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Effects of Weather-Conditions on the Turtle Creek Plankters near Dallas, Texas[1]

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An annual temperature cycle exists in fresh waters. This cycle, associated with periods of winter and summer stagnation, and spring and fall turnover, is governed by the addition and loss of heat. The amount of heat (in gram-calories) needed to raise the water temperature from its winter minimum to its summer maximum, is known as the "annual energy" or "heat budget." The heat-gain occurs in the spring, and effects spring-turnover; the heat-loss occurs in the fall, and effects fall-turnover. Over a period of years, the heat gained equals the heat lost (Allee 1939.) Plankters in their life cycles also exhibit seasonal cycles closely correlated with the temperature cycle. There are spring- and autumn maxima and winter- and summer minima in populations.

In September of 1952, a study to determine the effect of weather conditions upon plankton-organisms was begun in a small impounded stream about two miles from the Southern Methodist University campus. This impounded lakelet has long been called "Exall's Lake." The study was started at the end of the summer stagnation — period of 1952, and ended in the summer stagnation-period of 1953.

Turtle Creek in Dallas, the site of this survey, is in the Trinity River drainage system. It flows, at our station, at an altitude of 470 to 450 feet above sea-level. The mean annual rainfall at Dallas is 36.16 inches; the mean annual temperature is 65° F. At our station, the surface soil is Houston Black Clay underlaid by Cretaceous limestone of the Austin formation, here some six hundred feet thick and composed of chalk, marl, and calcareous shale. The chalk is hard, resists erosion, and contains many mollusk shells, and the teeth and vertebrae of fishes (Albritton, 1941.)

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Turtle Creek rises in surface- and ground waters of the Love Field Terrace of the Trinity River basin. It drops from 100 to 120 feet from its source to its confluence with the Trinity. Its banks in many areas are deeply cut into the limestone, as just below the dam, near the Highland Park city garage, where the bed of the creek is 16 feet below the ground level. Flow in Turtle Creek is intermittent; the largest flow occurs in April and May, when the average monthly rainfall for Dallas County is from four to five inches.

My work was done on Exall Lake, an impoundment of Turtle Creek in Highland Park, between the Dallas Country Club on Beverly Drive and the Highland Park city garage (at Lakeside and Lexington). This impoundment is four city-blocks long and varies in width from 50 to 200 feet, with a maximum depth of 4.87 meters. The bottom materials are composed of rock overlaid with sand, muck and a thick layer of detritus. The upper region of the lakelet (which is subject to current-action) has a sand bottom.

Methods

All plankton samples and physico-chemical data were taken from one station, located directly under the bridge at the retaining-dam. Weekly plankton samples of 20 liters were taken here at a depth of 2.44 meters, with a two-liter Juday-Foerst sampler. The depth selected seemed to present a more stable condition than that which characterized upper and lower levels at this point. The plankton was concentrated from 20 liters to 20 milliliters by straining through a Wisconsin-type plankton net covered with #20 silk bolting-cloth. Plankters were preserved in a 4% formalin solution and counted with a Sedgwick-Rafter cell. All plankton results are given in organisms per liter. Temperature was taken weekly with a Taylor maximum-minimum Fahrenheit thermometer. A Whitney underwater thermophone was used in the study of thermal stratification. Chemical analysis of the water was made as outlined in *Limnological Methods* (Welch 1948) ; pH was determined with a Beckmann pH meter. Rainfall data were obtained from the U.S. Weather Bureau station located at Love Field, Dallas.

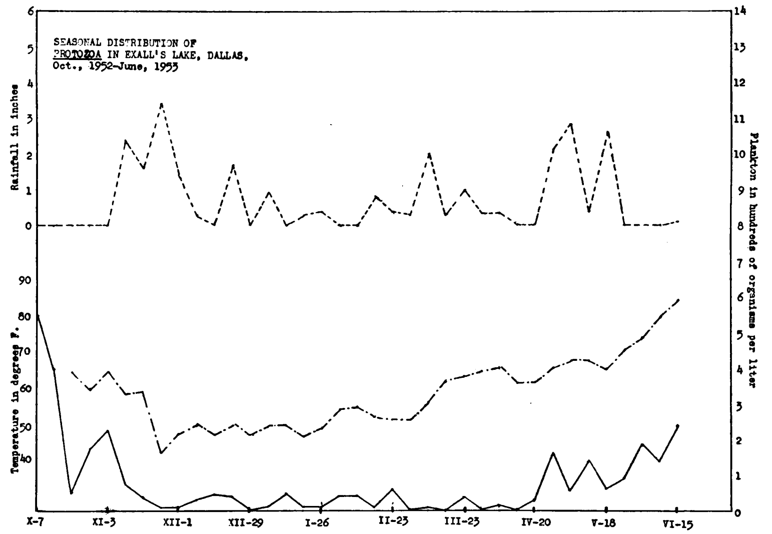
Chemical and Physical Data

This small body of water more closely conforms to a temperate lake of the third order, in which the bottom temperature approximates that of the surface water. During my study, I noted little temperature-fluctuation between upper and lower water-levels. Thermal stratification was evident in the deepest areas only during late spring and early summer. After the fall turnover, no stratification existed until after the spring turnover. The water-flow throughout the survey was intermittent. No water flowed over the dam until Nov. 10, 1952, and thereafter the flow was continuous until May 31, 1953. During this period the flow-rate was dependent upon the amount of rainfall (Graph I).

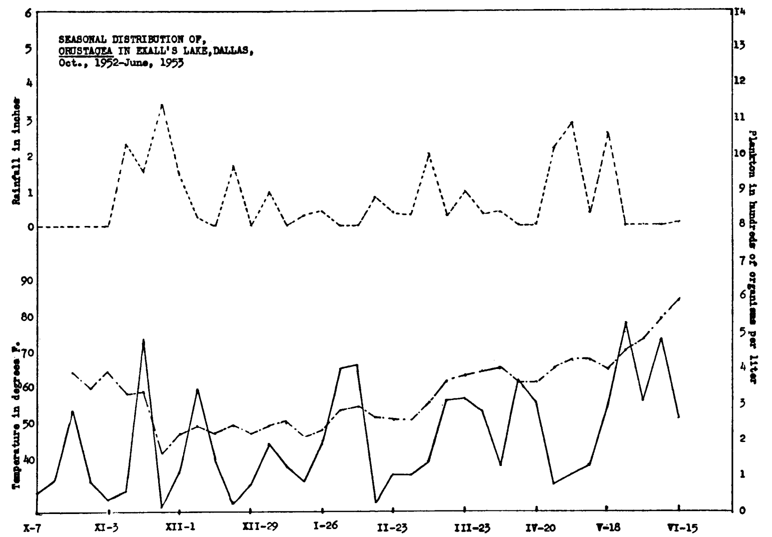
Chemical analysis of the water was made several times during my study; the amount of dissolved O_2 ranged from 5.1 to 8.2 p.p.m.; the pH ranged from 7.4 to 8.1. The highest pH reading came just prior to the fall rains which started water flowing over the dam. Methyl-orange alkalinity ranged from 90 to 118 p.p.m. and was typical of waters in this area. The CO_2 content of the water was rather high (17 to 23 p.p.m.) ; probably owing to the abundant decaying organic materials on the bottom. Chlorides were present in a concentration of 8 to 18 p.p.m.

Discussion

Phytoplankton. — Only certain genera of phytoplankton were especially abundant in this survey — perhaps owing to the depth at which the samples were taken. The diatom Bacillariaceae were represented by five genera: *Synedra* and *Navicula* occurred more commonly, while *Fragilaria, Amphora,* and *Nitzschia* occurred in but limited numbers. The largest number of individuals per liter was found in February, just prior to the spring warming period. As the water warmed, the diatoms showed a general decrease from 400 per liter on Feb. 2, 1953, to 72 per liter on June 8, 1953, which conforms to the observations of Tressler & Wagner (1940.) The Cyanophyceae were present throughout the study in limited numbers, with little correlation with weather conditions. The genera most frequently represented were *Oscillatoria* and *Anabaena.* The Chlorophyceae were represented by the following genera: *Genicularia, Gym-*

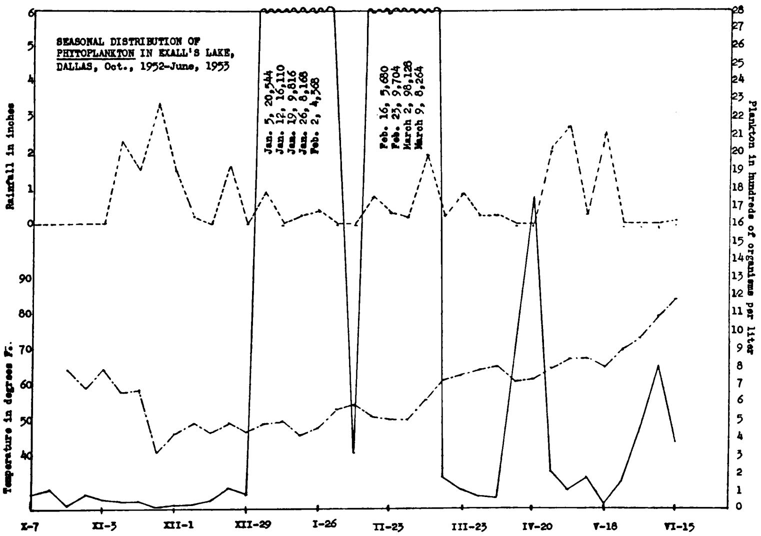


GRAPH I.

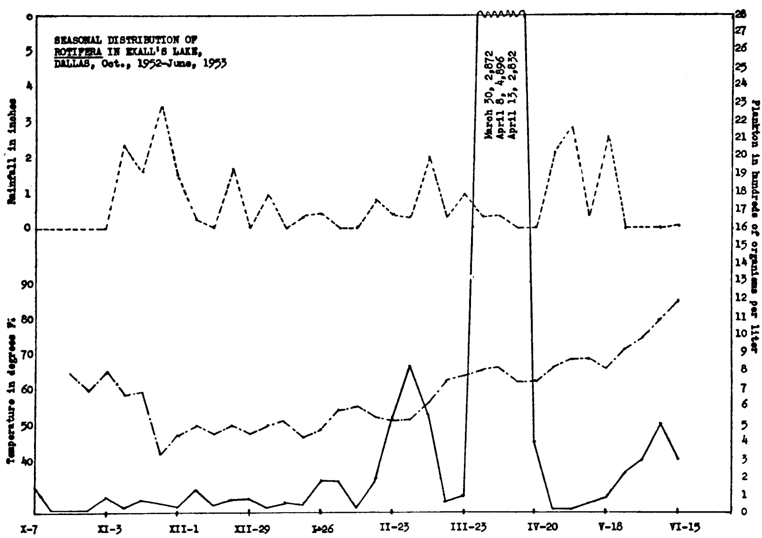


GRAPH II.

nozyga, Closterium, Spirogyra, Zygnema, Scenedesmus, Gloeocystis, Eudorina, Pediastrum, Pandorina, and *Golenkina.* All of these showed a steady increase during the spring cycle. Their numbers increased until March 2, 1953, when there were 98,016 plankters per liter; as temperature increased, there was a corresponding decrease in numbers. *Eudorina,* the dominant organism, did not appear in my



GRAPH III.



GRAPH IV.

collections until Jan. 5, 1953. During the spring period of high productivity, it showed three bloom cycles. The first cycle reached a maximum population of 20,360 individuals per liter; the second cycle had a maximum population of 98,000 per liter; the last cycle had a maximum of only 1800 per liter. The first bloom followed a slight period of warming from 47° to 49° F. The maximum was obtained at a temperature of 51° F. As the waters continued to warm, the population decreased (Graph III).

Zooplankton. — The Protozoa were represented by 8 genera, with flagellates dominant. *Euglena* and *Phacus* were most numerous at the beginning and at the end of the survey. Their numbers decreased as the temperature decreased. When the temperature reached 64° F., they apparently started to encyst. A few encysted individuals were observed during the winter cycle. On March 23, with water temperature at 63° F., the first motile individuals of the spring phase of the cycle appeared in the plankton counts (Graph I).

Other genera of Protozoa represented were *Ceratium, Vorticella, Arcella,* and *Paramecium.* Most of these appeared for only a brief period during my study and there is no evidence to link their appearance and disappearance with weather conditions. *Difflugia* appeared throughout the study in small numbers, but weather-conditions did not apparently affect their numbers.

The Rotifera were represented by 9 genera: *Asplanchna, Keratella, Polyarthra, Triarthra, Brachionus, Monostyla, Rotaria, Lecane,* and *Trochosphaera.* The rotifer population was typical of local alkaline waters as found by Patterson (1941). There were but few genera, but large populations of these were present. These findings confirm the observations of Pennak (1953). During the fall period, rotifers of nearly all genera were observed carrying eggs. The adults did not disappear completely, but continued to produce eggs. The largest population-fluctuation was found during the spring maxima (Graph IV). In April, *Keratella* showed 4480 per liter, *Triarthra* 256 per liter, *Brachionus* 264 per liter, *Asplanchna* 208 per liter, and *Polyarthra* 624 per liter. At the height of the spring reproductive cycle, I found some rotifers with as many as five eggs attached. With the advent of heavy rains, the same genera were represented in the weekly plankton-counts in reduced numbers. This condition was probably due to wash and dilution. As the summer stagnation period approached, the rotifer population declined. When the flow of water over the dam stopped, the rotifer population increased slightly (Table 1).[3]

[3] I have referred, in several places, to my "Table 1", which (because of its detail and length) could not be included in this paper, but which appears in the bound copies of the thesis, contained in the Fondren Library of Southern Methodist University. The references are retained here, for such students as may care to consult the original Graphs I-IV, here reproduced, graph the assembled data for Protozoa, Crustacea, phytoplankton, and Rotifera.

Some rotifers, such as *Lecane*, a typical acid-water rotifer (Pennak 1953), appeared only occasionally in the counts.

Copepoda.—Two genera of copepods were found in Turtle Creek. *Cyclops* was dominant and was found in every month throughout the survey, but more abundantly during cold weather. On November 17, with water temperature at 58° F., 360 organisms were present per liter. Ovisacs were always present on a few females throughout my study. Nauplii, which were present during the entire study, nearly always outnumbered the adult copepods. Peaks in production were noted on Dec. 8, 1952, with 336 per liter; Feb. 2, 1953, 400 per liter; and June 8, 1953, 382 per liter. A peak-period occurred about every 8 weeks, each lasting about two weeks. The period of lowest productions was at the start of my study. *Diaptomus,* the other copepod genus, appeared in small numbers the first seven weeks of the survey—the females with ovisacs. Their failure to reappear may be attributed, according to Pennak (1953), to the fact that some species of *Diaptomus* reproduce only during the summer months and have only one generation a year (Graph II).

Cladocera.—These were represented by three genera. *Bosmina* was the dominant organism throughout my study, but was never abundant, as its peak-population was but 24 per liter. *Daphnia* did not appear in the study until March 16, 1953. It reached its peak of 112 per liter on April 13, when the water temperature was 62° F. Females were observed with from two to eight eggs in their brood chambers. As the water-temperature increased, their numbers decreased. *Diaphanosoma* did not appear until June 1, when the water temperature was 72° F. It was found (in numbers of 32 per liter) only after water had stopped flowing over the dam (Graph II).

Free Eggs.—Egg-production reached its peak in April, when 976 per liter were counted. This coincides with the spring population peaks of the Rotifers, Cladocera, and Copepoda. The temperature was around 64° F. (*Euglena* and *Phacus* returned to the cycle at this same period.) Most of the eggs appeared to be those of rotifers and copepods. Statoblasts of *Plumatella* appeared at various times during the survey, but apparently had no connection with the temperature cycle.

Conclusions

1. The Turtle Creek impoundment is like impounded streams generally, in that fluctuations in current and water level are greatly reduced. Eddy (1934) found a similar situation in impounded waters in Illinois. From September 1952, to June 1953, a depth fluctuation of no more than 30 cm. was recorded. The temperature of the water usually showed little difference in the upper and lower levels, although thermal stratification was observed in June. Harris & Silvey (1940) found similar conditions in other Texas impoundments.

2. Various factors are involved in the production of the plankton. If the general chemical factors are favorable, weather-factors are mainly responsible for the seasonal cycles in plankton population, a conclusion arrived at by Lackey (1938).

3. Temperature-change, as well as the amount of light and rainfall, seems to be the controlling factors in plankton populations. With temperature-increase, the plankton population as a whole increases to a maximum; then a leveling off or a decline takes place as summer stagnation approaches. With temperature-decrease, the population as a whole decreases. Generally, the plankton population followed the bi-modal curve described by Campbell (1941). Temperature runs through the same cycle every year with minor variations, but the production of the plankton, as concluded by Pennak (1946), is not always consistent. The seasonal changes due to temperature-fluctuation are in the main quantitative, and the number of genera represented is essentially the same. This confirms the work of Lackey (1938).

4. Rainfall is an important factor in explaining extreme fluctuations in plankton populations. Heavy rains, such as occurred with us in November, March, April and May, were followed by extreme lowering of plankton populations by dilution. During the fall and winter, cold rains effected more rapid water-temperature changes than could be effected by air-temperature fluctuations. In the spring, warm rains speeded the warming process (Table I).

5. Although I made no measurement of light or turbidity, we know that light acts as a limiting factor where phytoplankters are concerned (Riley 1940). Observed turbidity was obviously greatest during periods of heavy rainfall, when the dilution from rainfall was the greatest. All plank-

ton counts decreased during this period; I believe, therefore, that dilution rather than lack of light is the major cause of the decline in population.

6. Diatoms were most numerous during January and February, when the water temperature varied from 46.5° to 55° F. Their increase (according to Pearsall, 1923), is believed to be associated with the large amount of oxygen and dissolved chemicals in cold water, rather than to the low temperatures involved. The phytoplankton showed a positive response to temperature-rises and were characteristic of the spring annual algae described by Transeau (1916). *Eudorina,* the dominant organism, bloomed sporadically, appearing at 49° F., and disappearing in temperature above 55° F. The blooms were apparently stimulated by slight rises in temperature. *Pandorina* appeared at the start of the summer season when the temperature was 72° F. Their numbers then increased, but were reduced by dilution during periods of heavy rainfall.

7. The Protozoa were most numerous during the spring maximum. Their growth is apparently a response to an increase in water-temperatures as described by Lackey (1938). Some species were sporadic in appearance. *Euglena* and *Phacus* disappeared at temperatures below 64° F. and reappeared at 64° F. Their behavior may be attributed to encystment or the production of other resting-forms as described by Pennak (1953).

8. The rotifers as a group followed the temperature curve. Cooling of the water was already in progress when my study started; and rotifer population declined until the period of spring warming, when the peak-production was attained. *Polyarthra* and *Keratella* showed the greatest increase in population during the spring maximum in March and April. Campbell (1941) found similar results in Douglas Lake, Michigan. During the fall cycle, rotifer eggs were produced in limited numbers. The largest production came just prior to and during the spring maximum when some individuals were observed with as many as five eggs. When extreme fluctuations in population were observed (due to weather conditions), the same genera appeared a week later in reduced numbers. The optimum temperatures were 51° F. for *Polyarthra* and 62° to 65° F. for *Keratella.*

9. Of the Copepoda, only *Cyclops* and nauplii were pres-

ent throughout the survey. The largest number of adults occurred during the fall cooling-period, and in the early summer. Their production does not appear to be related closely to temperature, because increases occurred in both falling and rising temperatures. An explanation of this phenomenon might be the existence of summer and winter species of *Copepoda,* as inferred by Pennak (1953).

10. The Cladocera were sporadic in their appearance. The greatest population was found in April when other plankters (except *Eudorina*) were most abundant. Temperature normally plays an important role in their appearance and disappearance. Depth is another factor in the vertical distribution of this group which may be governed by the amount of light available. Plankton samples were taken at the same period in the day each week, and at the same depth. However, some days on which samples were taken were rainy and cold, others were warm and bright. It is also known that the older individuals seek lower levels than the younger ones. All of the above mentioned factors probably operate not only in the determination of a behavior pattern for Cladocera, but for other groups of plankton. Pennak (1953) states that "it is useless to predict or formulate any preconceived notions concerning the seasonal abundance of Cladocera in any particular lake or pond."

11. The occurrence of Bryozoa statoblasts seems to be related to the breakdown of the colony after the polypids have formed brown bodies. Once released, the statoblasts remain viable for long periods. Rogick (1938) records statoblasts viable after 1190 days of drying. Weather fluctuations seem to have no relation to their appearance in the plankton counts although they do control the life span of the polypid.

12. Egg production of rotifers and copepods was stimulated in the fall by decreasing water-temperatures. In the spring, egg-production was stimulated by a slight rise in temperature prior to the spring peak. Spring egg-production was much more pronounced than fall egg-production.

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Distribution of the Barnacle Chthamalus dalli Pilsbry at Cabrillo Point, Monterey Bay, California

William B. Stallcup

In this work, I tried to learn the vertical distribution of *Chthamalus dalli* in the Monterey Bay intertidal zone, and its distribution in such areas as receive, or are protected from, wave impact.

Literature regarding the intertidal distribution of *C. dalli* is scant. Fox (1947) in his unpublished study of sessile barnacles in the Monterey region has given something of the ecology of this species; and Michener (1939) in similar work on the barnacles of the Moss Beach region has stated briefly the distribution of a related species, *Chthamalus fissus* Darwin.

The present data were gathered during July of 1948, chiefly in the rocky intertidal region provided by Cabrillo Point, Monterey Bay. I made many observations and area-counts at many stations around the Point. Counts were made in the following manner: each area was divided into