dissolved solids in the water varied between 60 and 123 ppm. Apparently the variation is due largely to the fluctuation in phytoplankton populations. The inorganic materials, however, remained relatively static throughout the season. For example, chlorides fluctuated only 2 ppm; sulphates, 4 ppm; magnesium, 3 ppm; calcium, 2.8 ppm. Ammonia nitrogen and phosphorus showed more relative fluctuation because the stability of these elements is not as great as those mentioned above. Ammonia nitrogen is influenced by the pH of the water, that is, as the lake water swings from acidic to basic, much of the ammonia is volatilized. Moreover, phosphorus fluctuation is apparently due to its changes in combination with other elements within the lake and between the bodies of plants and animals within the environment. It has also been shown that there is some exchange of phosphorus between water and bottom mud. Therefore, the recorded amounts of this element could be much in error, contingent upon the position of the phosphorus at the time of sampling (Hayes et al., 1950). Since the water of Parvin Lake is constantly being replaced, it would seem that the amount of available phosphorus is certainly adequate for the support of plants and animals.

Hydrogen ion concentration. Like some other chemical phases of limnology, hydrogen ion concentration is not well understood as it relates to the animals and plants of a particular lake. An increase in the pH of Parvin Lake occurred during the middle of the summer. This change in pH began about the last week in August. It was noted that this increase closely paralleled the decrease in volume of flow of the feeder stream. It is therefore suggested that the decreased flow permitted a greater concentration of hydroxyl ions to be built up in the areas of open water. Since the water was already basic in character, evaporation and stagnation contributed still more toward this alkaline condition.

Oxygen. For the most part, the water maintained a condition of oxygen saturation. The two exceptions to this were: (1) a period when the localized growth of Canada waterweed was at a peak and thereby produced enough oxygen to bring supersaturation of that area; (2) the condition of oxygen depletion that existed in the hypolimnion during the period of thermal stratification. At no time was there any evidence of oxygen depletion affecting the larger aquatic organisms other than to cause their migration to the oxygenated thermocline or epilimnion. This was particularly noticeable in the case of fish. The number of fish caught by angling increased perceptibly during the above-mentioned period.

As a final point concerning the productivity and chemically related factors in Parvin Lake, it is suggested that the recent formation of the lake has influenced its richness. Since the basin of this lake was once agricultural land (grazing), it may be assumed that a considerable amount of organic and inorganic material was inundated. Plant and animal remains within the lake have added to these materials. Undoubtedly the original inorganic material in the substrate is still in the process of leaching and is contributing to the fertility of the lake.

Biological Factors

Vegetation. The dominant submerged vegetation in Parvin Lake is Canada waterweed, *Elodea canadensis*. Its position in the lake is somewhat confined to the shallow western end and to the protected coves. Its maximum growth has been attained by about August 1 and had become so dense in the inlet that fishermen were unable to fish in that area. It was at this time that dissolved oxygen content and temperature reached maxima. This would seem paradoxical were it not known that *E. canadensis* is one of the highest producers of oxygen (Schaeperclaus, 1933). On days of bright sunlight, bubbles of oxygen could be seen rising from the beds of submerged waterweed.

In coves on the northwestern side of the lake there were considerable areas

of pondweed, *Potamogeton richardsoni*. Since this plant is less dense in its growth, it is believed that these areas offer excellent foraging grounds for trout. It was observed that schools of minnows and many aquatic insects frequented these beds of pondweed.

The main function of the higher aquatic plants in Parvin Lake would seem to be that of breeding grounds for aquatic invertebrates. Undoubtedly, these plants also serve as protection for smaller fish, and resting, feeding, and hiding areas for the larger fish. Their contribution to the oxygen level of the lake as a whole is apparently of slight significance since the flow and wave action of the water tend to maintain a condition of oxygen saturation. The role of the larger aquatic plants in the chemical balance of the lake would lie in their contribution to the dissolved phosphorus and nitrate in the water.

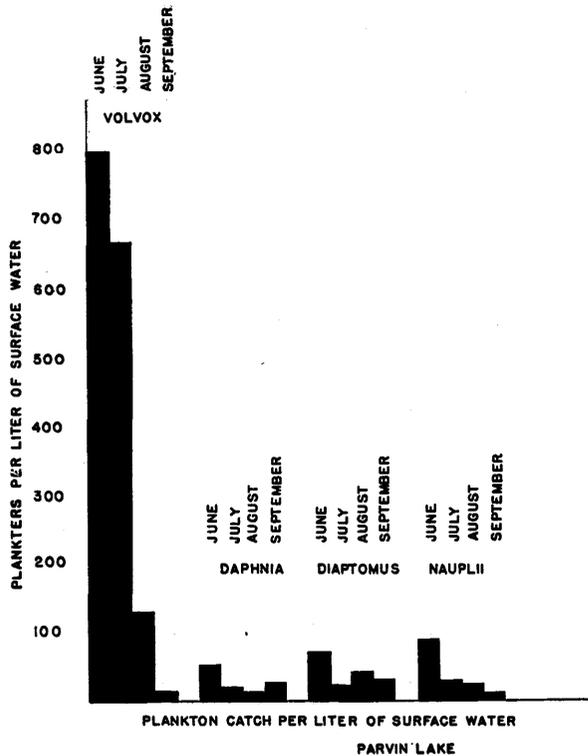


FIGURE 2. Plankton catch per liter of surface water. Parvin Lake.

Plankton. A quantitative evaluation was made of four plankters. These were: *Daphnia longispina*, *Diaptomus coloradensis*, *Volvox globator*, and the nauplii of *Diaptomus*. Of these plankters, *Volvox* was the most easily observed since it contains chlorophyll and is relatively large. At times of peak populations of *Volvox* (fig. 2) the water had a definite greenish appearance. The increased population of *Volvox* caused a decrease in the penetration of light into the deeper portions of the lake and, in turn, apparently affected the position of the other plankters in the area. For example, *Diaptomus*, which was usually found at depths of 15–20 feet, was found at depths of 3–8 feet when large numbers of *Volvox* appeared in the surface water. How changes in stratification of plankton affected the feeding of fishes in Parvin Lake is not known (fig. 4).

Since plankton is often used as an index of lake productivity, it would seem that such an index could be applied in the case of Parvin Lake. It is probable

that the excellent fish growth that has been recorded for this lake (Klein, 1950) might be traced directly or indirectly to the relatively large crop of plankton which is produced.

Bottom organisms. The diversity of bottom organisms in Parvin Lake was not great, although the number of organisms per square foot was often high.

The most abundant organisms were midge larvae, *Chironomus* spp. There were about 5 species of chironomids, but no attempt was made to identify them. It was noted that their periods of emergence were scattered throughout the entire summer. This factor is thought to be of importance since both midge larvae and adults are utilized as trout food.

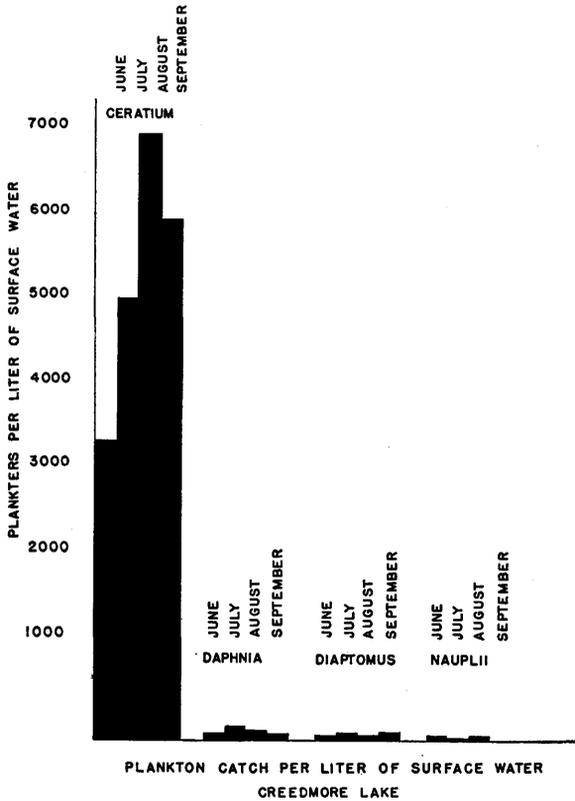


FIGURE 3. Plankton catch per liter of surface water. Creedmore Lake.

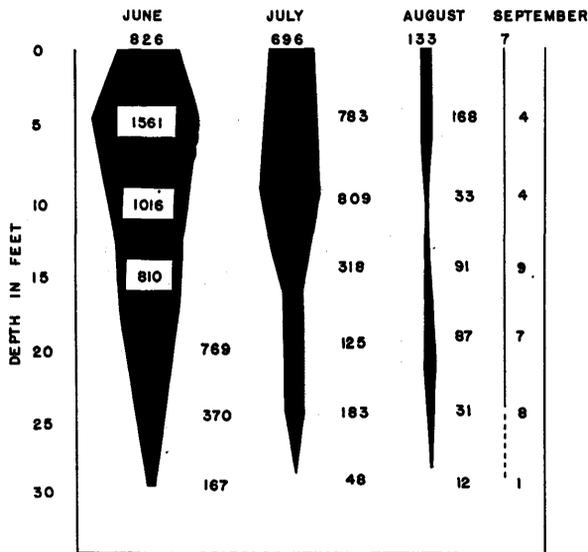
Aquatic earthworms were second in abundance among the bottom animals. There was considerable fluctuation in the earthworm population as it was sampled, however. Apparent variations in their numbers can probably be attributed to their vertical migrations within the organic ooze on the bottom of the lake basin. Therefore, when the worms were deep in the bottom mud, they were beyond reach of the Ekman dredge.

Undoubtedly the annelids in Parvin Lake were utilized to some extent by fishes, but their significance as a food item is probably slight. The main contribution of aquatic earthworms is their ability to bring about mixing of the bottom material and to aid in the breakdown of detritus. By this means they contribute to the food of the more numerous midge larvae, which are detritus and ooze feeders.

CREEDMORE LAKE

Physical Factors

Physiography. Like Parvin Lake, Creedmore has a single basin. Since its surface area is only 14.2 acres, there is little variation in the bottom contour. The basin is bowl-shaped with a regular shore line. The eastern, southern, and western portions of the littoral zone are gently sloping. In contrast, the northern shore line dips abruptly toward the deepest portion of the basin which is about 25 feet from that shore. It is estimated that during spring run-off the greatest depth of the lake was about 11 feet. During the course of the investigation the depth at the sampling station, which was considered the deepest spot in the basin, did not exceed 10 feet. By the first of October the depth at the sampling station had decreased to about 8.5 feet.



DISTRIBUTION OF AVERAGE PLANKTON CATCH (PER LITER)
PARVIN LAKE (JUNE TO SEPTEMBER)

FIGURE 4. Distribution of average plankton catch (per liter). Parvin Lake (June to September).

The bottom type in Creedmore is essentially homogeneous. The predominant mass of bottom material consisted of muck interspersed with fragments of plants. The only departure from this bottom type was found on the eastern shore where a small zone has a bottom type of sand and fine gravel. Since this is the wind-swept shore, it may be assumed that the molar action of waves has brought about the condition of a sandy beach. It is doubtful that this beach area ever will support rooted vegetation due to the constantly shifting nature of the substrate. It must, therefore, be considered very low in productivity as compared to the rest of the lake area.

Water temperature. Since Creedmore is a shallow lake, the water temperatures were relatively uniform throughout the summer (fig. 1). The homothermos conditions and the absence of thermal stratification are related to the shallowness of the lake and the great amount of wave action across its surface. At times of high wind, there was considerable turbidity which indicated that the water was in complete circulation. The amplitude of wave action may be visualized

when one considers that winds up to 80 mph were acting upon the lake's surface. On several occasions winds were of such violence that considerable quantities of water were whipped from wave crests and then dropped 10-12 yards from the lake. It is doubtful, however, that the quantity of water lost in this manner was of any significance. At any rate, it must be concluded that thermal stratification was impossible under such circumstances.

Water transparency and color. The Secchi disk readings on Creedmore Lake correspond to the depth at the sampling station (8.5-10 feet). In other words, transparency of the water was such that the lake bottom could be observed without difficulty. Therefore, the disk readings are not included in this study.

The true color of the water was clear. There was no variation from this during the season. Apparent color was light green. This color was attributed to the presence of phytoplankton and the refraction of light from the emergent and submergent vegetation.

Chemical Factors

As previously stated, Creedmore Lake has neither an inlet nor an outlet; therefore, concentration of various chemical constituents have been built up over a long period of time. This seems to be the result of the leaching of the substrate and, to a lesser extent, the leaching of the surrounding rocks. Total solids were considerably higher in this lake than in Parvin Lake. Volumetrically they were determined to fluctuate between 175 and 320 ppm. Again as in Parvin Lake, the fluctuation was largely due to changes in suspended organic matter, detritus, and plankton. As the water level decreased toward the latter part of the summer, the concentration of calcium, chlorides, and magnesium increased perceptibly. It appears that this increase resulted primarily from water evaporation.

The phosphorus content of Creedmore Lake was somewhat less than that of Parvin Lake. In attempting to account for this smaller quantity of phosphorus, it is suggested that there has been actual removal of this element. That is, phosphorus contained in the bodies of fish is removed from circulation when the fish are taken from the lake. Since there is no feeder stream in Creedmore, the above mentioned phosphorus is not being replaced from the drainage basin.

Ammonia nitrogen was present at the rate of about .06 ppm. This minute quantity was probably related to the pH of the water (7.7 to 8.8). Under this condition of alkalinity, the ammonia, for the most part, was volatilized as soon as it was manufactured. This condition is no doubt fortunate, inasmuch as the large amount of organic material on the lake bottom could conceivably produce toxic quantities of ammonia during the season of ice-cover.

Biological Factors

Vegetation. Probably the dominant vegetation in Creedmore Lake is pondweed, *Potamogeton* spp. Only a small portion of the littoral zone and the deep portion of the lake was devoid of this plant. The growth of *Potamogeton* was exceedingly heavy in the central portion of the lake and, as a result, discouraged most fishermen from fishing in that area. It may be assumed that large populations of aquatic invertebrates occupied the beds of *Potamogeton*, since "spot" sampling revealed many organisms clinging to the stems and leaves of these plants. Due to the high food factor, it is likely that fish utilized the pondweed region as a feeding and resting ground. Water temperatures were never appreciably higher over the pondweed beds than they were at the sampling station which was located in a weed-free spot near the north shore of the lake. Peak growth of *Potamogeton* was reached about the middle of August. Portions of dead stems and leaves could be found drifting or piled against the windward shore from that time until the first of October.

The second plant of importance in Creedmore Lake was the complex green alga, *Chara* spp. Apparently this plant covered the major portions of the lake

bottom, except for the sandy beach near the wind-swept shore. *Chara* always formed a thick mat of vegetation in those portions of the lake where organic ooze and detritus made up the substrate. Sampling in any of these areas always produced large numbers of amphipods. It was found also that the column of water immediately above the heavy *Chara* beds seemed to support a heavier plankton population than those *Chara*-free areas of the lake. No comparative study was made concerning this phenomenon.

Water smartweed, *Polygonum* spp., was also present in this lake. Its distribution was confined to the shallow, leeward shore. It is believed that the limnological significance of this plant was slight since it was not abundant nor were there many aquatic animals in or near the plants. Since the leaves are sparse and floating, there is little cover afforded by this plant.

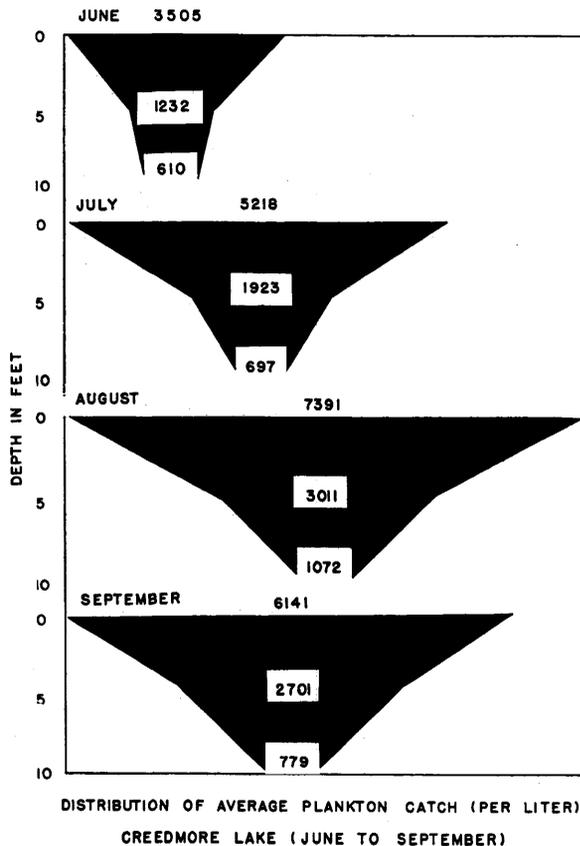


FIGURE 5. Distribution of average plankton catch (per liter). Creedmore Lake (June to September).

Plankton. An attempt was made to select the same genera of plankters for study in Creedmore Lake that were studied in Parvin Lake. This was possible with one exception. Namely, *Ceratium* spp. had to be substituted for *Volvox globator* since the latter was found only occasionally in Creedmore Lake. Thus, the four plankters considered in the Creedmore investigation were: *Daphnia longispina*; the copepod, *Diaptomus coloradensis*; the flagellate, *Ceratium* spp; and the nauplii of *Diaptomus*.

By far the most abundant plankter in Creedmore was *Ceratium*. At times

of good water transparency, there was some difference in its vertical distribution within the water column at the sampling station (fig. 5). A maximum population of 15,277 *Ceratium* per liter was recorded on August 30. *Ceratium* exhibited greater fluctuations than the other three organisms. *Diaptomus*, *Daphnia* and the nauplii showed similar population patterns in both Parvin and Creedmore Lakes. The over-all plankton population of Creedmore, however, was somewhat lower than that of Parvin. It is probable that the shallow character of Creedmore is directly related to the smaller standing crop of plankton in the lake. Further, there is no true limnetic zone in Creedmore and it is generally agreed that large plankton populations usually require open water of considerable depth. Finally, there is undoubtedly competition for space between higher aquatic plants and the various plankters in Creedmore Lake. In spite of this apparent crowding, there seemed to be adequate plankton to support the forage fish in the in-shore zone. From the few trout stomachs that were examined, there was no evidence that plankton was utilized by these fish in Creedmore Lake.

Bottom organisms. The bottom fauna of Creedmore Lake was monotonous. The major group of organisms was midge larvae, *Chironomus* spp., with aquatic earthworms ranking next in numbers of individuals. In some instances, amphipods, *Gammarus* spp., tended to confuse the picture of the bottom fauna. The latter could not be considered a true bottom organism in this lake since they were associated with the *Chara* plants. Because the plants were above the ooze substrate, it is assumed that they had been knocked from the vegetation by the dredge and subsequently appeared in the bottom samples.

Examination of a limited number of rainbow trout stomachs showed that bottom organisms were utilized to a limited extent in Creedmore Lake. The density of the vegetative mat, formed by *Chara*, may account for this lack of utilization. Moreover, the factor of vertical migration within the substrate, as it operated in Parvin Lake, was undoubtedly applicable in Creedmore Lake.

SUMMARY

Two mountain lakes were compared limnologically to determine the inter-relationship of the physical, chemical, and biological factors. Further, there was an attempt to determine the relationship of the above mentioned factors to the over-all productivity of these lake waters.

The following findings were believed to be pertinent to this study: (1) The great irregularity of the shore line of Parvin Lake tends to contribute to a greater productivity than that of Creedmore Lake, which has a regular shore line. (2) The constant replacement of important chemical constituents in Parvin Lake, due to a "feeder" stream and outlet, tends to place it in a higher productive bracket than Creedmore, which obtains water from run-off and seepage. Also the youthful condition of Parvin Lake permits the leaching of more inorganic material from its substrate than is true in the case of Creedmore. (3) Plankton exhibited population fluctuations. Bottom organisms showed a somewhat inconsistent pattern of abundance, which might be attributed to vertical migrations within the substrates of the two lakes. (4) The biological productivity of Parvin Lake seems to be higher than that of Creedmore.

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