SEASONAL PLANKTON CHANGES AND PRIMARY PRODUCTIVITY IN BEECH RESERVOIR

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ABSTRACT

The Beech River drainage basin covers 302 square miles in west Tennessee and empties into Kentucky Lake at Tennessee River Mile (TRM) 136.0. Beech Reservoir, with a shoreline of 22 miles and a pool area of 347 hectares, is one of eight reservoirs located in this drainage basin.

In this study, phytoplankton productivity studies, phytoplankton standing crop and certain chemical analyses indicated that Beech is a more productive reservoir. Primary productivity values ranged from 85 mg C/m²/day in February to 5,563 mg C/m²/day in September. The 9-month primary productivity mean was 1,619 mg C/m²/day. Chlorophyll a concentrations ranged from 14 mg/m² in August to 124 mg/m² in March. Phytoplankton cell counts averaged 6,961,555/1. The major ionic change was shown when total iron increased in the hypolimnion during April. Iron concentrations reached a maximum in August.

INTRODUCTION

The Beech River watershed is located in west Tennessee near Lexington about midway between Nashville and Memphis (Figure 1). The topography of the watershed is gently rolling to hilly, and is dissected by many small streams which combine to form the Beech River.

Figure 1. Beech watershed located halfway between Nashville & Memphis, indicated by star.

The river flows eastward across Henderson and Decatur counties to join the Tennessee River near Perryville, at an elevation of approximately 360 feet, at Tennessee River Mile (TRM) 136.0. The Beech River drainage basin, about 22 miles long and 14 miles wide and lying within a 600-foot high rim, covers 302 square miles (Figure 2).

Figure 2. Beech River watershed.

Beech Reservoir (Figures 3 and 4) is the largest of eight reservoirs in the Beech River Tributary Area Development watershed project. The reservoir is situated on unconsolidated sediments of cretaceous age. Most of the basin is composed of these sediments which extend from the Mississippi River escarpment on the west to within 10 miles of the Beech-Tennessee River confluence on the east. These sediments consist of sands, clays, and marls which erode under the influence of surface waters and result in soils which are generally
The development plan for Beech River provided that Beech Reservoir would be the only reservoir in the watershed especially constructed for flood control, recreation, and a municipal water supply (for Lexington, Tennessee). To encourage recreational values of Beech Reservoir, the Tennessee Game and Fish Commission and TVA removed all rough fish in 1964 and restocked it with black bass, bluegill, and channel catfish. The reservoir was opened for fishing, boating, water skiing, and swimming in 1965. The pertinent facts about all permanent pool reservoirs in the watershed are shown in Table 1.

**TABLE 1. Normal Pool Reservoir Statistics (Agreement Between Beech River Watershed Development Authority and TVA)**

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Elevation (ft)</th>
<th>Pool Area (Acres)</th>
<th>Length of Shoreline (Miles)</th>
<th>Beneficial Land (Acres)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Beech</td>
<td>459.90</td>
<td>860</td>
<td>22</td>
<td>2,200</td>
</tr>
<tr>
<td>Cedar</td>
<td>436.85</td>
<td>150</td>
<td>8</td>
<td>800</td>
</tr>
<tr>
<td>Pine Oak</td>
<td>430.30</td>
<td>250</td>
<td>12</td>
<td>1,000</td>
</tr>
<tr>
<td>Redbud</td>
<td>439.15</td>
<td>230</td>
<td>7</td>
<td>800</td>
</tr>
<tr>
<td>Dugwood</td>
<td>396.56</td>
<td>119</td>
<td>11</td>
<td>1,300</td>
</tr>
<tr>
<td>Sycamore</td>
<td>469.96</td>
<td>220</td>
<td>9</td>
<td>950</td>
</tr>
<tr>
<td>Pine</td>
<td>464.85</td>
<td>216</td>
<td>4</td>
<td>775</td>
</tr>
<tr>
<td>Total</td>
<td>2,879</td>
<td>82</td>
<td>8,823</td>
<td></td>
</tr>
</tbody>
</table>

**METHOD**

Measurements of primary productivity, diatom, and phytoplankton were made at monthly intervals. All samples were collected at the sampling station above the dam. "Carbon-14 Technique"

It has been established that considerable variation occurs in seasonal primary productivity rates in lakes (Bogue at al., 1958; Goldman, 1960). However, the general productivity trends can be analyzed from monthly determinations with limited time and cost, depending upon population densities within the month. "Carbon-14 standardization was determined by C. R. Goldman, Institute for Hydrology, University of California, by combustion and gas chromatography. Water samples for "Carbon-14" standardization measurements were collected with a polyethylene (Van Dorn) water sampler at the surface and at depths of 1, 2, 3, and 7 m. The samples were transferred to clear 125-ml pyrex bottles, and 2.5 ml of NaOH-CO was injected into each bottle with a syringe. Duplicate sampling bottles were suspended at the collection depth for 4 hr. At selected depths, a dark bottle was used with the clear bottles to compensate for the amount of non-photochemical assimilation of C4. The C4 samples were usually incubated for 3 hours. After incubation, 1 ml of 10% Formalin was added to each bottle to stop the photosynthetic process and fix the products. The bottles were immediately placed in a light-tight box, and the bottles were wrapped in aluminum foil and the bottles in glass vials were sealed with Parafilm. The filters were held in darkness in the dark room until counted at the laboratory. Activity was measured with a thin-window, low-background, gas-flow proportional Beckman counter for which counting efficiency was 90%. Total inorganic carbon available for photosynthesis (mg C/l) was calculated by the following equation: (Trichelton, 1959). The equations incorporated in these procedures were processed through TVA's IBM 30 computers. By comparing a series of values of total light available during the incubation period, productivity during the incubation period could be extrapolated to the total productivity per day. Light data were obtained from the U.S. Weather Bureau stations. "Light Intensity (foot-candles)" (i.e., foot-candles per day, surface light intensity (foot-candles per hour), and monthly productivity data conducted by the Water Quality Branch, Division of Environmental Research and Development, TVA.)
in Figure 6 were determined during the day of investigation. Monthly mean values are not used in this figure. During February and March 1968, relatively low productivity measurements were found throughout the photic zone. A significant increase in surface productivity occurred in April and May (77 and 61 mg C/m²/day) at the surface. Surface productivity rapidly increased from June through October (1017, 143, 242, 405, and 422 mg C/m²/day). However, productivity at other depths was suppressed during September and October, especially October when no productivity occurred below 2 meters. The mouth of greatest productivity in lower depths (5 m) was August with 17 mg C/m²/day.

**Figure 6.** Seasonal comparison of the variation with depth of primary productivity, light penetration, temperature, and dissolved oxygen.

Greatest light penetration occurred in February (1 percent at 6 m). Light penetration ranged from 3 m to 4 m from March through August. Rapid reduction of light occurred during September and October (0.1 percent at 1.8 m and 1.2 m). At these times rapid reduction of light was closely related to water turbidity caused by organic detritus and phytoplankton.

The total photosynthesis per day of available light was extremely low on February 28 (49 photosynthesis per day) while the greatest solar radiation was observed on April 24 (724 photosynthesis per day). Solar radiation decreased from June to October from 646 photosynthesis per day to 210 photosynthesis per day.

Water temperature profiles did not indicate stratification during February and March; stratification was first found in April with the thermocline at approximately 6 m. Thermal stratification prevailed from April through September and ranged from 4 m to 6 m during April through August. As the water temperature slowly begins to cool in September, thermal stratification was evident even below 6 m. Surface temperatures ranged from 3.9°C to a maximum of 28.4°C in July and August. The average September surface temperature was 23.9°C. Temperatures and dissolved oxygen values were not determined in October.

**Figure 7.** Seasonal and daily variation in oxygen content (mg/L), and total productivity in mg/m²/day—Beach Reservoir.

The values in Table 2 should not be considered as 100% photosynthetically active cell substances because values are at 3 m (below the euphotic zone) sometimes were greater than those in photic zone. These larger values were obtained from dying and sinking phytoplankton—not an uncommon occurrence in small, shallow waters where this is little flow.

Total pigment concentration was highest throughout the profile during March. The concentration, 20-28 mg chlorophyll a/m³, was about twice as great as in either months. Total phytoplankton cell concentrations were similar in February, April, May, September, and October. During July, a notably larger concentration of single cells was found at 5 m than in the upper 3 m. De-composition of the cells was evident as low dissolved oxygen values were obtained during August (Figure 6) when almost anoxic conditions existed throughout the lower columns. An extremely low chlorophyll a concentration was obtained in August between the surface and a depth of 5 m.
Figure 8 illustrates the "standing crop" of phytoplankton in terms of actual number of phytoplankton cells. Cell numbers are reported as the mean values for the epipelagic waters during 1968. The spring maximum (approximately 12,656,000 cells/1) of total phytoplankton cells was reached in May. Similar concentra-
tions of total phytoplankton (12,516,000 cells/1) were measured in September after relatively low summer values.

WATER CHEMISTRY

Table 3 contains the means values for nitrogen and phosphorus in the upper 4.57 m and for the remainder of the water column of Beech Reservoir. Total nitrogen (organic, nitrate, nitrite, and nitrate) values in the upper 4.57 m ranged from 0.61 mg/l in May to 0.99 mg/l in October. Total nitrogen in the upper 4.57 m ranged from 0.67 mg/l in June to 0.43 mg/l in August, and the average total nitrogen was 0.74 mg/l from February through October. Ammonia concentrations were extremely high in the lower water mass in August and September (3.95 mg/l and 1.79 mg/l, respectively). Organic nitrogen values were also high during these two months (1.15 mg/l and 0.88 mg/l). On August 14, at depth of 7.92 m (5.20 m) below the surface was 0.01 mg/l, which was the highest value of the sampling period. A value of 3.50 mg/l to 0.71 mg/l in September. The highest average total phosphate concentration in the upper 4.57 m was 0.22 mg/l in March and the lowest concentration was 0.02 mg/l in August. The average phosphate concentration during the sampling period was 0.10 mg/l. The highest soluble phosphate value (0.10 mg/l) also occurred in March. Phosphate below a depth of 4.57 m had a 9-month mean slightly higher than in the upper 4.57 m and varied from 0.14 mg/l. A mean of 0.29 mg/l of total phosphate in the area below 4.57 m was recorded in August for the highest concentration during this study. High total phosphate concentrations were also recorded during April (0.28 mg/l) and May (0.34 mg/l).

Monthly values of chemical analyses other than nitrogen and phosphorus are shown in Table 4. Beech Reservoir water is low in nitrate, but has high values for total alkalinity and hardness. Total alkalinity was from 12.5 mg/l in the upper 4.57 m in February to 20 mg/l in June. Below the 4.57 m range was from 12 mg/l in February to 66 mg/l in August. Nine-month averages were 50 mg/l in the upper meters and 27.4 mg/l in the lower meters. Calcium hardness (21 mg/l) and highest calcium concentrations (4.9 mg/l CaCO₃) in the upper 4.57 m were recorded in August. Total hardness and CaCO₃ values below 4.57 mg/l were high for the reservoir during August (36.0 mg/l CaCO₃ and 11.0 mg/l CaCO₃). Mg²⁺ ions were scarce.

Sodium and potassium were present in relatively low concentrations. The chloride ion averaged 3.1 mg/l in the upper 4.57 m and 3.4 mg/l below 4.57 m. Sulfate and silica averaged 3.0 mg/l SO₄²⁻ and 1.4 mg/l in the top 4.57 m of water and 2.4 mg/l SiO₂ in the bottom 4.57 m.

Below 4.57 m, the average pH was 7.60 for the upper 4.57 m and 6.8 below 4.57 m. The lowest pH (6.2) was recorded at 7.62 m in July and at 7.32 m in September. Lower pH values were found during periods of low stratification and turnover. The average pH (7.6) was recorded at the surface on March 27.

On April 24, total iron increased rapidly to 2.000 µg/l at 8.86 m near the bottom with a mean of 1.165 µg/l below 4.57 m. Total iron in the hypolimnion increased from 283 µg/l in March to 1.165 µg/l in April and continued throughout the studies. The higher con-
centrations gradually rose toward the upper limit of the hypolimnion (approximately 4.57 m from the surface). On August 14, the maximum total iron concentration (15,000 µg/l) was measured at a depth of 7.92 m on
The same data, at 6.10, 7.00 a.m. 1/2 was recorded. A decrease in iron (12,200 µg/l) was observed at the reservoir bottom in September and the decrease continued throughout most of the fall. Han and magnesium concentrations followed a similar pattern.

**DISCUSSIONS**

Monthly fluctuations of total productivity per square meter in the phytoplankton were pronounced. The data from Figure 6 from March through September (Figure 5). The rate of increase was rapid as expected for a small, shallow reservoir. A large portion of the nutrients was tied up in dissolved and particulate fractions as shown in Table 4.2, which noted a small increase in DO and ammonia, whereas the more extensive nitrates were nitrates. Apparently nutrients were never the limiting factors since availability of light was low and nutrients were present in high concentrations.

The depletion of hypolimnetic oxygen was evident from April through mid-June. (Figure 8) shows the time and amounts of incidences of hypolimnetic productivity. Productivity from the hypolimnion by the phytoplankton set off and other changes in the oxygen depletion occurring below the thermocline. This change in the pattern of oxygen depletion occurs when a heavy phytoplankton crop settles onto the thermocline and sets up a stratified system. In the Cypriophyta, the mechanism for suppression of phytoplankton growth is the generation of dissolved oxygen, which is the difference between the two layers. In the Cypriophyta, the mechanism for suppression of phytoplankton growth is the generation of dissolved oxygen, which is the difference between the two layers. Oxygen depletion occurs earlier each year in these reservoirs than in reservoirs such as Nettley and Norrice which have smaller phytoplankton crop sets. Oxygen depletion occurs in the Cypriophyta, the mechanism for suppression of phytoplankton growth is the generation of dissolved oxygen, which is the difference between the two layers. Oxygen depletion occurs earlier each year in these reservoirs than in reservoirs such as Nettley and Norrice which have smaller phytoplankton crop sets. Oxygen depletion occurs in the Cypriophyta, the mechanism for suppression of phytoplankton growth is the generation of dissolved oxygen, which is the difference between the two layers.