EVALUATION OF PREDICTED AND OBSERVED EFFECTS FOR A 90° F MIXED TEMPERATURE LIMIT, BROWNS FERRY NUCLEAR PLANT

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1.0 Executive Summary

As a result of continuing discussions between TVA and EPA, Region IV, concerning thermal discharges at Browns Ferry Nuclear Plant and consistent with EPA's understanding expressed at a meeting on December 20, 1979, TVA has developed a 316(a) demonstration to show the 86°F thermal standard at Browns Ferry Nuclear Plant is more stringent than necessary and that a 90°F maximum would satisfactorily protect aquatic life in Wheeler Reservoir. This document and accompanying package include background information on the cooling tower system, costs of alternative cooling systems, a 316(a) demonstration, the final 316(b) demonstration, and support documentation. A summary of cooling tower status and the 316 demonstration follows.

The once-through heat dissipation system was originally designed and constructed to meet maximum water temperature criteria of 93° F and a 10° F temperature rise, judged by TVA to be adequate to protect aquatic life in Wheeler Reservoir. These criteria were consistent with regulatory requirements at the time. In December 1971, EPA informed TVA that these criteria would be changed for waters of the Tennessee River Basin in Alabama as follows: "Waters of the Tennessee River Basin and portions of the Tallapoosa shall not be increased more than 5° F, above the natural prevailing background temperatures, nor exceed a maximum of 86° F."

Consequently, to meet these limitations, TVA installed six 16-cell mechanical draft cooling towers designed to operate in either helper or closed-mode. However, the cooling tower system did not perform as

designed and during some summer months it was necessary to significantly derate the plant or risk noncompliance with the 86° F maximum mixed-reservoir thermal standard.

TVA asked for, and EPA granted interim relief from the 86° F maximum mixed-river temperature on July 13, 1977, requiring TVA to comply with a 90° F maximum mixed-reservoir temperature and a 5° F maximum temperature rise any time the upstream temperature exceeded 81° F. TVA's initial strategy for long-term resolution of difficulties related to thermal standards and deficient cooling tower performance included structural upgrading of all existing cooling towers. New fill material was installed in one tower at a cost of about one million dollars in expectation of improving thermal performance. Unfortunately it was not significantly improved by the fill addition. Therefore it became necessary to explore other options to obtain long-term resolution of the problems.

One option currently available for meeting the 86° F thermal standard is the addition of two mechanical draft cooling towers. This option would cost about $35 million more (this includes capital cost, operating and maintenance, and plant load reductions during tower construction) than the preferred (base cost) option of improvementing the existing system to meet a 90°F thermal limit. Another option would be to modify the existing tower system at an incremental cost (over the base cost option) of $150 million in lieu of adding towers. A third option for meeting the 86° F thermal standard is to operate the existing tower system in its current status with derating at an incremental cost of $250 million.

Options currently available for meeting a 90° F thermal limit include modifying the existing tower system by upgrading thermal performance in lieu of adding towers. This has the base cost and is the preferred option. Other alternatives for meeting a 90° F thermal limit include addition of two mechanical draft cooling towers at an incremental cost of $33 million or operating with the existing tower system in its current status with derating at an incremental cost of $100 million.

TVA, following extensive data evaluation, now believes that permanent relaxation of the 86°F thermal standard to a 90°F limit would adequately assure the protection and propagatation of a balanced and indigenous population of shellfish, fish, and wildlife in and on the Tennessee River (Wheeler Reservoir). In addition, such a relaxation would avoid the more costly alternatives of either taking large load reductions or installing additional cooling towers at the plant.

2.0 Background Report on Heat Dissipation System and Costs of Alternative Cooling Systems - Browns Ferry Nuclear Plant

2.1 Browns Ferry Nuclear Plant

Browns Ferry Nuclear Plant was begun in 1966 as part of TVA's program designed to meet projected load requirements. Construction of the plant began in May 1967 after the Atomic Energy Commission (AEC) issued provisional construction permits for units 1 and 2. Unit 3 was given a construction permit in July 1968. Commercial operation was achieved on units 1, 2, and 3 on August 1, 1974; March 1, 1975; and March 1, 1977, respectively. Units 1 and 2 were shutdown in March 1975 because of a cable fire. Following the fire outage, all 3 units were placed in service in September 1976.

2.2 History of Heat Dissipation System

The history of auxiliary cooling facilities in the face of changing criteria and thermal standards as they were finally adopted by the Environmental Protection Agency (EPA) is described in considerable detail in the final environmental statement (Issued on September 1, 1972). Aspects that pertain to the present situation are repeated herein.

2.2.1 Thermal Standards--The heat dispersal system for the Browns Ferry plant was originally designed and constructed to meet standards permitting a temperature rise of 10° F with a maximum temperature of 93° F. These standards were judged by TVA to be adequate to protect aquatic life, and the State of Alabama subsequently proposed identical standards in compliance with the Water Quality Act of 1965.

However, in April 1971, the Federal Water Pollution Control Administration (now EPA) recommended that the State of Alabama adopt temperature standards that would limit the maximum temperature rise of a stream by the addition of heat to no more than 5^{o} F with a maximum allowable water temperature not to exceed 90^{o} F. Exceptions were made in the Tennessee River Basin and portions of the Tallapoosa River Basin designated by the Alabama Department of Conservation as supporting smallmouth bass, sauger, and walleye. In these areas the temperature was not to exceed 86^{o} F. Thus, Wheeler Reservoir was officially designated as supporting this type fishery. The Cahaba River drainage basin was later included in this category. The State of Alabama did not immediately adopt these recommended temperature standards.

While changes to more restrictive standards were often mentioned, it was not until December 17, 1971, that EPA informed TVA that criteria would be more stringent for waters of the Tennessee River Basin in Alabama as follows; "Temperature shall not be increased more than 5^{o} F above the natural prevailing background temperatures, nor exceed a maximum of 86^{o} F."

These temperature standards, proposed by EPA for the State of Alabama, were published by EPA in the March 11, 1972, Federal Register. Alabama adopted these standards and EPA approved them on September 19, 1972.

As reflected in the 1971 recommendation establishing the 86° F maximum temperature, EPA's protocol for the application of temperature criteria in setting standards was species dependent. Although temperature criteria have undergone substantial development since 1971, this protocol has not changed. For example, Brungs and Jones (1977; EPA Environmental Research Laboratory-Duluth) reported that the evolution of freshwater temperature criteria has advanced from the search for a single "magic number" to the generally accepted protocol for determining mean and maximum numerical criteria based on the protection of appropriate, desirable and/or important fish species.

Therefore, in the following assessment of a 90° F thermal standard on the biota of Wheeler Reservoir, it is appropriate to emphasize important fish species, particularly smallmouth bass, sauger, and walleye. This approach is in accord with the rationale established by EPA (Mount, 1969; Brungs and Jones, 1977). In general, the rationale followed by EPA is that the sensitivity to thermal increases is greater for selected fish species (in this case sauger, smallmouth bass, and walleye) than for the food producing capacity (plankton and benthos) of their environment.

2.2.2 Diffuser System--It was recognized in the early stages of plant design that condenser circulating water should not be discharged directly into the surface strata of Wheeler Reservoir. Instead, it was decided that by means of a diffuser, the condenser circulating water should be mixed as quickly as possible with as much unheated

reservoir water as possible. By this procedure, no excessively warm surface strata would exist and the mixing zone would be restricted to a relatively small area.

Based on extensive TVA studies and the experience of others at the time Browns Ferry was designed, it was concluded that these heat dispersal facilities would adequately protect the waters of Wheeler Reservoir for the following uses: Public water supply, swimming and other whole body water-contact sports, shellfish harvesting, fish and wildlife, agricultural and industrial water supply, and navigation.

In light of EPA's letter of December 17, 1971, and TVA's policy to take appropriate action on a timely basis to meet any further applicable standards, TVA determined that the diffuser system alone was not adequate to ensure acceptable conformance with this proposed standard. The alternatives of mechanical draft cooling towers, natural draft cooling towers, spray canal system, and cooling lake for heat dissipation were reevaluated, and it was decided that mechanical draft cooling towers would provide the best long-term solution to meet the more stringent thermal standards. The towers were designed to supplement the diffuser system by dissipating part or all of the heat directly to the atmosphere.

2.2.3 Cooling Towers--The heat dissipation system selected consists of six 16-cell rectangular, mechanical-draft cooling towers (Figure 2.2-1)

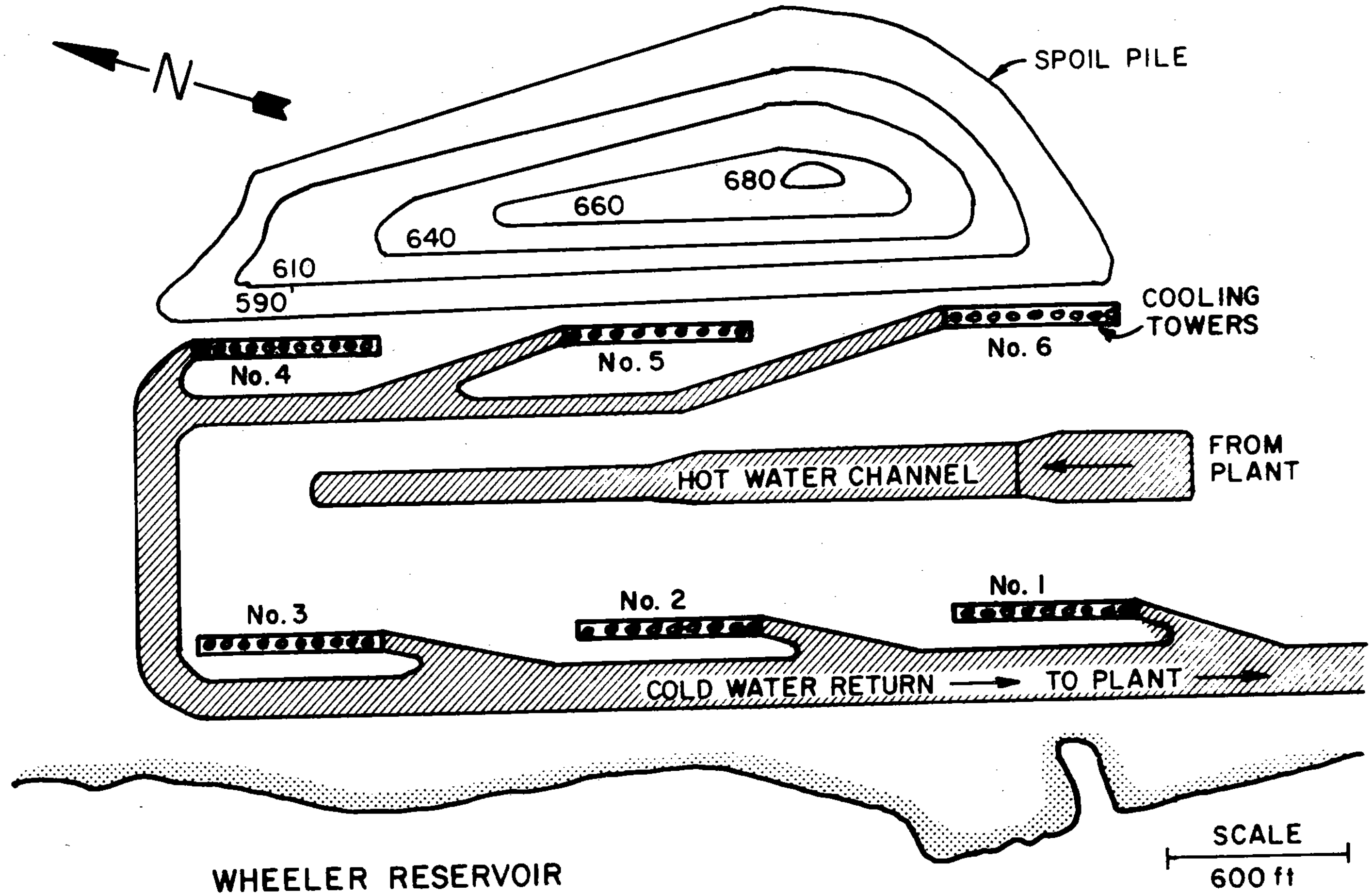


Figure 2.2-1 : Plan View of Browns Ferry Cooling Tower Basin

designed to operate in either helper or closed-mode. Conditions requiring operation of the towers occur most commonly during spring and summer months. When cooling towers are not required to comply with thermal water quality standards, the cooling system of the plant is operated in open mode as originally designed.

Once in operation the cooling towers failed to meet the design requirements. As a result, during some summer months it was necessary to significantly derate the plant or risk noncompliance with the thermal standards adopted for Wheeler Reservoir. In addition to the operating deficiency, one cooling tower structurally failed on July 10, 1977. Subsequent inspections revealed that all of the towers needed structural upgrading. The use of the cooling towers was restricted until structural repairs could be completed in early 1979. For these reasons, on July 13, 1977, TVA asked EPA for relief from the 86° F maximum mixed-reservoir temperature. EPA granted such relief on July 15, 1977, requiring that TVA comply with a 90° F maximum mixed-reservoir temperature and a 5° F maximum temperature rise at any time the ambient upstream temperature exceeded 81° F. EPA also asked TVA to present a strategy for the long-term resolution of the problem. The following section outlines the several alternative means for this resolution.

2.3 Currently Available Options for Thermal Compliance

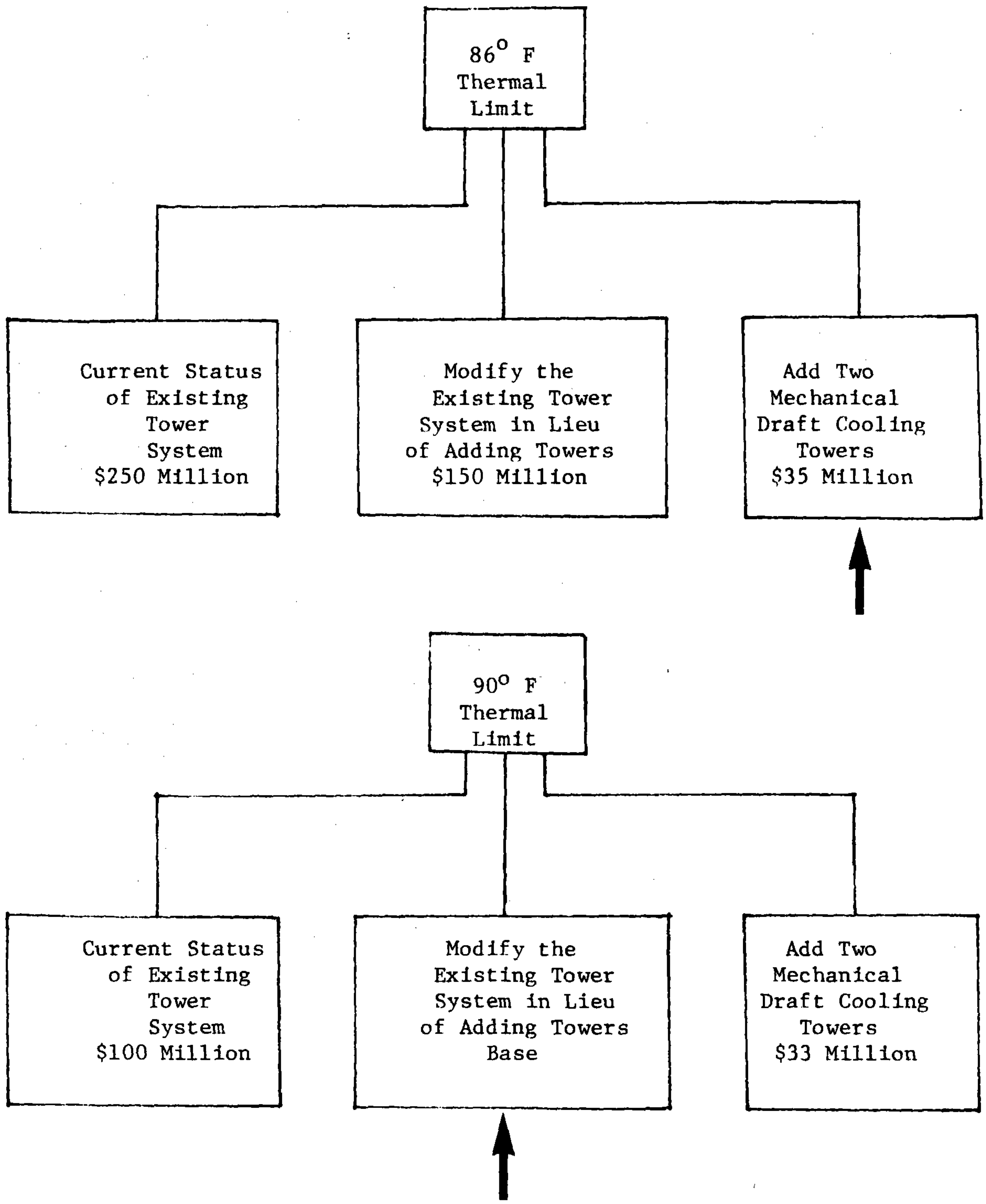
Since the summer of 1977, Browns Ferry has operated to meet a mixed-reservoir thermal limit of 90° F while studies and investigations were being performed by TVA to determine a permanent solution to inadequacies

in the cooling towers. Figure 2.3-1 shows the incremental costs for meeting either the existing 86° F thermal standard in the reservoir or a 90° F limit using modifications of the existing tower system with a 90° F thermal limit as the base cost option.

Studies conducted show that operation with an 86° F maximum mixed-reservoir temperature would require TVA to (1) add two round mechanical draft cooling towers at an incremental cost over the base cost of $35 million (this includes capital cost, operating and maintenance, and plant load reductions necessary during tower construction), (2) incur load reductions at an incremental cost of $250 million over the life of plant if no towers were added, or (3) modify the existing tower system and incur load reductions at an incremental cost of $150 million (includes modifications and plant load reductions). The addition of two round mechanical draft cooling towers is the most cost-effective alternative to meet the 86° F thermal standard.

For the 90° F thermal limit, the most cost-effective alternative, and the option which is preferred, would be to modify the existing tower system, thereby minimizing required load reductions. Modifications to the existing cooling towers included testing of one cooling tower with a different fill material which indicated only a small improvement in performance. Trends in the data, however, indicated potential for improved performance at higher ambient conditions than were available during the testing period. This trend was identified in test data taken on both the modified and unmodified cooling towers. To quantify this improvement, additional testing will be performed during the summer of 1980. An extensive study is also underway to investigate methods of narrowing the operating margins of the plant's

INCREMENTAL COSTS* OF AVAILABLE OPTIONS



*Total incremental costs including load reduction penalties, capital costs, O&M costs, etc.

Figure 2.3-1

internal constraint temperature. Additional alternatives to modifying the tower system are: (1) Adding two round mechanical draft cooling towers at an incremental cost of $33 million, or (2) incurring load reductions at an incremental cost of $100 million with the existing towers in their current condition.

An alternative to adding cooling towers also studied is the construction of a new intake pumping station located on the river to supply water for the plant nuclear safety cooling system. The cost of a new intake pumping station has been estimated to be on the order of $60 million with a 5-year construction period ($60 million does not include any load reductions necessary during the construction period). The 5-year period could be extended substantially due to activities necessary in the licensing of the new pumping station. Another alternative to adding cooling towers examined is seismic qualification of gate structure 2, gates 1 and 1A, the discharge control structure, and the cool water channel dike. A previous investigation indicated a high degree of uncertainty in being able to adequately qualify all of these structures. Neither of these alternatives would be attractive unless the 90^{o} F thermal limit were obtained in conjunction with operation in helper mode in lieu of closed mode.

2.4 Summary and Conclusions of Options Available

If the Browns Ferry Nuclear Plant is required to operate to meet the 86^{o} F maximum mixed-reservoir temperature, the most cost-effective approach would be to add two round mechanical draft cooling towers thereby minimizing plant load reductions during summer months.

Assuming a permanent 90° F thermal variance, tower additions can be avoided by increasing the existing tower capability by about 6 percent. Recent tests indicated that tower capability increases with increasing wet bulb temperatures which prevail in summer. Additional testing will be performed in the summer of 1980 to quantify the actual capability at these extreme conditions. Adoption of a 90° F limit may make the addition of new cooling towers unnecessary. This is the perferred option.

3.0 Hydrothermodynamics and Biotic Aspects of Wheeler Reservoir

Wheeler Reservoir was formed in 1936 by the closure of Wheeler Dam at Tennessee River Mile (TRM) 275.0. Water surface elevation in Wheeler Reservoir normally varies six feet or less annually. From approximately April through July, reservoir elevation is near maximum (556 feet above mean sea level) and fluctuates only slightly, while during the remainder of the year it is approximately five to six feet lower. Normal minimum pool is 550 feet above mean sea level.

Reservoir depths vary from about 50 feet near Wheeler Dam to about 25-30 feet in the main river channel near the plant site. Reservoir widths vary from 5,000 to 10,000 feet in the 19 miles between the plant and the dam. Approximately 60 percent of the reservoir's total volume of 1,120,000 acre-feet at normal maximum pool is downstream of the plant. From the vicinity of the plant upstream, Wheeler Reservoir is characterized by a main river channel of about 2000 foot width and 20-30 foot depth and extensive, shallow (5-15 feet) overbank areas on either side of the main channel.

3.1 Hydrothermodynamics of Wheeler Reservoir

The average annual river flow past the plant site can be estimated from a streamflow gaging station at Whitesburg, Alabama, about 39 miles above the Browns Ferry site, which the U.S. Geological Survey has maintained since 1937. The average daily streamflow at this station for 46 years of record is about 42,500 cfs. At the Browns Ferry site the estimated average annual streamflow is about 45,000

cfs. Table 3.1-1 lists the percentage of days the mean daily flows at the Browns Ferry site could be below the indicated discharge based on the Whitesburg gage data for the period 1951 to 1970.

Instantaneous river flows in the vicinity of the plant are primarily dependent upon discharges from Guntersville Dam (TRM 349), which is 55 miles upstream, and from Wheeler Dam (TRM 275), which is 19 miles downstream of the plant. The hourly releases from Guntersville and Wheeler Dams for 10 years of record (1959-68) are illustrated by the flow duration curves of Figures 3.1-1 and 3.1-2. These hourly records show that the periods of low or no flow are only a few hours duration. Low or no flow occurrences can be eliminated by adjusting the daily operation of Guntersville and Wheeler Dams.

Wheeler Reservoir stratifies because water depth is greater than the depth of the surface layer affected by solar radiation. This stratification is usually weak because of the relatively short transit time in Wheeler Reservoir (1-2 weeks) and the fact that the turbine intakes on Wheeler Dam withdraw water from the entire vertical depth of the reservoir.

Tables 3.1-2 to 3.1-7 summarize temperature extremes and stratification in lower Wheeler Reservoir by month from 1974 to 1979. Temperature data were collected by hourly water temperature monitors at TRM 275.0 near Wheeler Dam and at TRM 286.0 just

Table 3.1-1. Frequency of river flows near Browns Ferry Nuclear Plant, 1959-1968.

Tennessee River Mean Daily Discharge at Browns Ferry (cfs)	Percent of Days Mean Daily Discharge Is Lower
50,000	76
45,000	67
40,000	56
33,000	35
30,000	27
25,000	17
20,000	10
15,000	6
10,000	3
5,000	1
1,000	0.3

Table 3.1-2. Summary of temperature extremes and stratification frequencies in Lower Wheeler Reservoir during 1974.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec.
Near Wheeler Dam												
Maximum (°F)	53.2	53.6	57.1	73.6	85.0	88.6	90.0	90.0	89.7	76.8	65.3	53.7
Minimum (°F)	44.2	44.9	46.9	38.8	61.2	71.3	78.8	78.0	63.8	61.2	49.4	42.5
0 - 1.5	92.7	93.2	92.6	59.9	2.3	18.9	17.6	25.4	65.4	52.0	84.4	97.9
1.6- 3.0	6.7	6.0	5.9	12.5	12.6	27.3	29.4	24.8	17.0	19.5	14.0	1.7
3.1- 5.0	0.6	0.8	1.2	10.3	18.1	32.7	37.0	26.7	12.2	16.9	1.6	0.4
5.1- 7.0	0	0	0.2	7.4	21.3	16.1	13.8	17.2	5.0	7.1	0	0
7.1-10.0	0	0	0.2	7.5	25.5	4.4	1.9	5.9	0.4	4.1	0	0
10.0-	0	0	0	2.4	20.3	0.6	0.3	0	0	0.5	0	0
Near the Elk River												
Maximum (°F)	59.6	54.8	62.0	75.0	84.9	89.3	90.8	92.3	89.9	80.8	69.2	55.5
Minimum (°F)	43.4	43.7	46.2	53.2	67.6	75.8	79.6	78.1	65.5	61.8	49.1	42.2
0 - 1.5	95.2	94.7	95.0	69.7	52.3	62.0	53.8	63.4	71.7	66.8	89.0	96.8
1.6- 3.0	4.0	4.7	2.4	9.6	20.1	19.3	26.4	19.0	14.7	14.7	7.6	2.4
3.0- 5.0	0.9	0.6	1.9	12.2	12.9	12.5	14.2	11.6	9.8	9.7	3.3	0.8
5.1- 7.0	0	0	0.5	2.3	8.1	4.3	3.6	5.1	3.5	6.3	0.1	0
7.1-10.0	0	0	0.1	4.1	5.6	1.9	2.0	0.8	0.3	2.4	0	0
10.0-	0	0	0	2.1	1.0	0	0	0	0	0.1	0	0

Note: For a given hour, the difference between the maximum and minimum temperatures is computed and sorted by range (eg., 0-1.5). The number of occurrences in each range is divided by the number of observations to give the precent of time in each range.

Table 3.1-3. Summary of temperature extremes and stratification frequencies in Lower Wheeler Reservoir during 1975.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Near Wheeler Dam												
Maximum (^{o}F)										71.6	69.0	51.9
Minimum (^{o}F)										61.8	51.6	45.3
0 - 1.5										57.5	82.0	96.9
1.6- 3.0										25.6	9.2	3.0
3.1- 5.0										15.6	7.5	0.1
5.1- 7.0										1.0	1.3	0
7.1-10.0										0.3	0	0
10.1-										0	0	0
Near the Elk River												
Maximum (^{o}F)										73.5	73.7	52.5
Minimum (^{o}F)										49.3	51.9	45.1
0 - 1.5										77.8	92.1	96.1
1.6- 3.0										17.2	5.2	3.9
3.1- 5.0										4.4	1.8	0
5.1- 7.0										0.3	0.6	0
7.1-10.0										0	0.3	0
10.1-										0.2	0	0

Note: For a given hour, the difference between the maximum and minimum temperatrues is computed and sorted by range (eg., 0-1.5). The number of occurrences in each range is divided by the number of observations to give the percent of time in each range.

Table 3.1-4. Summary of temperature extremes and stratification frequencies in Lower Wheeler Reservoir during 1976.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Near Wheeler Dam												
Maximum (^oF)	45.5	55.0	63.0	74.8	78.8	85.5	88.4	87.2	84.5	76.1	57.6	51.8
Minimum (^oF)	38.5	41.7	52.1	58.9	64.7	68.1	76.5	79.3	74.4	56.0	48.1	41.8
0 - 1.5	100.0	84.9	66.8	22.4	49.1	25.0	9.8	42.2	76.6	90.3	84.2	94.8
1.6- 3.0	0	13.1	22.6	19.0	19.6	22.9	31.8	37.0	16.8	7.9	12.3	4.5
3.1- 5.0	0	2.0	9.7	26.1	15.6	12.6	32.6	15.5	6.0	1.8	3.4	0.5
5.1- 7.0	0	0	0.9	17.4	7.5	9.9	17.6	5.2	0.6	0	0.1	0.1
7.1-10.0	0	0	0	13.5	6.8	15.3	8.2	0.2	0	0	0	0
10.1-	0	0	0	1.6	1.3	14.2	0	0	0	0	0	0
Near the Elk River												
Maximum (^oF)	46.0	55.0	65.0	74.8	80.4	88.3	87.3	89.1	88.0	78.0	59.2	64.6
Minimum (^oF)	35.4	41.8	53.0	59.0	64.1	70.5	78.6	79.2	74.5	56.5	49.0	36.0
0 - 1.5	99.7	92.6	85.7	44.7	58.2	53.9	47.8	60.0	70.7	86.3	94.2	93.6
1.6- 3.0	0.3	5.6	8.3	20.2	16.9	11.3	31.3	25.0	18.7	8.9	4.2	4.7
3.1- 5.0	0	1.1	3.7	13.7	11.7	12.9	17.0	10.8	8.4	4.6	1.6	0.9
5.1- 7.0	0	0.5	2.2	13.9	8.4	7.9	3.8	3.4	1.5	0.3	0	0.1
7.1-10.0	0	0.2	0.2	6.0	3.6	9.9	0	0.8	0.6	0	0	0.1
10.1-	0	0	0	1.5	1.3	4.1	0	0	0	0	0	0.5

Note: For a given hour, the difference between the maximum and minimum temperatures is computed and sorted by range (eg., 0-1.5). The number of occurrences in each range is divided by the number of observations to vege the percent of time in each range.

Table 3.1-5. Summary of temperature extremes and stratification frequencies in Lower Wheeler Reservoir during 1977.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Near Wheeler Dam												
Maximum (°F)	42.2	50.9	64.8	75.0	84.9	87.6	94.5	90.0	89.7	76.2	66.1	54.6
Minimum (°F)	33.1	33.4	49.2	56.9	64.7	73.9	82.3	82.7	75.0	45.8	52.1	42.6
0 - 1.5	96.6	90.5	75.8	44.1	12.0	10.3	28.7	45.5	78.7	85.6	97.9	92.7
1.6- 3.0	3.0	7.4	10.0	17.9	12.9	34.8	30.1	33.1	16.4	12.9	2.0	7.3
3.1- 5.0	0.4	1.9	11.3	8.1	23.4	43.3	24.5	17.6	4.8	1.5	0.1	0
5.1- 7.0	0	0	2.3	10.2	23.3	11.2	12.1	3.8	0.1	0	0	0
7.1- 10.0	0	0.1	0.5	12.3	23.1	0.5	4.2	0	0	0	0	0
10.1-	0	0	0	7.5	5.3	0	0.4	0	0	0	0	0
Near the Elk River												
Maximum (°F)	43.6	52.7	65.0	74.9	85.0	87.0	94.3	94.9	90.0	75.8	67.4	56.3
Minimum (°F)	34.7	36.5	49.3	54.1	68.1	65.6	80.9		73.9	60.5	50.3	35.8
0 -1.5	99.7	83.5	76.9	66.6	40.5	59.4	57.6	49.1	71.0	82.1	97.1	98.9
1.6- 3.0	0.7	13.5	16.9	9.0	29.3	28.0	27.7	26.4	17.3	14.3	2.4	1.1
3.1- 5.0	0	3.0	4.2	8.1	21.5	9.4	11.4	20.5	10.0	3.3	0.6	0
5.1- 7.0	0	0	1.5	9.1	5.2	2.7	3.1	3.0	1.8	0.3	0	0
7.1-10.0	0	0	0.1	4.4	3.0	0.3	0.1	0.9	0	0	0	0
10.1-	0	0	0	2.1	0.4	0.1	0	0	0	0	0	0

Note: For a given hour, the difference between the maximum and minimum temperatures is computed and sorted by range (eg., 0-1.5). The number of occurrences in each range is divided by the number of observations to give the percent of time in each range.

Table 3.1-6. Summary of temperature extremes and stratification frequencies in Lower Wheeler Reservoir during 1978.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Near Wheeler Dam												
Maximum (°F)	45.3	44.1	62.4	74.4	85.0	90.0	93.6	91.4	88.4	79.3	70.3	59.3
Minimum (°F)	35.4	34.6	41.1	51.3	62.7	66.9	78.8	82.4	76.7	63.8	57.9	46.2
0 - 1.5	97.2	92.5	74.0	23.3	32.7	0.6	18.0	56.4	67.4	92.3	91.7	97.4
1.6- 3.0	2.8	6.9	9.7	17.1	16.6	9.9	31.3	22.4	16.5	6.3	7.2	2.6
3.1- 5.0	0	0.6	6.7	20.1	7.3	19.0	24.1	16.1	10.3	1.3	1.0	0
5.1- 7.0	0	0	6.7	6.3	3.5	22.8	19.4	3.8	5.2	0	0.1	0
7.1-10.0	0	0	2.8	11.4	6.8	31.9	6.6	1.2	0.7	0	0	0
10.0-	0	0	0	21.8	33.1	15.7	0.7	0	0	0	0	0
Near the Elk River												
Maximum (°F)	48.3	45.9	64.9	74.4	85.0	90.0	93.5	93.4	89.6	80.3	70.2	59.2
Minimum (°F)	32.4	35.6	41.3	56.2	46.1	75.3	83.4	58.0	75.3	84.5	56.7	45.8
0 - 1.5	99.3	92.8	74.6	39.7	40.2	20.6	38.7	58.1	60.7	75.7	84.0	97.6
1.6- 3.0	0.7	6.1	10.3	23.9	9.1	26.0	26.1	24.6	20.1	18.3	13.2	2.4
3.1- 5.0	0	1.0	8.0	16.4	9.8	33.6	20.9	11.7	11.3	5.0	2.8	0
5.1- 7.0	0	0	3.5	10.7	13.6	14.3	10.4	4.7	6.3	1.1	0	0
7.1-10.0	0	0	3.8	7.2	13.6	5.2	3.9	1.0	1.7	0	0	0
10.0-	0	0	0	2.0	13.6	0.3	0	0	0	0	0	0

Note: For a given hour, the difference between the maximum and minimum temperatures is computed and sorted by range (eg., 0-1.5). The number of occurrences in each range is divided by the number of observations to give the percent of time in each range.

Table 3.1-7. Summary of temperature extremes and stratification frequencies in Lower Wheeler Reservoir during 1979.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Near Wheeler Dam												
Maximum (^{o}F)	47.7	49.8	60.4	73.5	79.1	87.5	87.8	91.3	84.9	77.0	65.5	52.5
Minimum (^{o}F)	37.8	37.4	45.0	55.5	63.7	69.5	77.8	79.8	71.5	63.7	52.0	46.0
0 - 1.5	99.1	89.1	80.9	58.1	28.3	14.1	45.5	34.8	73.5	88.2	93.9	97.8
1.6- 3.0	0.9	7.9	10.9	20.5	17.5	25.9	20.0	23.1	22.4	9.5	4.2	2.2
3.1- 5.0	0	2.2	5.8	14.4	28.7	28.6	25.8	27.5	3.8	2.3	1.1	0
5.1- 7.0	0	0.7	2.4	6.1	16.8	18.2	6.8	11.9	0.3	0	0.7	0
7.1-10.0	0	0	0	0.8	6.9	10.9	1.9	2.7	0	0	0	0
10.0-	0	0	0	0	1.8	2.4	0	0	0	0	0	0
Near the Elk River												
Maximum (^{o}F)	50.3	54.1	64.0	74.8	82.0	89.9	87.2	91.2	87.2	78.6	66.4	53.1
Minimum (^{o}F)	37.1	37.6	46.3	58.4	65.5	73.3	77.4	80.9	70.3	64.6	49.8	42.2
0 - 1.5	97.3	90.8	83.6	62.4	44.6	31.5	67.7	38.6	67.2	83.9	89.3	94.7
1.6- 3.0	2.4	5.5	10.1	19.1	21.9	31.3	24.5	30.5	22.3	14.6	7.6	4.3
3.1- 5.0	0.3	3.3	5.2	12.7	18.3	23.1	7.3	17.3	8.5	1.4	3.1	0.8
5.1- 7.0	0	0.1	0.9	3.9	7.6	9.7	0.4	13.0	1.7	0.1	0	0.1
7.1-10.0	0	0.3	0.1	1.8	6.1	3.9	0	0.7	0.3	0	0	0
10.1-	0	0	0	0	1.4	0.4	0	0	0	0	0	0

Note: For a given hour, the difference between the maximum and minimum temperatures is computed and sorted by range (eg., 0-1.5). The number of occurrences in each range is divided by the number of observations to give the percent of time in each range.

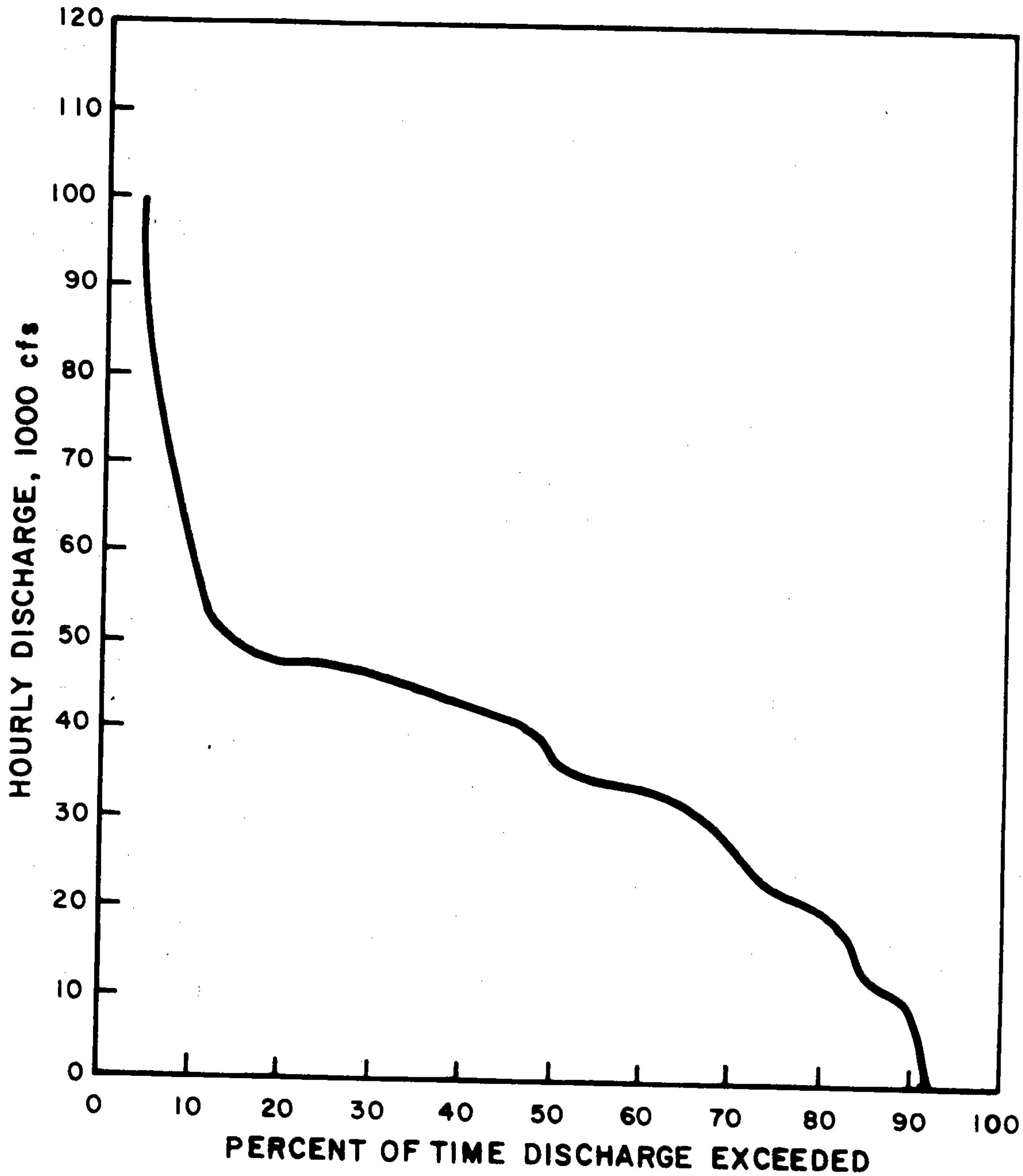


Figure 3.1-1: Frequency of Guntersville Dam Discharge 1959-1968

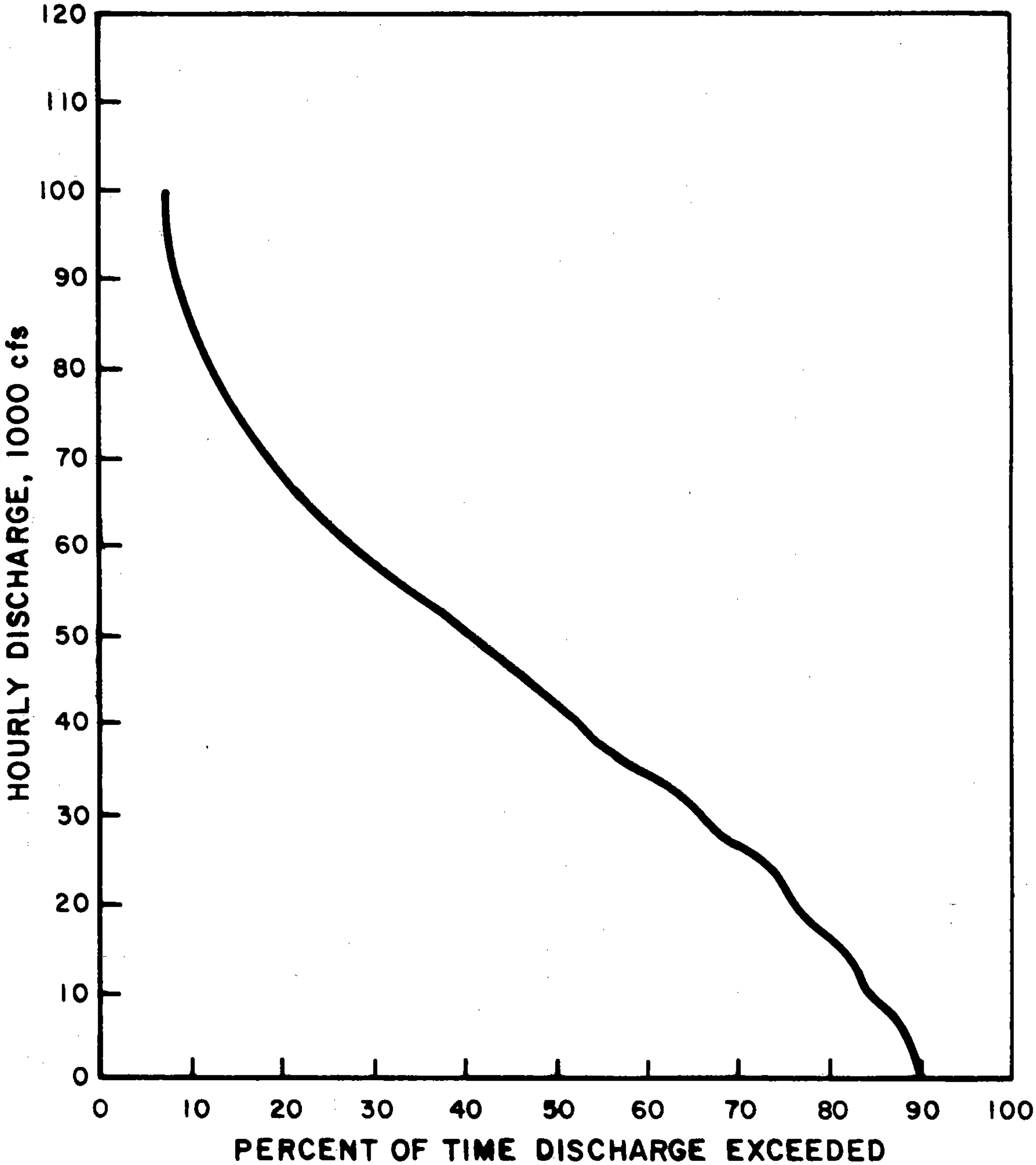


Figure 3.1-2 : Frequency of Wheeler Dam Discharge
1959-1968

upstream from the mouth of Elk River. Data collected from March 1975 to September 1976 (Tables 3.1-3 and 3.1-4) show ambient temperature for lower Wheeler Reservoir because the Browns Ferry plant did not operate during that period. Surface temperatures as high as 92.3°F were recorded. Stratification is usually weak (0-5°F), but can occasionally be moderately strong (May 1975, June 1976). Surface temperature extremes are generally higher near the Elk River inflow, probably reflecting solar heating of low Elk River flow resulting from shutdown periods at Tims Ford Dam. Stratification is generally stronger near Wheeler Dam where water depths are greatest.

Overbank areas in the vicinity of the plant and upstream respond quickly to diurnal heating and cooling because of shallow depth. Cooler water temperatures in the main river channel are the result of the greater water depth and the temperature of releases from Guntersville Dam. As discussed by Ungate (1978), the difference in temperature between main channel and overbank areas make determination of plant effects on water temperature difficult.

Table 3.1-8 shows the frequency of high ambient river temperatures at the five-foot depth during summer months of 1969-1977, as recorded hourly by a water temperature monitor at TRM 297.8. Data from this monitor were used to compute ambient river temperatures for purposes of demonstrating compliance with thermal standards at the plant. <u>Temperatures in excess of 90.0°F have been recorded at the five-foot depth at this location</u>. In

Table 3.1-8. Frequency of high ambient river temperatures, five foot depth - TRM 297.8.

	Temperature Range (°F)	Year 1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
June - August	<86	85.1	97.6	98.2	99.1	98.5	99.9	97.0	99.5	83.5	91.0
	86 - 87	10.4	1.9	1.3	0.9	1.3	0.1	2.3	0.3	10.4	6.7
	87 - 88	4.0	0.4	0.4	0	0.2	0	0.7	0.1	3.5	1.7
	88 - 89	0.5	0.1	0.1	0	0	0	0	0.1	2.1	0.6
	89 - 90	0	0	0	0	0	0	0	0	0.4	0
	>90	0	0	0	0	0	0	0	0	0.1	0
July only	<86	56.0	95.2	95.2	98.5	95.4	99.6	97.9	98.5	58.3	81.7
	86 - 87	30.5	3.9	3.4	1.5	3.9	0.4	1.7	1.0	23.5	13.9
	87 - 88	11.9	0.7	1.2	0	0.7	0	0.4	0.3	10.4	3.3
	88 - 89	1.6	0.2	0.2	0	0	0	0	0.2	6.4	1.1
	89 - 90	0	0	0	0	0	0	0	0	1.1	0
	>90	0	0	0	0	0	0	0	0	0.3	0

Note: All numbers are percent of time in given period.

July of an extremely hot year (eg., 1969 and 1977), water temperatures at the five-foot depth can exceed 86°F more than 40 percent of the time. Temperatures at the five-foot depth exceeded 86°F during each year of the period examined.

3.2 Aquatic Biota in Wheeler Reservoir

3.2.1 Plankton Community

Wheeler Reservoir, with a normal flow through time of about one to two weeks, is typical of other Tennessee River mainstream reservoirs in that productivity and standing stock of phytoplankton and zooplankton generally increases in the lower reaches of the reservoir. Similar increases in Chickamauga Reservoir, as well as general increases from upper to lower mainstream Tennessee River reservoirs, were summarized by Urban et al. (1979).

As in most other Tennessee River mainstream reservoirs, the phytoplankton community in Wheeler Reservoir is usually dominated numerically by the Chrysophyta in winter and early spring, Chlorophyta in spring and early summer, and Cyanophyta in summer and fall. The zooplankton community is frequently dominated by Rotifera, although Cladocera or Copepoda occasionally dominate. Distinct seasonal trends for zooplankton are not apparent as for phytoplankton.

3.2.2 Benthic Macroinvertebrate community

Abundant aquatic macroinvertebrates observed in the vicinity of BFNP before plant operation were: Asiatic clams (*Corbicula manilensis*), oligochaetes, *Hexagenia* sp., *Caenis* sp., Chironomidae, *Chaoborus* sp., snails, sponges, byrozoans, and a few mussels and crayfish (Browns Ferry Environmental Statement, Volume 3, September 1972). With the exception of *Corbicula manilensis*, all of these organisms are widespread geographically, and are

ubiquitous in reservoirs or slow-flowing rivers. The Asiatic clam, *Corbicula* is not indigenous to North America, but is very abundant in the Tennessee River basin and has spread north at least as far as Ohio.

3.2.3. Fish community

The fish community in Wheeler Reservoir is dominated by warm-water species. With the exception of sauger and walleye, all the important game and commercial species are in this category, including smallmouth bass. Sauger and walleye are recognized by fisheries scientists and managers as coolwater species (Hokanson 1977; Kendall 1978). Species in this category occur in conjunction with both warmwater and coldwater species. Definitive thermal-effects data for smallmouth bass, compiled since 1972, indicate that a "coolwater" classification for this species is not warranted. Recent studies show that the temperature requirements for smallmouth bass, particularly in relation to growth, survival, and preference, are essentially the same as those for largemouth bass and other warmwater centrarchids (Stauffer *et al*., 1976; Reynolds and Casterlin 1976; Wrenn in press).

Although the temperature requirements for sauger and walleye are essentially the same (Hokanson 1977), sauger is the dominant species in Wheeler Reservoir. Walleye is of marginal concern in Wheeler Reservoir, since: (1) The species is rare in the reservoir, (2) there is no established walleye fishery, and

(3) occurrence is sporadic throughout the mainstream Tennessee River system. Adult sauger are neither common nor widely distributed in shallow overbank areas or embayments where substrates are primarily mud and/or silt. They prefer and select areas of moderate current over rock, gravel, and mixed rubble substrate in streams and tailraces or about reefs in deep water zones of lakes and reservoirs. They may move between or among various habitat types and substrate zones but apparently spend little time in nonpreferred areas. To our knowledge no reefs exist in the deep pool water above Wheeler Dam (TRM 275-287), and sauger are seldom caught there. Most netting and cove rotenone records indicate that less than one percent of all fish captured by these methods are sauger. In the Wheeler Reservoir transition zone between pool and river channel (TRM 287-308) sauger are captured by netting near heated water outfalls, largest numbers occur in fall and winter. Nearly all efforts by sport fishermen are expended between TRM 308.0 and Guntersville Dam at TRM 384.8.

Sauger, especially maturing individuals, may be spread throughout the reservoir, but sampling indicates relatively few adult sauger downstream of the plant site. When sauger begin moving in early winter on annual spawning runs, they generally move in such a way that by November or early December they concentrate near dams, existing municipal, industrial, and steam plant thermal discharges. These concentrations are of such common occurrence that sauger fishermen in the Tennessee River basin

concentrated efforts below the dams and in and about steam plant discharge basins in November. Good sauger fishing often continues through April and even early May.

Smallmouth bass generally are not migratory; rather, they are considered resident in an area. Usually they move locally in a vertical plane along shoreline features and show a seasonal response (i.e., depth selection) to temperature. Smallmouth bass are distributed in two distinct, well separated zones of Wheeler Reservoir, neither of which should experience much effect from the Browns Ferry Nuclear Plant's warmwater effluent. The upstream population appears to prefer the tailrace and river channel below Guntersville Dam (TRM 348.8-308.0). The downstream population is associated with the limestone bluffs from TRM 288.0 to Wheeler Dam (TRM 274.9), and in the Elk River, (the main Wheeler tributary) from its mouth (TRM 284.5) to its source. In its upper portions, Elk River is principally a smallmouth bass-rock bass stream.

Fish monitoring investigations, conducted quarterly since the winter of 1968, have shown the following to be important in the sport harvest: Largemouth bass, smallmouth bass, spotted bass, white bass, crappie, bluegill, and sauger. Important commercial fish are; bigmouth buffalo, smallmouth buffalo, channel catfish, flathead catfish, blue catfish, carp, drum, and paddlefish. Although striped bass occasionally appear in Wheeler Reservoir and its tailwaters, the species is not discussed here since it

has neither established populations nor does it occur in significant numbers. The dominant prey species in Wheeler Reservoir are gizzard and threadfin shad.

4.0 Hydrothermodynamics and Biotic Interactions for a 90°F Thermal Limit

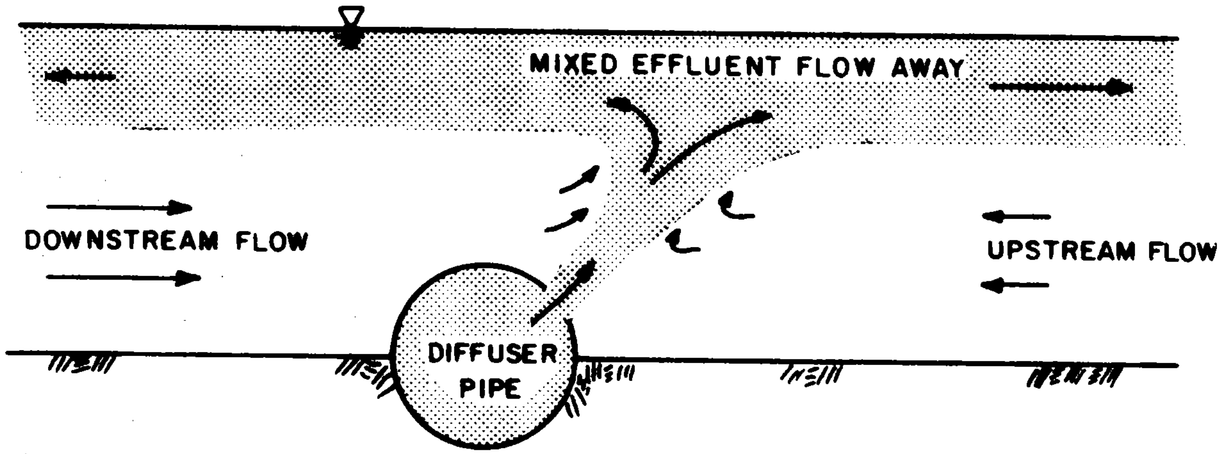
4.1 Hydrothermodynamics

Three 600-foot long submerged multiport diffusers discharge condenser cooling water to the river. As proposed, the condenser cooling water system will be operated in either open or helper modes. In open mode, the plant pumps 4350 cfs from the reservoir through steam condenser where the cooling water is heated approximately 25°F before discharge through diffusers. Open mode will be used when plant induced temperatures do not exceed the 5°F rise or 86°F maximum standard. In helper mode, condenser cooling water is routed to six mechanical draft cooling towers before discharge to the diffusers. Helper mode will be used to meet the 5°F rise criterion whenever the standard cannot be met in open mode. In addition, helper mode will be used whenever natural temperatures approach or exceed 86°F, in which case a maximum mixed river temperature of 90°F applies. If the 5°F rise or the 90°F maximum criteria cannot be met in helper mode, the plant will be derated.

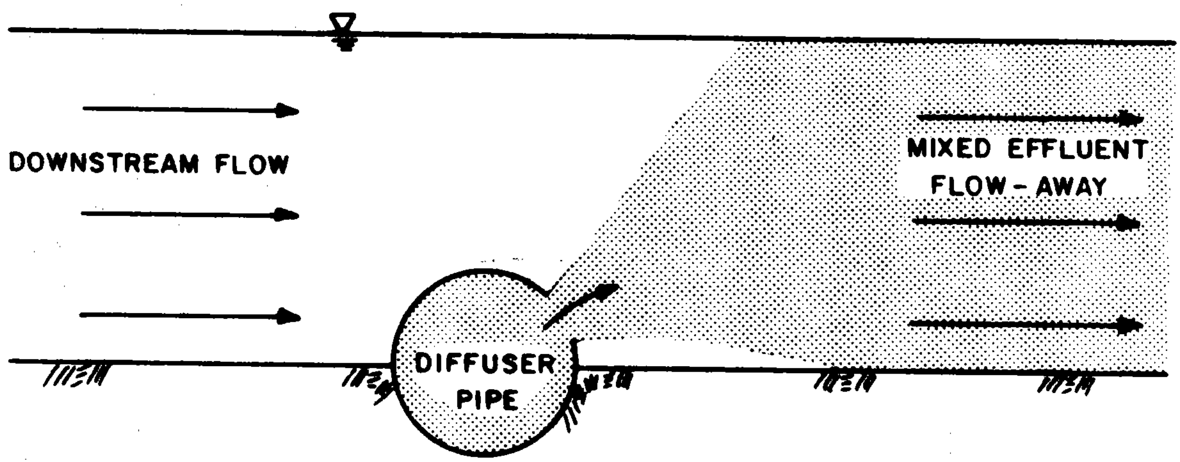
4.1.1 Near Field Effects

Mixed reservoir temperature downstream of the plant depends on flow rate and temperature of both the diffuser discharge and the reservoir. The induced dilution from the diffuser system was predicted using analytical models developed by MIT (Jirka and Harleman, 1973) and TVA. Calculations

assumed a diffuser system discharge of 1450 cfs per unit for open mode cooling and 1225 cfs per unit for helper mode cooling at various reservoir flow rates. Ambient reservoir temperatures varying from 81°F to 90°F were also assumed. The discharge temperature was calculated for open mode cooling using a condenser temperature rise of 25°F and was assumed to be a constant 94°F for helper mode cooling. Schematic representations of diffuser-induced mixing are shown in Figure 4.1-1. Generally speaking, diffuser-induced mixing falls into one of two regimes: Stratified or well mixed. In the stratified flow regime, which is strongest during periods of low or zero river flow, the buoyant diffuser effluent rises immediately to the surface, entraining cool reservoir water from the lower layers as it rises. Heated effluent may flow both upstream and downstream in a buoyant surface layer, and mixing water may be drawn from both upstream and downstream as illustrated in Figure 4.1-1a. When reservoir flow is large, the role of buoyancy in diffuser performance is much smaller, and the effluent may become well mixed over the full depth of the reservoir as illustrated in Figure 4.1-1b. In this case, the diffuser effluent mixes with virtually all water which would naturally pass over it and induces additional entrainment flow, which is usually limited by the available reservoir flow.



a) STRATIFIED FLOW REGIME



b) WELL MIXED FLOW REGIME

Figure 4.1-1 : Diffuser Flow Regimes

Figures 4.1-2 and 4.1-3 show the predicted mixed temperature at the diffuser for open and helper mode cooling, respectively. "Mixed temperature" is defined here as the temperature of the mixed effluent and reservoir water at the edge of the diffuser mixing zone at a five-foot depth. Figure 4.1-2 shows mixed temperatures greater than 90°F do not occur for open mode cooling when ambient river temperatures are less than 85°F. Figure 4.1-3 shows that mixed temperatures greater than 90°F do not occur for helper mode cooling when ambient reservoir temperatures are less than 88°F. As flow increases, even higher ambient reservoir temperatures do not cause mixed temperature to exceed 90°F for either helper or open mode cooling. For all ambient reservoir temperatures from 81°F to 90°F, a mixed temperature rise in excess of 5°F will not occur for most flow conditions. If low or reverse flow conditions persist for sustained periods (i.e., longer than three hours), reentrainment of the diffuser plume may occur and mixed temperatures greater than those predicted may result.

Using the analytical model of diffuser performance, the frequency of high plant-induced mixed temperatures was predicted for the summer months of 1969-1977 in Table 4.1-1. Hourly flows from Guntersville and Wheeler Dams and hourly water temperatures at the five-foot depth at TRM 297.8 (Table 3.1-8) were used in the analysis. If hourly reservoir flows at the Browns Ferry site were calculated

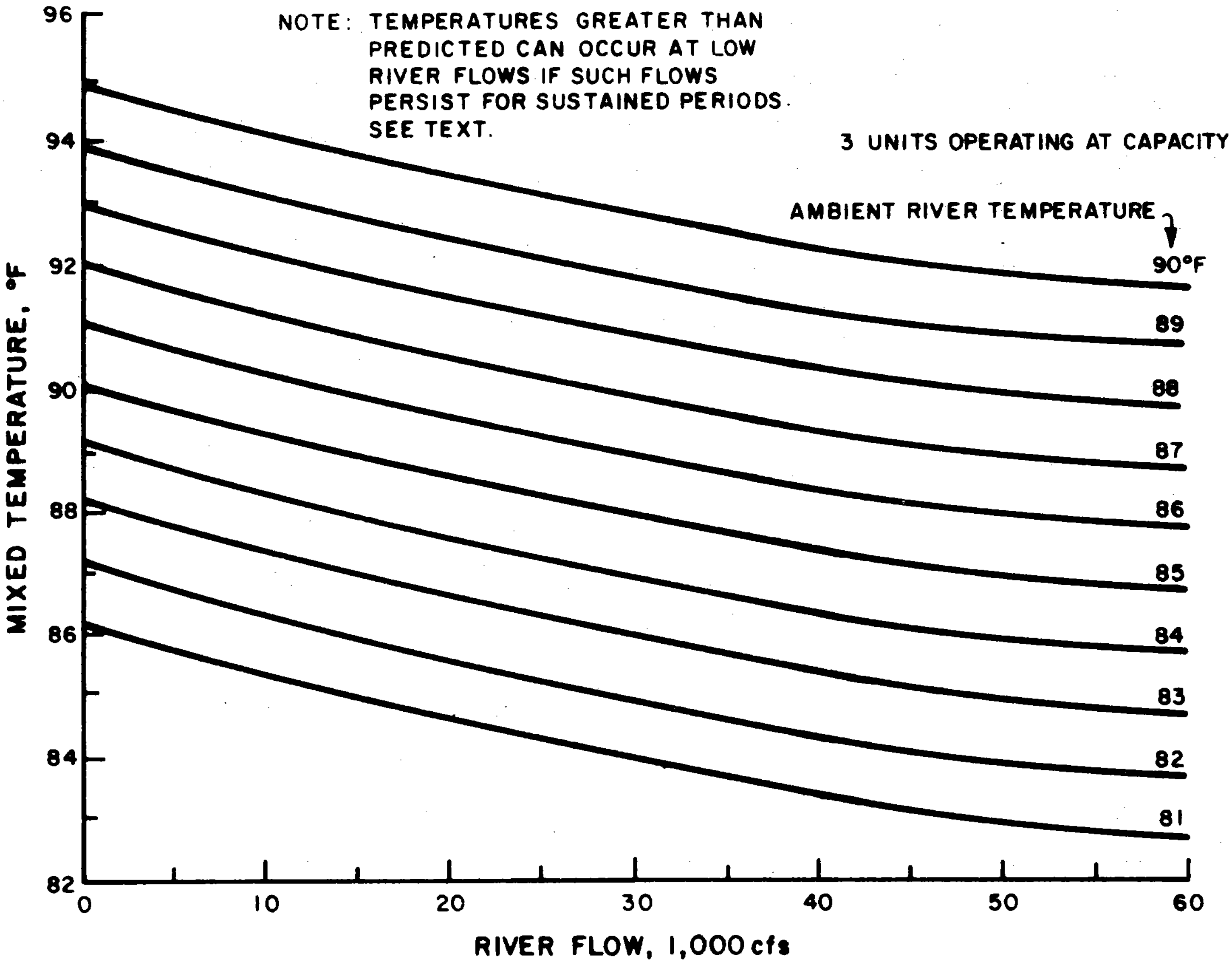


Figure 4.1-2: Predicted Mixed Temperature at Diffuser
Open Cycle – Discharge Temperature 25°F Above Ambient

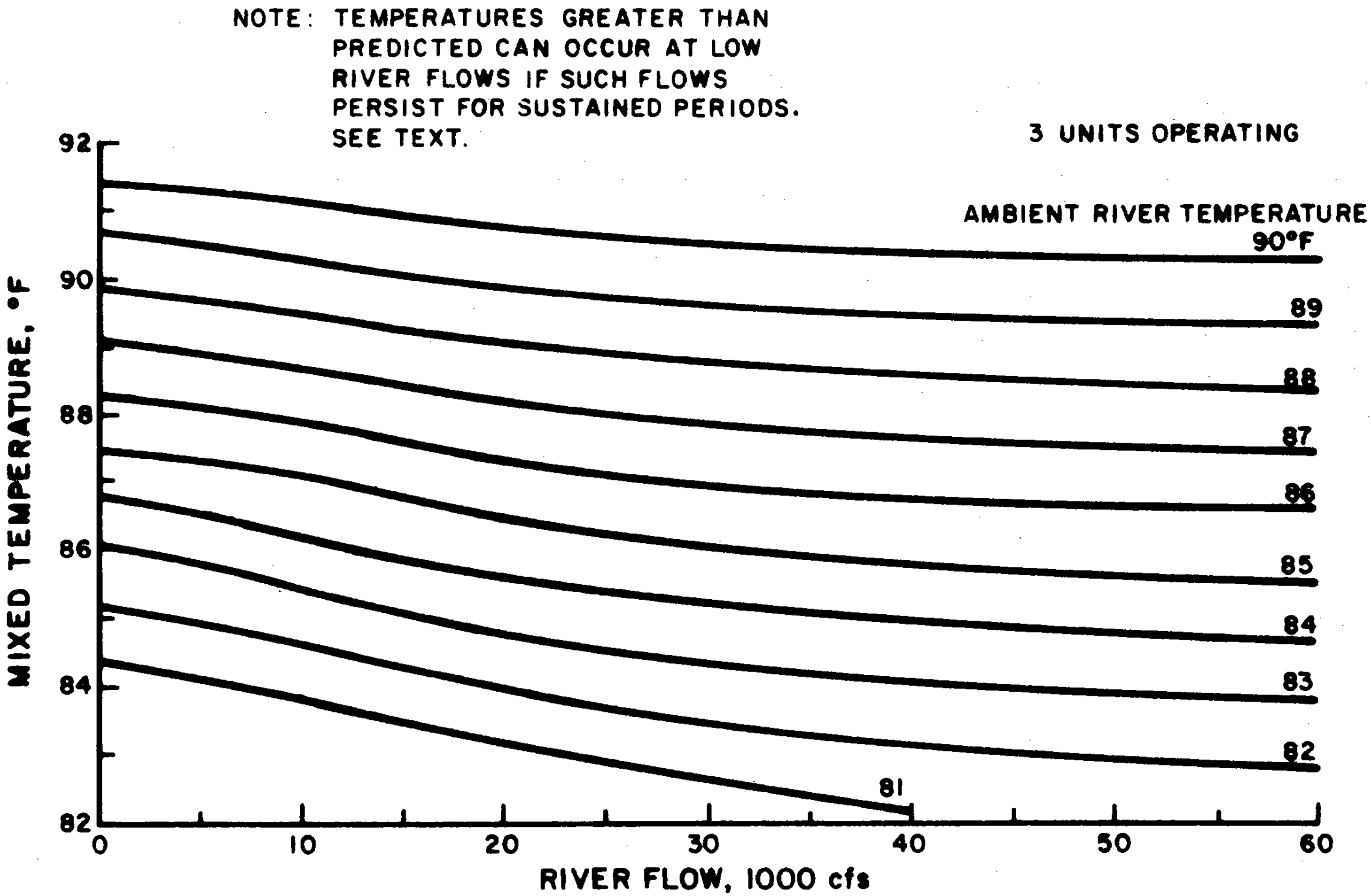


Figure 4.1-3: Predicted Mixed Temperature at Diffuser
Helper Mode – Discharge Temperature = 94°F

to be less than 10,000 cfs due to zero flow periods at the dams, flow at the plant site was set equal to 10,000 cfs in accordance with current TVA release practices to minimize cooling tower usage at Browns Ferry. Full plant operation was assumed and hourly wetbulb temperatures were used to characterize cooling tower performance. Assumptions for the use of helper and open mode cooling discussed earlier were also used.

Table 4.1-1 shows that mixed temperatures are greater than 86°F from 0.4 to 29.8 percent of the time in a given summer, as compared to from 0.1 to 16.5 percent of the time for ambient conditions (Table 3.1-8). During July, mixed temperatures are greater than 86°F from 1.4 to 59.2 percent of the time in a given summer, as compared to from 0.4 to 44.0 percent of the time for ambient conditions (Table 3.1-8). A summary of the frequency of high ambient and mixed reservoir temperatures in the summer months for 1969-1977 is given in Table 4.1-2. High ambient temperatures exceed 86°F 4.8 percent of the time on average, while high mixed temperatures at the edge of the mixing zone exceed 86°F 9.2 percent of the time.

The proposed mixing zone for the plant is 1800 feet wide and extends 2200 feet downstream of the diffusers over the entire water depth. The mixing zone has been defined on the basis of field studies which show that diffuser induced

Table 4.1-1. Predicted frequency of high mixed river temperatures at edge of diffuser mixing zone (five foot depth) Browns Ferry Nuclear Plant.

	Temperature Range (°F)	Year								
		1969	1979	1971	1972	1973	1974	1975	1976	1977
June-August	<86	74.4	92.9	94.4	97.3	96.6	99.6	94.3	99.4	70.2
	86 - 87	11.2	5.5	4.2	2.3	2.2	0.4	4.0	0.3	16.3
	87 - 88	11.6	1.5	1.3	0.4	1.1	0	1.5	0.2	9.7
	88 - 89	2.7	0.1	0.1	0	0.1	0	0.2	0.1	3.0
	89 - 90	0.1	0	0	0	0	0	0	0	0.8
	>90	0	0	0	0	0	0	0	0	0*
July only	<86	30.8	89.5	87.1	96.0	89.7	98.6	96.8	98.3	31.5
	86 - 87	26.9	7.1	9.5	3.3	6.8	1.3	2.4	1.0	30.8
	87 - 88	34.1	3.2	3.2	0.7	3.5	0.1	0.7	0.5	26.0
	88 - 89	7.9	0.2	0.2	0	0.4	0	0.1	0.2	9.1
	89 - 90	0.3	0	0	0	0	0	0	0	2.5
	>90	0	0	0	0	0	0	0	0	0.1

Note: All numbers are percent of time in given period.

*Less than 0.05 percent of the time

Table 4.1-2. Frequency of high ambient and mixed river temperatures at the five foot depth near Browns Ferry Nuclear Plant, 1969-1977.

	Temperature Range (°F)	Month June	July	August	All Summer
Ambient River Temperatures	<86	99.8	87.9	97.7	95.2
	86 - 87	0.2	8.0	2.0	3.4
	87 - 88	0	3.0	0.3	1.1
	88 - 89	0	1.0	0	0.3
	89 - 90	0	0.1	0	0*
	>90	0	0*	0	0*
Mixed River Temperatures	<86	99.4	78.8	93.7	90.8
	86 - 87	0.5	10.2	5.1	5.3
	87 - 88	0.1	8.4	1.1	3.1
	88 - 89	0	2.2	0.1	0.7
	>90	0	0*	0	0*

mixing takes place within one diffuser length of the discharge point (Ungate 1978, Johnson and Clift 1974, and Almquist et. al. 1978). The thermal structure of the mixing zone is often partially stratified. This is illustrated in Figures 4.1-4 to 4.1-6, which show summer 1977 temperature records at an hourly water temperature monitor situated at the downstream edge of the proposed mixing zone (TRM 293.5).

June 1977 temperatures are shown in Figure 4.1-4. The bottom temperatures from the upstream station at TRM 297.8 are also shown for comparison. Bottom temperatures at Browns Ferry were 1-2°F warmer than those upstream. Surface temperatures from the 0.5-foot, 3-foot and 5-foot depth sensors were elevated 1-4°F above bottom temperatures most of the time. This persistent stratification appears to be the result of the diffuser discharge. Some of the stratification may be natural since the surface temperatures at the upstream station were 1-2°F above bottom temperatures. In general the diffuser apparently increased reservoir temperatures 1-2°F and also added 1-3°F to surface temperatures. In no case was more than 5°F added to surface temperatures at the plant site. Bottom temperatures at the plant site were 83-84°F by the end of June. Although the diffuser discharge is a major influence near the plant, the prevailing meteorology can also dominate the thermal structure. A storm event of June 6-7 with the accompanying high winds produced fully mixed river temperatures that decreased 3°F by June 7.

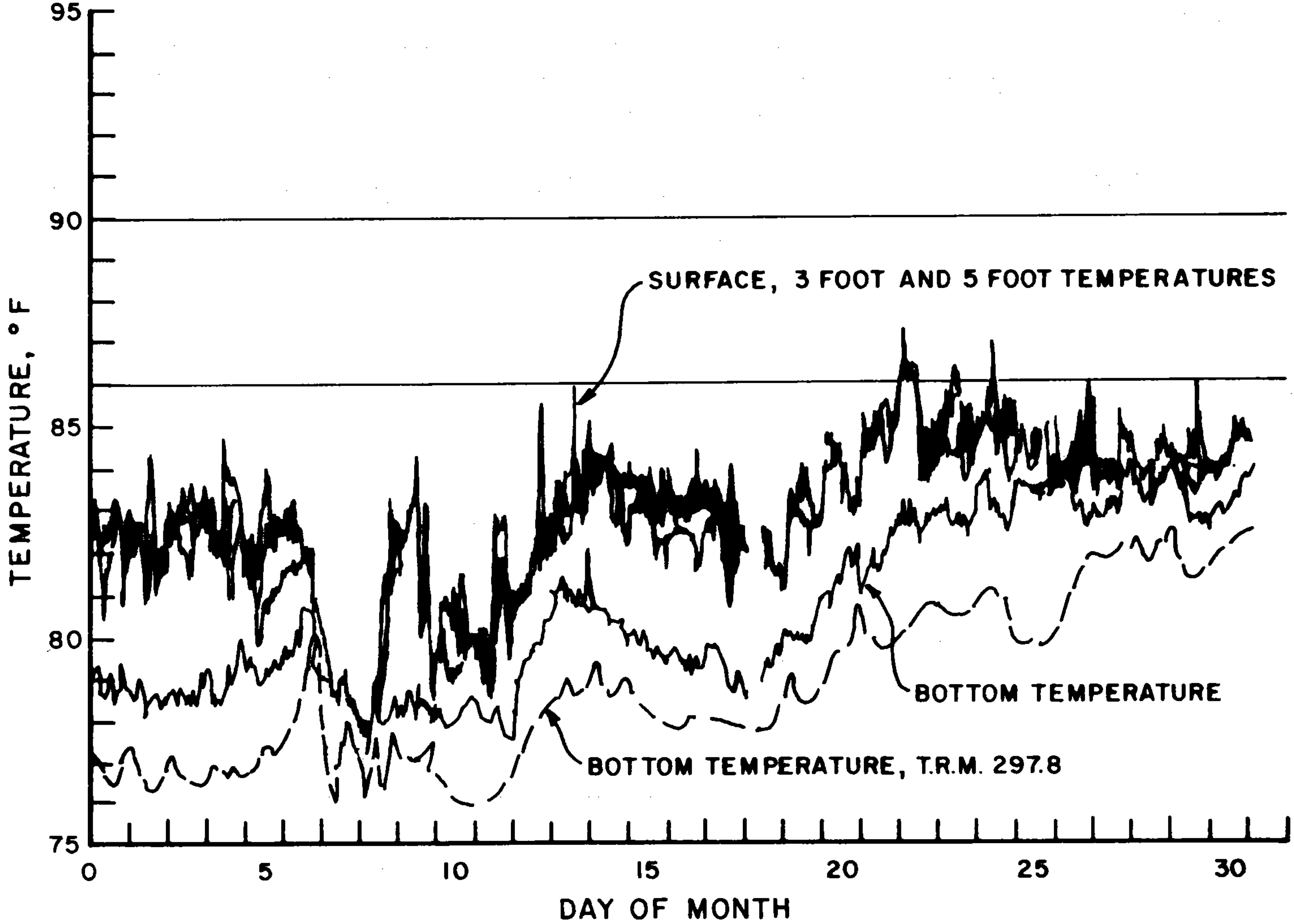


Figure 4.1-4 : Temperature Data at T.R.M. 293.5 During June 1977

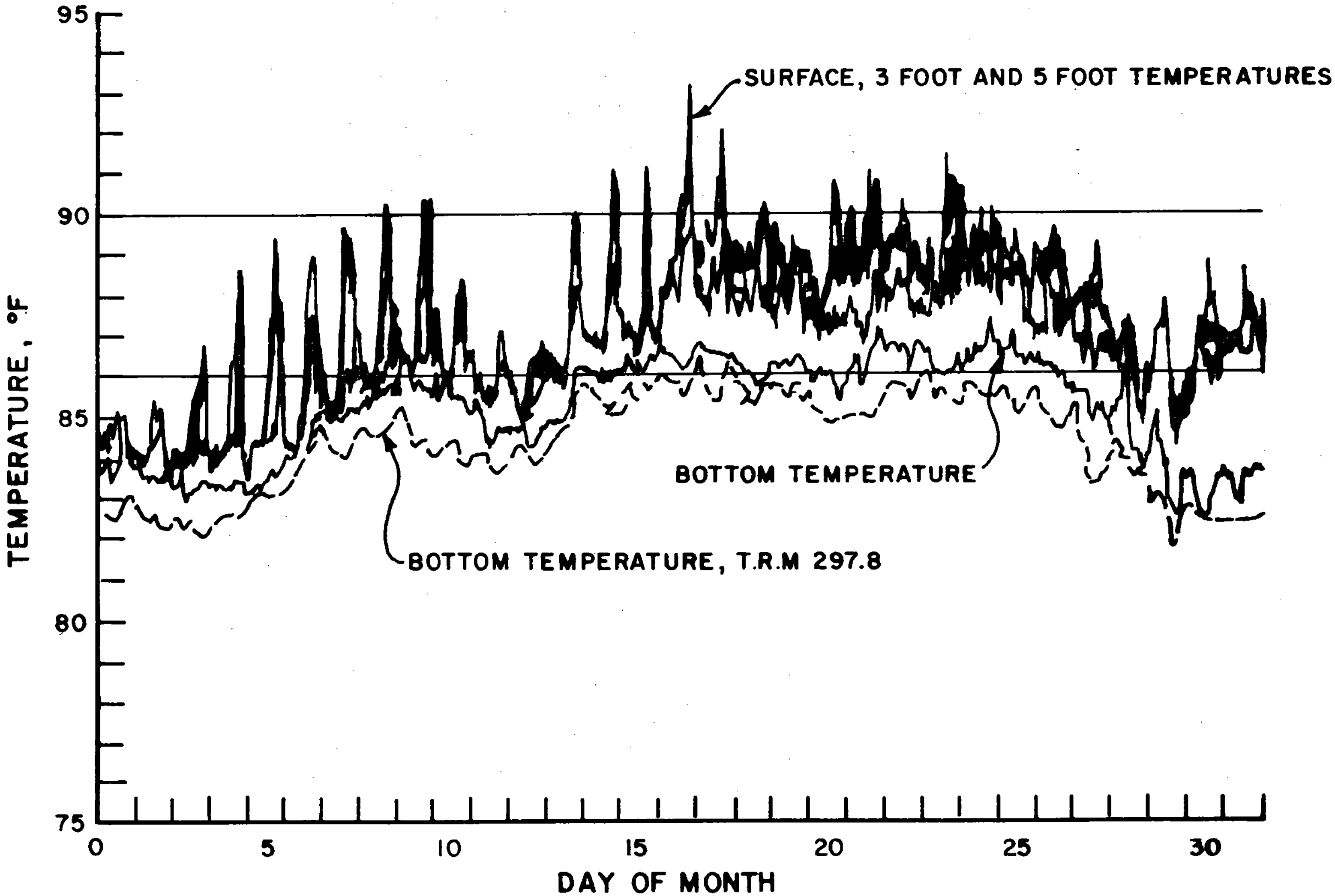


Figure 4.1-5 : Temperature Data at T.R.M. 293.5 During July 1977

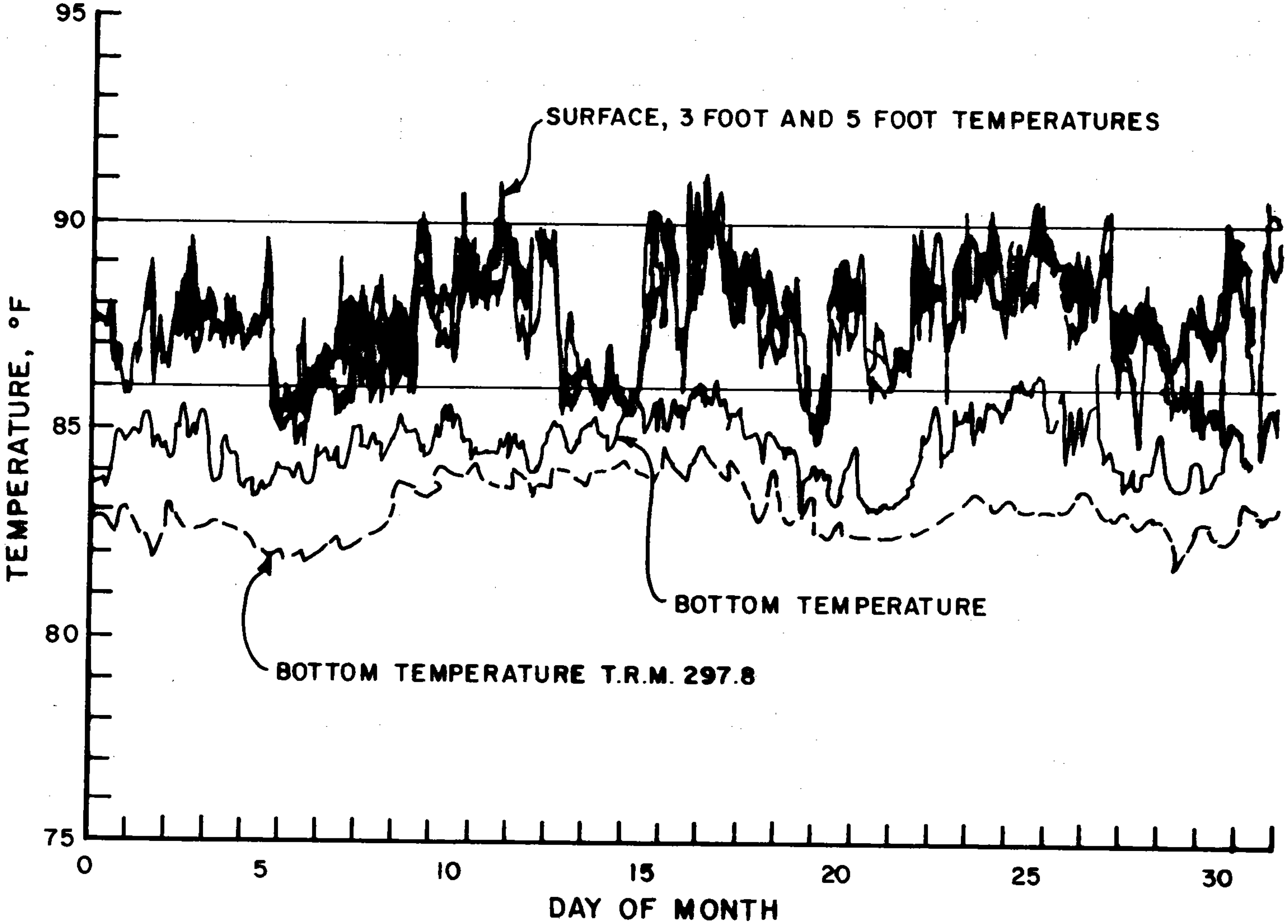


Figure 4.1-6: Temperature Data at T.R.M 293.5 During August 1977

Plant site temperatures for July 1977 are shown in Figure 4.1-5. Stratification was less than during June because the plant was operated in closed or helper mode to minimize heat discharge to the reservoir. During the second half of July, Wheeler Reservoir was more strongly stratified because the plant returned to open cycle operation. Bottom temperatures from the upstream station are plotted for comparison with those at the edge of the mixing zone. Bottom temperatures in July were much closer to bottom temperatures upstream than during June. The contrast between June and July plant site temperatures shows that the diffuser discharge significantly affects water temperatures near the site when the plant is in open mode.

August 1977 water temperatures at the plant site are shown in Figure 4.1-6. They exhibited stratification of 2-3°F, which is characteristic of open mode operation. Bottom temperatures were again 1-2°F above those at the upstream location. Bottom temperatures at the edge of the proposed mixing zone were very stable throughout August, varying between 83°F and 86°F. Bottom temperatures upstream were even more constant at between 82°F and 84°F. This suggests that relatively little natural heating was occurring at this depth during August although diurnal heating was significant in the surface layer.

4.1.2 Far Field Effects

The heat discharged by Browns Ferry Nuclear Plant is mixed in the reservoir by flow- and wind-induced turbulence and is rejected to the atmosphere by surface heat exchange processes as it is transported downstream. Simultaneously, the reservoir is warmed and cooled naturally by solar and atmospheric radiation.

As discussed in Section 3.1, Tables 3.1-2 through 3.1-7 summarize temperature extrema and stratification in lower Wheeler Reservoir by month from 1974-1979, respectively. Temperature data were collected by hourly water temperature monitors at TRM 275.0 near Wheeler Dam and at TRM 286.0 immediately upstream from the mouth of the Elk River. Data collected from March 1975 to September 1976 (Tables 3.1-3 and 3.1-4) show ambient temperatures for lower Wheeler Reservoir because the Browns Ferry Plant was not operated during this period. Plant effects are included in the temperature data for the remainder of the monitoring period.

Tables 3.1-5 and 3.1-6 show stratification data for 1977 and 1978, respectively, two of the three warmest years in the ten year period from 1969-1978 (Table 3.1-8). Maximum surface temperatures these years were higher than for any other year, peaking at 94.9°F in August 1977 at TRM 286.0. The degree of stratification, however, was similar

to other years. Browns Ferry was operated with a 90°F maximum temperature limit and without cooling towers during most of this period. Table 3.1-7 shows data from 1979 for similar plant operating conditions. Temperature extrema for 1979 are lower than those for 1975, a year in which Browns Ferry did not operate after March 22. Stratification in 1979 was similar to that of other years. Thus, it is difficult to conclude what, if any, plant effects exist in lower Wheeler Reservoir from examination of Tables 3.1-2 to 3.1-7.

In an attempt to quantify plant effects in lower Wheeler Reservoir, an hourly heat balance model for Wheeler Reservoir downstream of the Browns Ferry diffuser was applied to compare the natural and heated temperature patterns characteristic of the far field region of the discharge. An unsteady flow model for Wheeler Reservoir was combined with an hourly surface heat exchange and mixing model to produce a far field temperature model. Natural and plant induced temperatures were routed from the diffuser location to Wheeler Dam on an hourly time scale. The hourly simulations allow diurnal heating and cooling and the effects of peaking power operation on water temperatures to be studied.

Wheeler Reservoir below the Browns Ferry diffuser is schematized as ten fully mixed volume elements, each with a length of about two miles and variable in width and depth. The surface area and volume of each element changes with

reservoir elevation. The volumes and surface areas of the volume elements near the plant were adjusted to account for the gradual spread of the thermal plume from the diffusers to the banks of the reservoir.

The model concurrently simulates natural and heated temperatures beginning at the diffuser site. Natural upstream boundary conditions (without the plant) are the ambient temperature data from the recorder at TRM 297.8. The upstream boundary conditions (with plant operation) are calculated from the proposed plant operating strategy at full load and the natural temperature record. The additional heat is assumed to be fully mixed in the first volume element. Calculated heat transfer from surfaces of the volumes is based on hourly meteorology and the hourly calculated natural or heated water temperatures.

Vertical temperature stratification was not included in this model. Because Wheeler Reservoir is stratified, two sets of model calculations were made: One with fully mixed volume elements over the entire depth and one with fully mixed volume elements that encompassed only the stratified surface layer of 10 foot depth. Comparison of the two sets of calculations should show the effects of the plant discharge on stratified temperature profiles in lower Wheeler Reservoir.

The summer of 1977 was selected for study because persistently warm meteorology was observed. Comparisons of actual temperature data for July 1977 with model results are given for fully mixed and stratified layer volume elements at TRM 292.5 in Figures 4.1-7 and 4.1-8, respectively; at TRM 286.0 near the mouth of the Elk River in Figures 4.1-9 and 4.1-10, respectively; and at TRM 275.0 near Wheeler Dam in Figures 4.1-11 and 4.1-12, respectively. Model results are based on hypothesized maximum plant output and thus are not directly comparable with temperature data, which were for actual plant operating conditions. However, plant conditions in the latter half of July 1977 were close to assumed conditions.

Actual temperatures at TRM 292.5 (Figures 4.1-7 and 4.1-8) showed almost no nighttime stratification, but exhibited daytime surface heating of 2-5°F, with surface temperatures exceeding 90°F. Modeled temperatures which include plant effects are about 0.6°F higher than temperatures without plant effects for fully mixed volumes (Figure 4.1-7) and about 1.2°F higher for stratified layer volumes (Figure 4.1-8). The stratified layer elements show better agreement with actual temperature data than the fully mixed elements. Diurnal fluctuations in temperature in the stratified element 10 feet thick show a wide variation similar to the variation in actual data from surface to bottom. Surface temperature peaks were not adequately modeled because the ten-foot

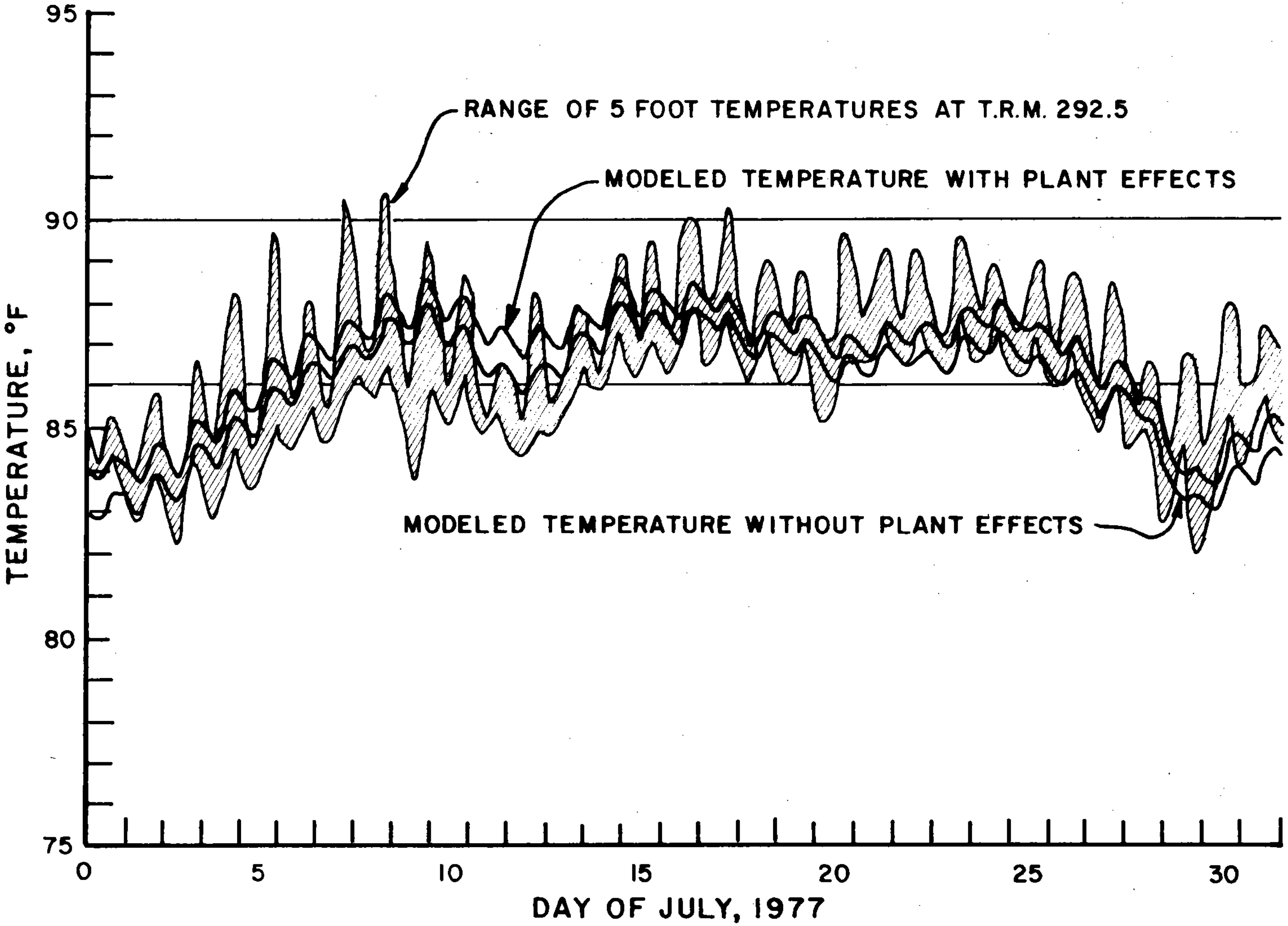


Figure 4.1-7 : Comparison of Modeled Temperature using Fully Mixed Volume Elements with Temperature Data at T.R.M. 292.5

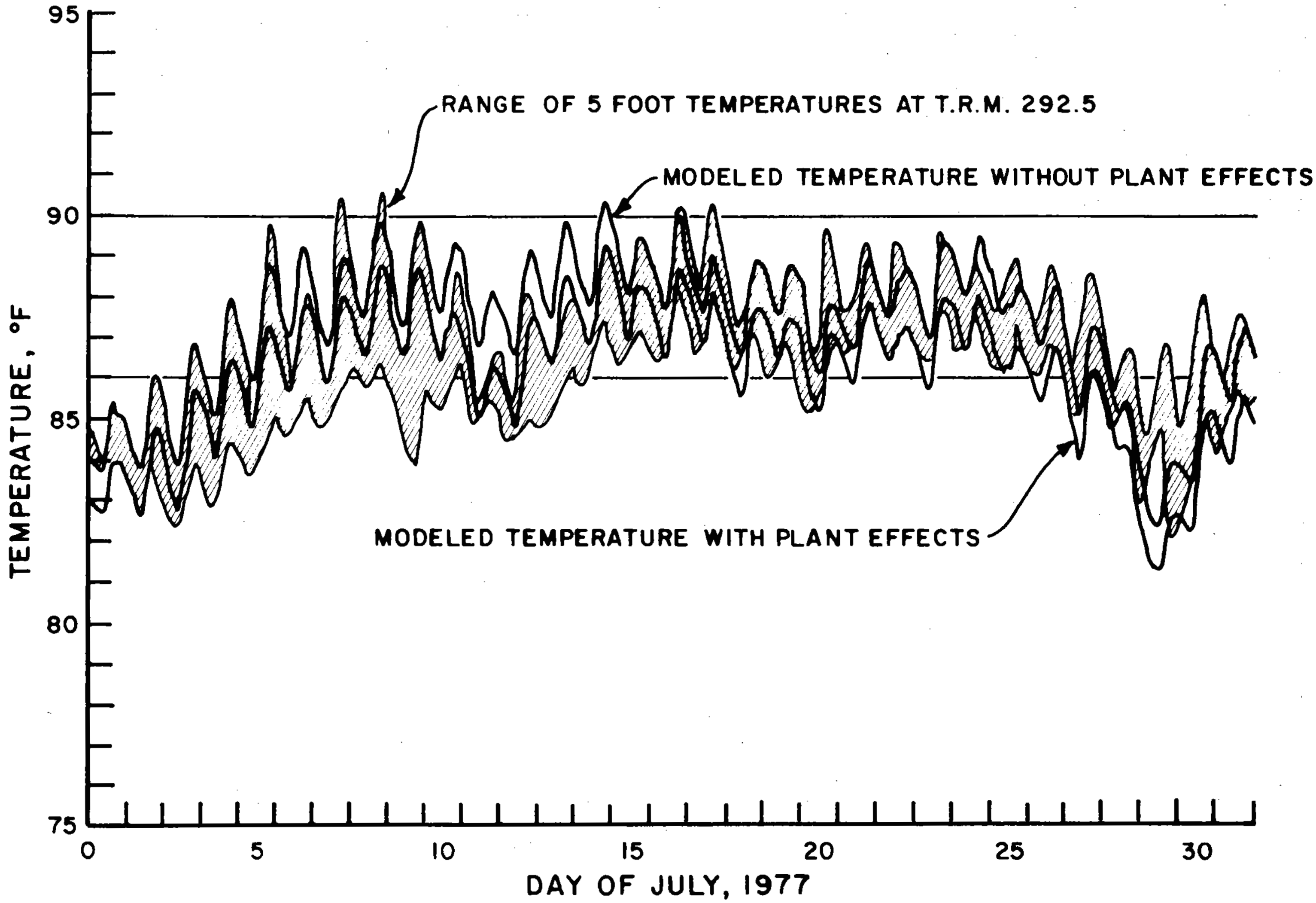


Figure 4.1-8 : Comparison of Modeled Temperature using Stratified Layer Volume Elements with Temperature Data at T.R.M. 292.5

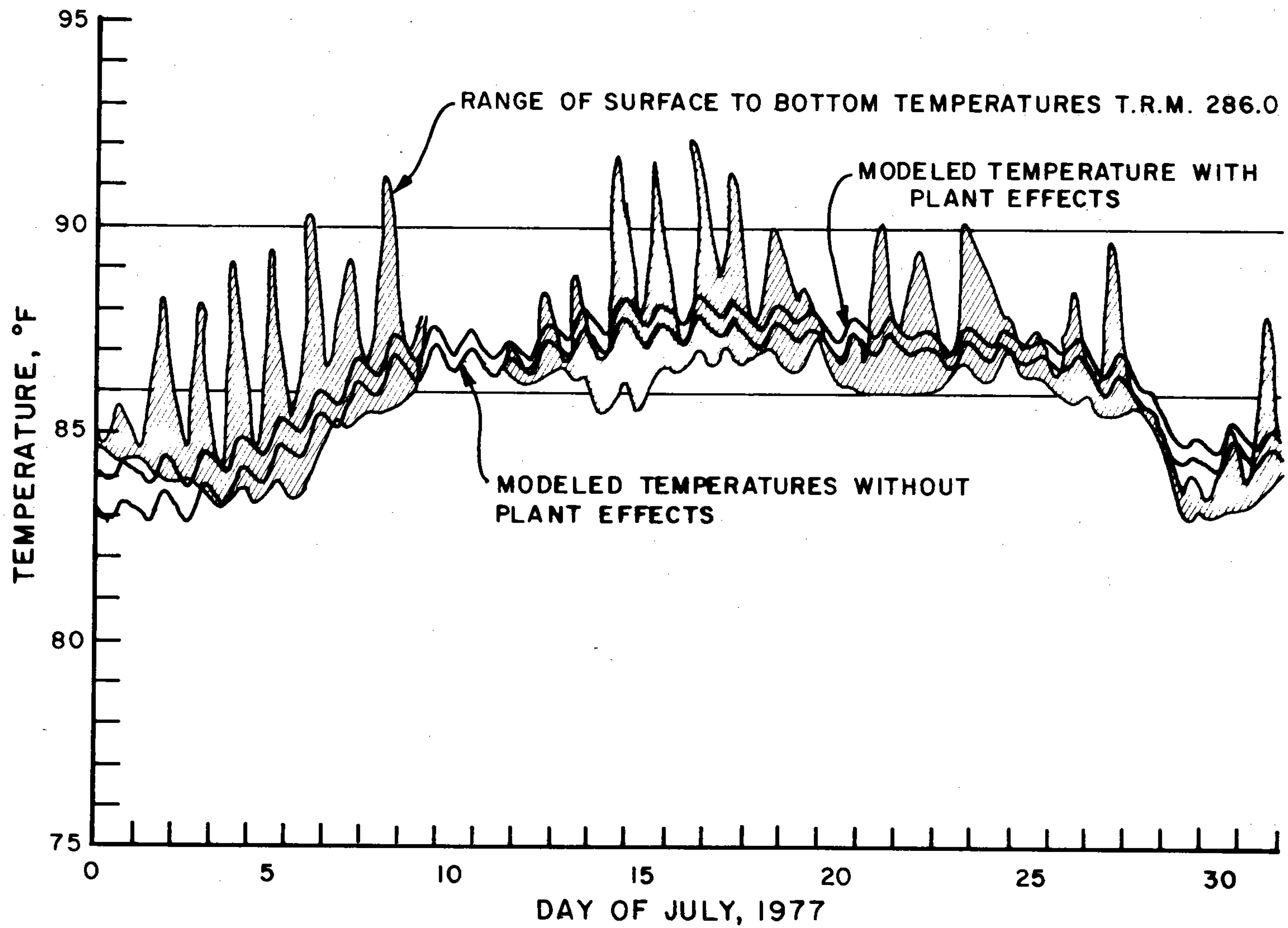


Figure 4.1-9: Comparison of Modeled Temperature using Fully Mixed Volume Elements with Temperature Data at T.R.M. 286.0

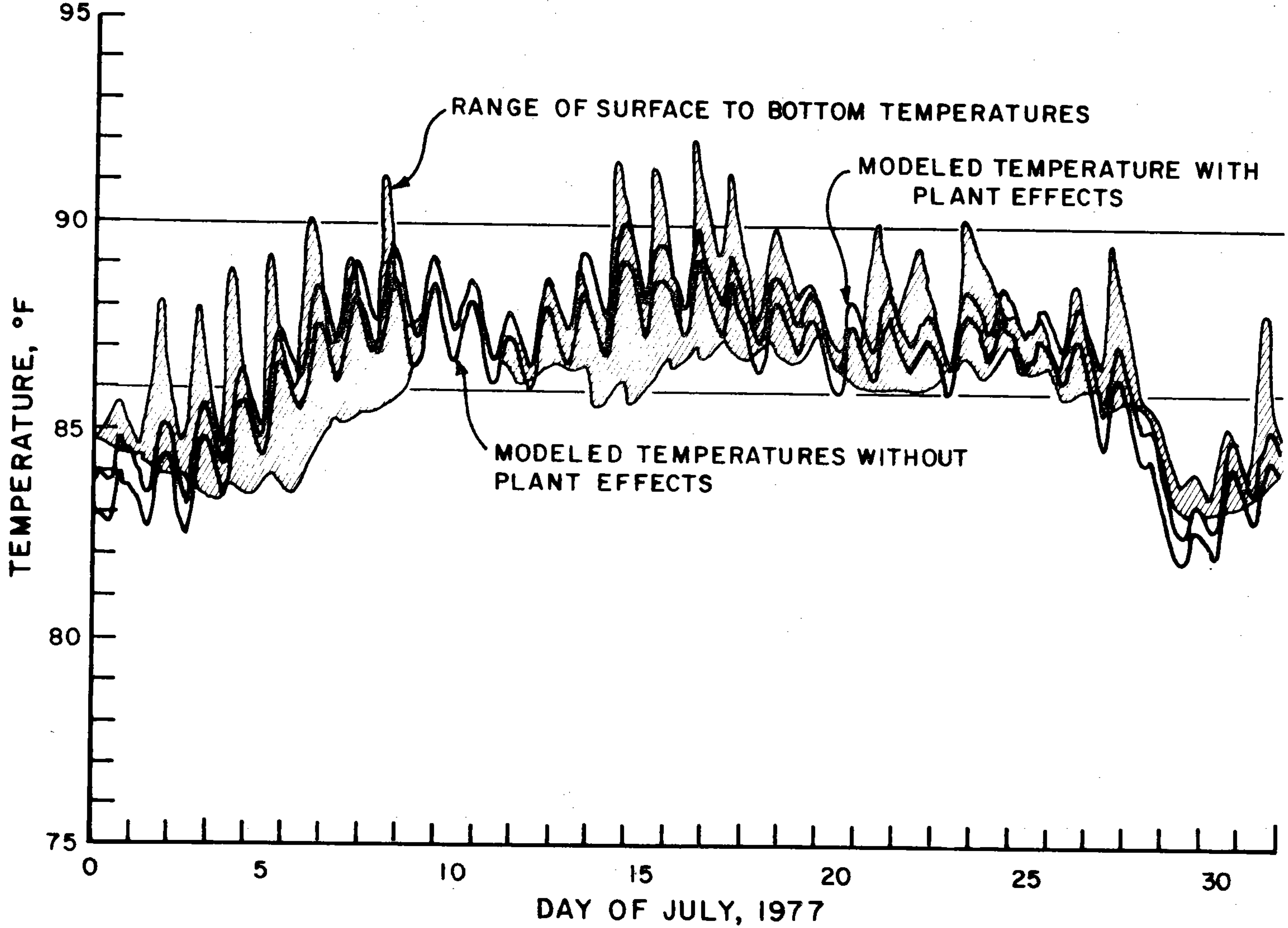


Figure 4.1-10 : Comparison of Modeled Temperature using Stratified Layer Volume Elements with Temperature Data at T.R.M. 286.0

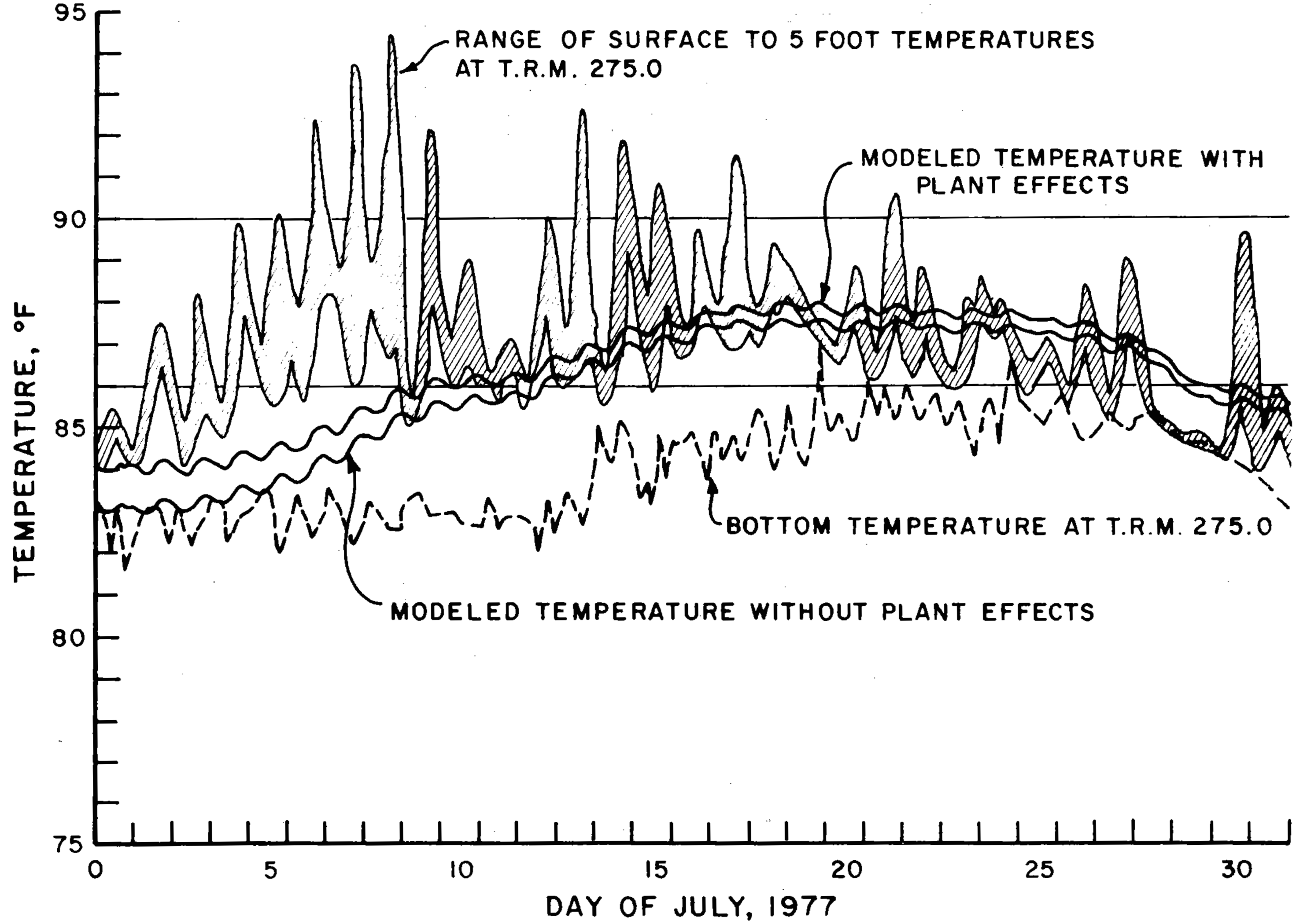


Figure 4.1-11 : Comparison of Modeled Temperature using Fully Mixed Volume Elements with Temperature Data at T.R.M. 275.0

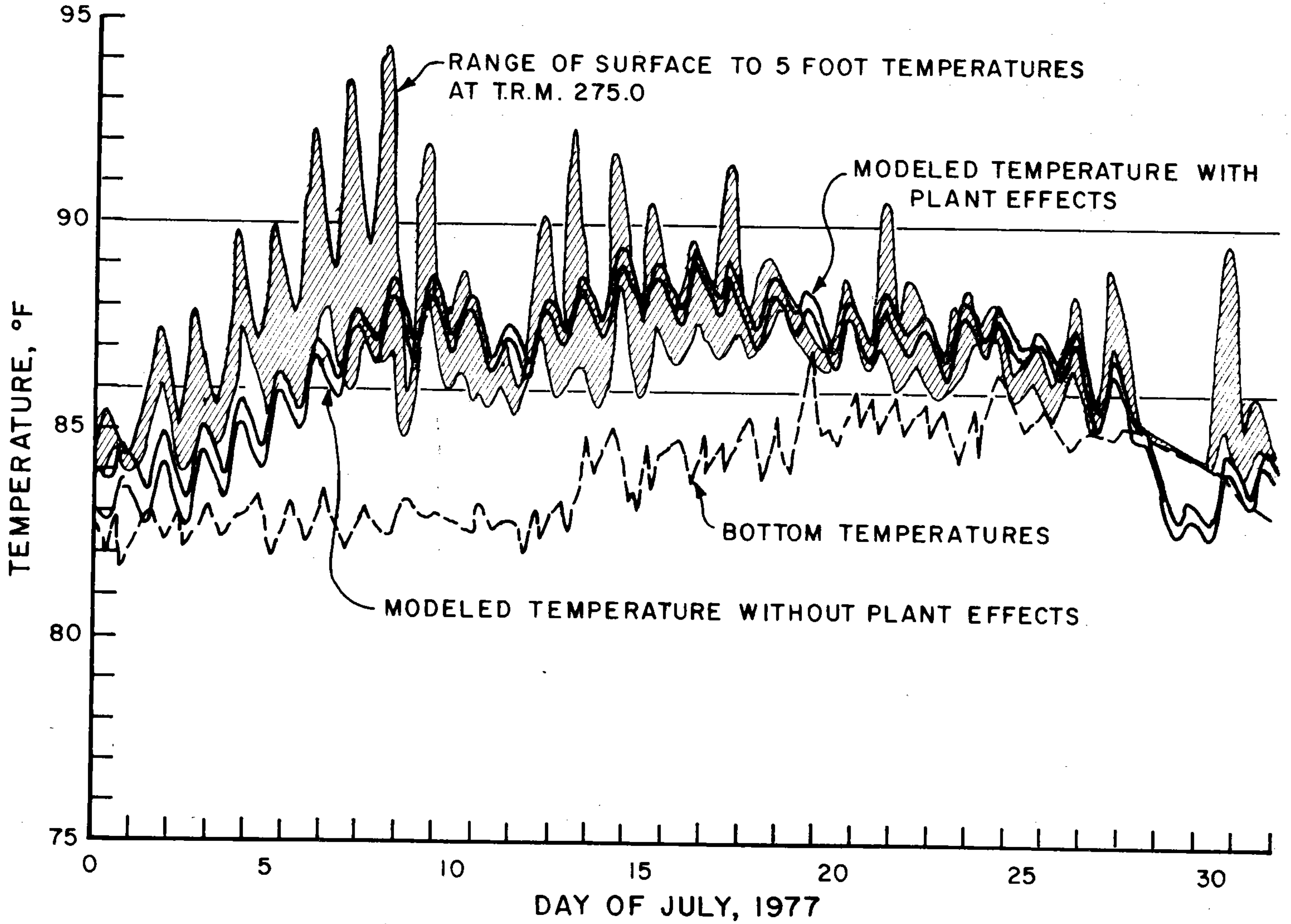


Figure 4.1–12 : Comparison of Modeled Temperature using Stratified Layer Volume Elements with Temperature Data at T.R.M. 275.0

thick stratified element does not respond as quickly to meteorological conditions as the one to two-foot thick layer measured in the prototype.

From a comparison of field data and model results in Figures 4.1-7 and 4.1-8, it can be inferred that the primary temperature effects of the Browns Ferry thermal discharge are in the surface layer of the reservoir. This corroborates observations noted in the discussion of near field diffuser effects.

Actual temperatures at TRM 286.0 near the mouth of the Elk River (Figures 4.1-9 and 4.1-10) showed diurnal heating effects of 2-5°F in the surface temperature. Surface temperatures exceeded 90°F on several occasions. Modeled temperatures which include plant effects are about 0.5°F higher than temperatures without plant effects for fully mixed volume elements (Figure 4.1-9) and about 0.7°F higher for stratified layer volumes (Figure 4.1-10). Ten-foot stratified layer volume elements again show better agreement with actual temperature data than the fully mixed volume elements, supporting the conclusion that plant temperature effects are primarily evident in the surface layer. Because the modeled temperatures agree well in absolute magnitude with actual temperature data, it can also be inferred that plant-induced temperature effects are probably evident from bank to bank in the surface layer downstream of the plant. This is

supported by the fact that from 66 to 100 percent of the river flow is entrained by the Browns Ferry diffusers.

Temperatures at TRM 275.0 near Wheeler Dam (Figures 4.1-11 and 4.1-12) during July 1977 were more stratified than at TRM 286.0 at the mouth of the Elk River. Surface temperatures exceeded 86°F most of the month. Modeled temperatures which included plant effects were still about 0.5°F higher at TRM 275.0 (the same as at TRM 286.0) than temperatures without plant effects for fully mixed volume elements (Figure 4.1-11). This shows the effect of assuming fully mixed volume elements, which dampen temperature dynamics and distort surface heat transfer processes. Stratified elements show temperatures about 0.4°F higher for the case with plant effects than the case without plant effects (Figure 4.1-12). The stratified layer volume elements again fit the actual temperature data better than the fully mixed volume elements.

In summary, the far field temperature effects of the Browns Ferry thermal discharge are primarily evident in the full width of the stratified surface layer of lower Wheeler Reservoir. The magnitude of this effect is on the order of 1°F or less. Insignificant effects on the vertical structure of the stratified layer were noted.

4.2 Potential and Measured Biotic Responses and "Worst Case" Predictions for a 90° F (32.2° C) Thermal Limit

A monitoring program required by NRC Environmental Technical Specifications was initiated at the Browns Ferry Nuclear Plant (BFNP) in 1969. Quarterly samples of the phytoplankton, zooplankton, and benthic macroinvertebrate communities have continued since the winter of 1969. Larval fish surveys were initiated in 1971, while juvenile and adult fish surveys were initiated in 1969 as part of this monitoring program. Sample stations and methodologies currently used for plankton and benthic macroinvertebrate surveys are summarized in Table 4.2-1; stations and methodologies for fisheries surveys are summarized in subsequent sections.

Results of this monitoring program have been compiled into semiannual and annual reports that are on file in the Division of Water Resources Western Area Office in Muscle Shoals, Alabama. Site specific rationales and state-of-the-art technology advances resulted in some methodology alterations. These changes as well as current sample and data analysis methodologies are described in detail in reports cited in section 6.0.

In the following text these data are summarized and discussed briefly to evaluate the effects of permanently operating BFNP at a 90° F (32.2° C) maximum temperature. These evaluations emphasize summers during the 90° F interim variance which was established on July 15, 1977, by EPA and NRC and on July 18, 1977 by AWIC. The summer sample period has been emphasized in this evaluation because June-September is the only time that the Alabama standard of 86° F (30° C) is exceeded.

Table 4.2-1. Number of samples collected from each station as specified in the quarterly biological monitoring required by NRC Environmental Technical Specifications for Browns Ferry Nuclear Plant used in this evaluation.

Stations Below BFNP	Phytoplankton Enumeration/ Identification	Phytoplankton Productivity	Zooplankton	Benthic Macroinvertebrate
TRM 277.98	8[a]	8[a]	2[b]	9[c]
283.94	8	8	2	9
288.78	8	8	2	9
291.76	8	8	2	9
293.70	8	8	2	9
Stations Above BFNP				
295.87	8	8	2	9
301.06	8	8	2	9
307.52	8	8	2	9

a. Duplicate samples from 0.3, 3.0, and 5 m collected with Kemmerer sampler.

b. Duplicate bottom-to-surface tows with net (0.5 m, 80 μm mesh) equipped with flowmeter.

c. Nine randomly collected Ponar grab samples.

4.2.1 Phytoplankton

Moderate increases in water temperature toward an algal species' optimum growth range increase its productivity and importance in the phytoplankton community (Patrick 1974). Cairns (1956) has reported that chrysophytes dominate up to 86° F, chlorophytes dominate from 86° F to 95° F (35° C), and cyanophytes dominate when water temperatures exceed 95° F. These general limits can be shifted by site variations such as relative nutrient enrichment (Bush et al. 1974). Reid (1961) stated that blue-greens can predominate in southern temperate aquatic communities when water temperatures exceed 66°F. In Wheeler Reservoir Chrysophyta usually dominate the phytoplankton in winter and early spring, Chlorophyta in spring and early summer, and Cyanophyta in summer and fall. Of the three algal groups mentioned, diatoms and green algae are superior to blue-green algae as food sources.

Evaluations of the effects of operating BFNP at a permanent 90°F (32.2° C) limit on phytoplankton are based on community parameter comparisons between upstream and downstream stations and between preoperational and operational years with emphasis on the two years (1978 and 1979) during the temporary variance period. Samples in 1977 were collected prior to obtaining the thermal variance. As previously stated, only summer samples are included in this evaluation.

The most probable plant effect would be changes in parameters at downstream stations. Downstream increases would be expected for

the interaction of added heat with other factors such as increased nutrient availability. Dycus and Ungate (1979) showed that flows from the north overbank are entrained into BFNP and that this water has a much more abundant plankton community than that in the river channel proper. Taylor and Dycus (1980) showed that most plankton entrained into the intake during summer is apparently killed and most zooplankton disintegrated. They hypothesized an increased supply of nutrients available for algal uptake in the river channel after discharge through the diffusers and decomposition of organism fragments. Hence, larger phytoplankton numbers would be expected downstream.

Plant generation levels, sample date, and the five preceding days are shown in Table 4.2-2. The 1972 and 1973 samples were taken during the preoperational phase. During the 1974-1977 operational phase monitoring the 86^{o} F (30^{o} C) maximum river temperature limit was adhered to by BFNP. Only one unit was in operation in 1974; either one or two units were in operation during parts of 1975 and 1976, however, neither operated at the time samples were taken; but all three units operated during the 1977 monitoring survey (unit 3 only at a low level). During the interim variance period with 90^{o} F (32.2^{o} C) limit for which phytoplankton data are available (summers of 1978 and 1979), operational monitoring surveys were conducted with all three units operating. If thermal effects are to occur from operation of BFNP at the 90^{o} F (32.2^{o} C) temperature limit, they should have been evident during 1978 and 1979.

Table 4.2-2. Reactor power levels for Browns Ferry Nuclear Plant (units 1, 2, and 3) during sample periods, 1974-1979.

	Reactor Power (percent) (Day samples were taken)		
	Unit 1	Unit 2	Unit 3
July 8, 1974	100%	N/A*	N/A
July 7, 1975	0	0	N/A
July 1, 1976	0	0	N/A
July 12, 1977	54%	70%	4%
July 5, 1978	75%	38%	92%
July 5, 1979	97%	73%	98%
	(Range 5 days prior to sampling)		
July 3-7, 1974	64-100%	N/A	N/A
July 2-6, 1975	0	0	N/A
June 26-30, 1976	0	0	N/A
July 7-11, 1977	60-80%	40-82%	0-4%
June 30-July 4, 1978	70-95%	40-73%	97-98%
June 30-July 4, 1979	96-97%	71-99%	82-99%

*N/A - Not applicable, unit still under construction.

Water temperatures measured at the time plankton samples were collected are summarized in Table 4.2-3. These temperatures are instantaneous measurements which emcompass time of day differences induced by solar heating (i.e., differences in temperatures between stations cannot be attributed solely to operation of BFNP). These data show that during summers of 1972, 1973, 1974, 1975, 1976, and 1979, 86° F (30° C) was not exceeded at any station at the time of sample collection. During the other two years, 1977 and 1978, 30° C was exceeded at some stations downstream of BFNP. However, those high temperatures did not occur at stations immediately downstream of BFNP, rather they occurred several miles downstream in the forebay of Wheeler Reservoir and were probably the result of solar heating.

The phytoplankton assemblage in Wheeler Reservoir was diverse (Table 4.2-4) with 33 Chrysophyta, 56 Chlorophyta, and 23 Cyanophyta taxa identified from summer samples. Phytoplankton composition by major group is shown in Table 4.2-5 for (1) the preoperational sample period, (2) the operational sample period with 86° F (30° C) standard, and (3) the operational period with 90° F (32.2° C) limit. Blue-green algae (Cyanophyta) were usually dominant (50 percent of the standing crop). This occurred from 1972-1976 at both upstream and downstream locations but dominance was consistent and highest (> 75 percent of community numbers) during 1977, 1978, and 1979. Since blue-green algal dominance occurred prior to plant operation both up and downstream of BFNP, it is evident that plant operation,

Table 4.2-3. Wheeler Reservoir Temperatures (F) during summer phytoplankton sample periods, 1972-1979.

(°F Through Profile)

Depth (ft.)	TRM 277.98	TRM 283.94	TRM 288.78	TRM 291.76	TRM 293.70	TRM 295.87	TRM 301.06	TRM 307.52
July 5, 1972								
	(0907)*	(1059)*	(1351)*	(1747)*	(1615)*	(1515)*	(1416)*	(1330)*
3	78	79	78	78	78	78	78	78
10	78	78	77	--**	78	78	77	78
16	78	78	77	78	78	78	77	78
23	--	78			78			
30	--	77						
33	78	--						
39	--	77						
46	77							
July 9, 1973								
	(0815)*	(0930)*	(1105)*	(1130)*	(1350)*	(1425)*	(1330)*	(1605)*
1	82	83	84	85	84	85	82	83
3	82	83	84	84	84	84	81	83
10	82	83	83	--	83	83	81	83
16	82	83	82	82	83	83	81	83
23	81	82			82			
30	--	82						
33	--	81						
49	80							
July 8, 1974								
	(0955)*	(0855)*	(1030)*	(1118)*	(1242)*	(1310)*	(0925)*	(1245)*
1	83	83	82	83	--	85	80	81
3	82	83	81	83	84	83	79	81
5	82	83	80	82	82	82	--	81
10	82	82	80	81	81	81	79	80
16	81	80	80		80	80	79	80
23	--	80			80			
30	--	80						
33	80	--						
39	78	77						
46	77							
49	76							

Table 4.2-3 (Continued)

Depth (ft.)	TRM 277.98	TRM 283.94	TRM 288.78	TRM 291.76	TRM 293.70	TRM 295.87	TRM 301.06	TRM 307.52
July 7, 1975								
	(1220)*	(1155)*	(1135)*	(1050)*	(0945)*	(0900)*	(0920)*	(1430)*
1	83	82	83	81	81	81	80	82
3	83	82	82	81	81	81	80	82
5	--	--	81	81	81	81	--	82
10	82	82	81	81	81	81	80	81
16	82	82	81		81	81	80	81
23	--	--			81			
33	82	82						
July 1, 1976								
	(1145)*	(1155)*	(1055)*	(1025)*	(1010)*	(0950)*	(0930)*	(0850)*
1	80	79	80	78	78	77	78	77
3	79	79	79	78	77	77	78	77
5	79	78	78	78	77	77	77	77
7	--	--	78	--	--	--	--	--
10	78	78	78	77	77	77	77	77
16	78	78	78	77	77	77	77	77
20	--	--	78	77	--	--	--	--
26	78	78	--	--	--	--	--	--
30	--	78			77			
33	78							
36	77							
43	77							
46	76							
49	75							
July 12, 1977								
	(1300)*	(1225)*	(1206)*	(1139)*	(1100)*	(1033)*	(1009)*	(0932)*
1	88	87	86	86	84	83	83	83
3	87	85	85	86	83	82	83	83
5	87	85	85	84	83	82	83	83
10	86	85	84	84	83	82	83	83
16	86	85	84	83	82	82	83	83
23	86	85	84	83	82	82	83	83
26	85	--					83	83
30	84				82			
31	--	84						
52	78							

Table 4.2-3 (Continued)

July 5, 1978

	(1300)*	(1221)*	(1152)*	(1122)*	(1058)*	(1028)*	(1001)*	(0920)*
1	89	88	88	86	85	86	84	84
3	88	88	88	85	86	86	84	83
5	88	88	88	85	85	85	84	83
10	86	86	86	85	85	84	84	83
16	86	86	85	85	85	84	84	83
23	85	85	85	85	85	84	84	83
30	85	85			85			
33	--	83						
36	84	83						
43	83							
46	79							

July 5, 1979

	(1607)*	(1532)*	(1505)*	(1435)*	(1200)*	(1130)*	(0938)*	(0852)*
1	83	85	85	84	84	81	80	80
3	83	85	86	84	84	82	80	80
5	83	85	85	84	84	82	80	80
10	83	84	85	82	83	80	80	80
16	82	83	82	82	83	79	80	80
20	--	--	82	82	--	--	--	--
23	81	83			81	79	80	80
30	81	83			81			
33	--	81						
36	80							
43	79							

*Collection times, CDT
**Dash indicates measurements were not taken at that depth

Table 4.2-4. List of phytoplankton genera collected from Wheeler Reservoir in summer, 1972-1979.

CHRYSOPHYTA

Actinella
Achnanthes
Asterionella
Attheya
Caloneis
Chaetoceros
Cocconeis
Cyclotella
Cymatopleua
Cymbella
Denticula
Diatoma
Dichotomoccus
Dinobryon
Eunotia
Fragilaria
Gomphonema
Gyrosigma
Mallomonas
Melosira
Meridion
Navicula
Nitzschia
Ophiocytium
Pinnularia
Rhizosolenia
Rhoicosphenia
Stauroneis
Stephanodiscus
Surirella
Synedra
Tabellaria

CHLOROPHYTA

Actinastrum
Ankistrodesmus
Arthrodesmus
Acanthosphaeria
Botryococcus
Bracteacoccus
Carteria
Characium
Chlamydomonas
Chlorella
Chlorogonium
Chodatella
Chlorococcum
Cloisteridium
Closteridium
Closteriopsis
Closterium
Coelastrum
Cosmarium
Crucigenia
Cryptomonas
Dactylococcus
Dictyosphaerium
Echinosphaerella
Elakathothrix
Euastrum
Eudorina
Franceia
Gloeoactinium
Gloeocystis
Gloenkinia
Gonium
Kirchneriella
Micractinium
Micrasterias
Mougeotia
Oedogonium
Oocystis
Pachycladon
Pandorina
Pediastrum
Planktosphaeria
Platydorina
Pleodorina
Polyedriopsis
Protococcus
Protoderma
Pteromonas
Pyramimonas
Pyrobotrys
Quadrigula
Scenedesmus
Selenastrum
Schroederia
Sphaerocystis
Spondylomorum
Staurastrum
Stigeoclonium
Tetradesmus
Tetraedron
Tetrallantos
Tetraspora
Tetrastrum
Treubaria
Trochiscia
Ulothrix

CYANOPHYTA

Anacystis
Anabaena
Anabaenopsis
Aphanocapsa
Aphanothece
Aphanizomenon
Arthrospira
Chroococcus
Coelosphaerium
Cylindrospermum
Dactylococcopsis
Eucapsis
Gloeothece
Gomphosphaeria
Lyngbya
Merismopedia
Myxosarcina
Nostoc
Oscillatoria
Phormidium
Raphidiopsis
Rhabdoderma
Spirulina

Table 4.2-5. Composition (percent) for major groups of phytoplankton by Tennessee River mile and year, 1972-1979 (summer), Browns Ferry Nuclear Plant, Wheeler Reservoir, Alabama.

				Operational - 30.0° C Standard				Operational - 32.2° C Limit	
		Preoperational		One Unit	No Unit		Three Unit	Three Unit	
Stations Below BFNP	Major Groups	1972	1973	1974	1975	1976	1977	1978	1979
277.98	Chrysophyta	65	33	32	18	27	2	5	2
	Chlorophyta	19	39	51	24	27	12	13	6
	Cyanophyta	16	32	17	57	46	83	81	91
283.94	Chrysophyta	66	29	29	23	39	5	4	5
	Chlorophyta	19	35	50	41	25	14	12	9
	Cyanophyta	12	35	21	35	36	81	84	84
288.78	Chrysophyta	70	32	43	31	35	3	3	13
	Chlorophyta	25	25	29	27	18	8	16	11
	Cyanophyta	5	32	28	42	48	89	78	75
291.76	Chrysophyta	59	25	55	23	41	3	2	16
	Chlorophyta	21	30	29	29	21	9	9	5
	Cyanophyta	17	40	16	48	38	89	88	78
293.70	Chrysophyta	61	18	50	28	43	4	3	14
	Chlorophyta	24	32	30	31	28	13	12	9
	Cyanophyta	15	50	20	40	29	83	83	76
Stations Above BFNP									
295.87	Chrysophyta	61	18	35	14	41	3	1	26
	Chlorophyta	29	28	49	25	20	11	2	18
	Cyanophyta	10	53	16	59	39	85	97	56
301.06	Chrysophyta	67	13	40	31	40	6	2	20
	Chlorophyta	27	25	37	28	27	13	9	16
	Cyanophyta	5	58	22	41	30	81	88	62
307.52	Chrysophyta	67	7	11	16	58	6	11	14
	Chlorophyta	17	40	49	37	33	17	25	23
	Cyanophyta	12	53	40	50	4	77	63	61

irrespective of applicable thermal maximums, was not totally responsible for this condition.

Estimates of phytoplankton standing crop from 1972 through 1979 are shown in Table 4.2-6. For all years, there was a general increase in numbers in a downstream direction. A comparison of data by station through time shows numbers to be relatively stable in 1972, 1973, and 1974, increasing at downstream stations in 1975 and 1976 when the plant did not operate, followed by an additional increase at most upstream and all downstream stations during 1977, 1978, and 1979 (Figure 4.2-1). Most of this increase was due to greater numbers of cyanophyte cells. A bloom of the blue-green alga Merismopedia occurred at TRM 295.87 (upstream) during 1978 where over 80 million cells/ℓ of the total 110 million cells/ℓ were this one genus. However, numbers of Merismopedia cells were less than 9 million/ℓ at the next station (TRM 293.70) which is immediately downstream from BFNP.

Increases in numbers at both upstream and downstream stations, especially this unusual bloom, show that heightened numbers during 1977 and 1978 must be related to factors other than operation of BFNP. Increases during 1979 occurred primarily at downstream stations, although upstream stations did show slight increases. Since 1979 was a cool wet year, reservoir water temperatures were relatively low and flows relatively high. At least two explanations for the downstream increases exist: (1) Increases were due to plant operation, as previously described;

Table 4.2-6. Phytoplankton numbers (all taxa combined) from 1972-1979 in Wheeler Reservoir, Alabama.

		Phytoplankton cells x $10^6/\ell$							
		Preoperational		Operational - 30° C Standard				Operational 32.2° C Limit	
				One Unit	Zero Unit		Three Unit	Three Unit	
Stations Below BFNP	Depth (m)	1972[a]	1973	1974	1975	1976	1977	1978	1979
TRM 277.98	0.3	3.0	1.7[b]	1.0	3.8	7.0	31.3	15.8	38.5
	3.0	2.7	2.1	1.2	10.8	5.9	34.5	39.9	53.7
	5.0	1.9	1.7	1.2	10.0	5.7	12.8	-d	33.2
	x	2.5[c]	1.8	1.1	8.2	6.2	26.2	27.8	41.8
283.94	0.3	2.0	1.3	1.5	3.8	7.6	14.8	42.5	40.4
	3.0	5.5	1.7	1.5	4.8	7.0	18.4	31.0	21.5
	5.0	2.5	1.4	1.2	2.7	7.6	11.9	23.1	-
	x	3.3	1.5	1.4	3.8	7.4	15.0	32.2	30.9
288.78	0.3	1.5	1.3	0.7	1.8	6.7	42.5	21.5	34.7
	3.0	1.1	1.5	0.7	1.5	5.2	39.8	25.3	23.7
	5.0	1.1	1.1	0.8	1.2	7.1	29.2	24.1	23.2
	x	1.2	1.3	0.7	1.5	6.3	37.2	23.7	27.2
291.76	0.3	0.7	0.4	0.7	1.3	3.3	22.2	52.4	44.6
	3.0	0.8	0.4	0.5	1.6	2.7	32.2	16.2	38.3
	5.0	0.9	0.3	0.4	1.7	1.6	18.9	10.1	18.5
	x	0.8	0.4	0.5	1.5	2.5	24.4	26.2	33.8
293.70	0.3	0.8	0.5	0.4	0.8	5.4	18.5	10.0	10.8
	3.0	0.7	0.5	0.3	0.7	3.3	28.6	11.4	8.2
	5.0	0.7	0.5	0.3	1.0	2.7	16.7	10.9	9.6
	x	0.7	0.5	0.3	0.8	3.8	21.3	10.8	9.5
Stations Above BFNP									
295.86	0.3	1.0	0.3	0.3	1.0	1.1	25.1	200.1	7.8
	3.0	0.7	0.4	0.2	1.6	0.8	27.3	83.4	4.5
	5.0	0.7	0.5	0.2	1.2	1.3	26.0	48.9	4.5
	x	0.8	0.4	0.2	1.3	1.1	26.1	110.8	5.6

Table 4.2-6. (Continued)

Stations Above BFNP	Depth (m)	Phytoplankton cells x $10^6/\ell$							
		Preoperational		Operational - 30^{o} C Standard				Operational 32.2^{o} C Limit	
				One Unit	Zero Unit		Three Unit	Three Unit	
		1972[a]	1973	1974	1975	1976	1977	1978	1979
301.06	0.3	0.5	0.4	0.4	0.8	1.1	11.0	12.6	6.5
	3.0	0.7	0.4	0.2	0.9	0.6	4.2	13.2	2.8
	5.0	0.6	0.3	0.2	0.7	0.9	2.2	16.3	1.4
	$\bar{x}$	0.6	0.4	0.2	0.8	0.9	5.8	14.0	3.6
307.52	0.3	0.7	0.1	0.2	0.4	0.2	6.1	1.2	1.8
	3.0	0.6	0.4	0.1	0.4	0.2	5.2	1.2	0.8
	5.0	0.5	0.4	0.1	0.2	0.1	3.9	1.8	1.8
	$\bar{x}$	0.6	0.3	0.1	0.3	0.2	5.1	1.4	1.5

a. Single samples were taken in 1972.
b. Mean of duplicate samples.
c. Mean of samples at all depths.
d. Data not available.

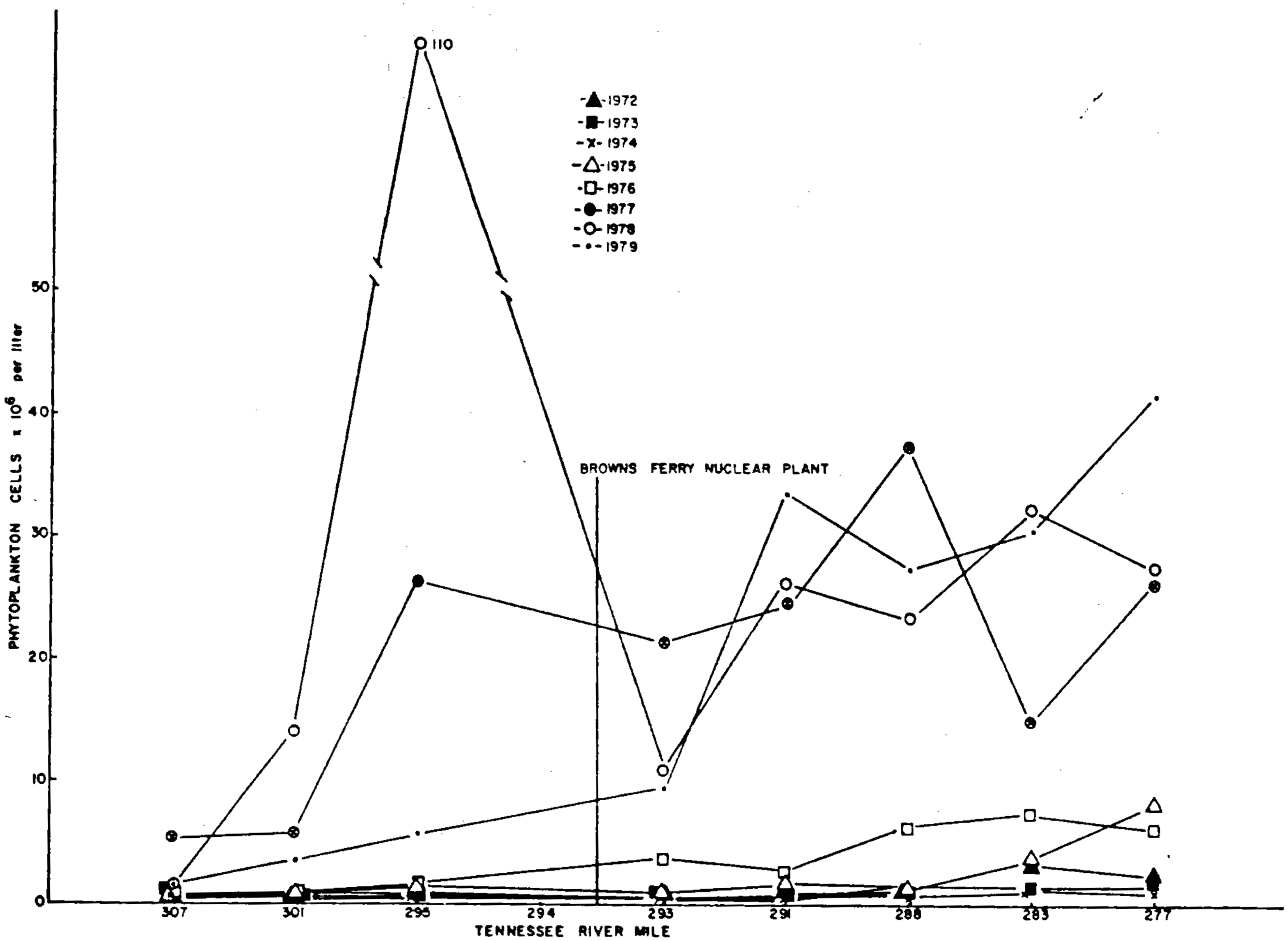


Figure 4.2-1. Phytoplankton cell numbers (sample mean from surface to 5m depth) collected at each station in Wheeler Reservoir, Alabama, in summer samples from 1972 to 1979.

or (2) high flows produced velocities in the upstream reach too great for large phytoplankton standing crops to develop; however, decreased velocities in the lacustrine portion of Wheeler Reservoir provided favorable conditions and phytoplankton numbers increased substantially at stations in this reach. Because of numerous interacting factors, delineation of the exact cause is not possible.

Phytoplankton productivity data from 1972 through 1979 are summarized in Table 4.2-7. In 1972, 1973, and 1975, the lower reaches of Wheeler Reservoir were eutrophic [based on criteria developed by Wetzel (1975) of 1000 mg $C/m^2/day$]. In 1974, 1976, and 1979, an even greater carbon assimilation rate occurred in both the lower and middle reaches and in 1977 and 1978 Wheeler Reservoir was hypereutrophic throughout most of the study area including some thermally unaffected stations (TRM 295.8). This clearly suggests causative factors not related to the plant.

Slightly eutrophic conditions during early and mid-1970's changed to highly eutrophic conditions during the late 1970's. Available data for all years studied except 1979 indicate this was the result of factors not related to operation of BFNP since parallel changes occurred both upstream and downstream of the plant. These data indicate that Wheeler Reservoir nutrient loading currently is probably borderline for a healthy balanced biota. An earlier evaluation by TVA (Mallard-Fox Creek EIS 1979) identified this condition and arrived at similar conclusions regarding the status of Wheeler Reservoir. The large increase in

Table 4.2-7. Estimated daily phytoplankton productivity measured in summer samples from Wheeler Reservoir, Alabama, during 1972-1979 (measured by carbon-14 incorporation).

mgC/m^2/day

		Preoperational		Operational 30° F Standard				Operational 32.2°F Limit	
				One Unit	Zero Unit		Three Unit	Three Unit	
	TRM	1972	1973	1974	1975	1976	1977	1978	1979
Stations	277.98	2202	1899	3784	1661	2072	5092	5728	2716
Below	283.94	2702	2539	5496	1935	2705	3393	7020	3545
BFNP	288.78	1167	452	2957	887	3803	4545	7076	5307
	291.76	1143	227	2791	691	1271	3309	7116	4333
	293.70	587	157	1872	374	1926	4779	5571	2373
Control	295.87	511	220	2129	419	888	6126	11778	2350
Stations	301.06	445	52	1789	294	515	1991	8390	797
	307.52	350	89	425	127	156	1358	1059	546

phytoplankton cell numbers during 1979 at downstream stations as compared to upstream stations cannot be easily reconciled, but the potential exists that operation of BFNP at the 90° F (32.2° C) limit could have influenced this increase. Even if this was the case, the phytoplankton community was not substantially different from that in 1977 when the 86° F (30° C) standard was in effect, and no adverse effects should accrue from a 90° F thermal limit for Wheeler Reservoir.

Data summarized in this section do not allow finite determination of the effects of operation of BFNP on Wheeler Reservoir phytoplankton at at 90° F (32.2° C) limit. These data do show eutrophic conditions in most of Wheeler Reservoir during periods of no plant operation and plant operation at the 86° F (30° C) standard. Hence, eutrophic conditions will probably exist whether BFNP is granted a permanent 90° F (32.2° C) limit or not.

4.2.2 Zooplankton

Water temperatures that reach 90° F are not expected to have adverse effects on zooplankton density or species composition. Assuming short exposure periods, temperatures in heated discharge zones generally must exceed 93° F before impact occurs (Benda and Gulvas 1976; Carlson 1974; Wrenn et al. 1979).

Evaluation of the effects on zooplankton of operating BFNP at a permanent 90° F (32.2° C) limit are similar to those used for phytoplankton. Community parameter comparisons were made between upstream and downstream stations and between preoperational and operational years. Zooplankton samples were collected concurrently with phytoplankton samples, and therefore, plant generation levels and water temperatures discussed in section 4.2.1 apply here.

The zooplankton assemblage was diverse during all years studied (Taylor et al. 1979). Taxa collected during the 90° F (32.2° C) limit period (1978-1979) are shown in Table 4.2-8. There were 19 cladoceran, 12 copepod, and 33 rotifer taxa collected at the eight stations during these two years. Only two cladoceran, one copepod, and three rotifer taxa were collected above but not below BFNP, while four cladoceran, four copepod, and seven rotifer taxa were found below but not above BFNP. More taxa at the lower stations would be expected because of the lacustrine nature of that portion of the reservoir.

Table 4.2-8. Species of zooplankton collected from Wheeler Reservoir, Alabama, near Browns Ferry Nuclear Plant during summer, 1978 and 1979.

	Tennessee River Mile							
	278	284	289	292	294	296[a]	301[a]	308[a]
Cladocera								
Alona costata Sars						X		
Alonella sp.				X				X
Bosmina longirostris (O. F. Muller)	X	X	X	X	X	X	X	X
Ceriodaphnia lacustris Birge		X		X	X			x
Chydorus sp.							X	
Daphnia ambigua				X				
Daphnia parvula Fordyce				X	X	X	X	X
Daphnia retrocurva Forbes	X		X	X	X	X	X	X
Diaphanosoma leuchtenbergianum Fischer	X	X	X	X	X	X	X	X
Holopedium gibberum Zaddach	X	X	X	X	X	X	X	
Ilyocryptus spinifer Herrick	X		X	X	X	X	X	
Leptodora kindtii (Focke)	X	X	X	X	X	X	X	X
Moina micrura Kurz	X	X	X	X				
Moina minuta Hansen	X	X	X	X	X			
Pleuroxus denticulatus Birge				X				X
Pleuroxus hamulatis Birge					X	X	X	
Scapholebris kingi Sars		X						
Sida crystallina O. F. Muller)				X	X	X	X	
Ceriodaphnia (immature)	X				X			X
Copepoda								
Canthocamptus robertcokeri M. S. Wilson					X		X	X
Cyclops bicuspidatus thomasi S. A. Forbes					X			
Cyclops varicans rubellus Lilljeborg			X					
Cyclops vernalis Fischer	X	X	X	X	X	X	X	X
Diaptomus dorsalis	X	X			X		X	
Diaptomus mississippiensis Marsh						X	X	X
Diaptomus pallidus Herrick	X	X	X	X	X	X	X	X
Diaptomus reighardi Marsh	X	X	X	X	X	X	X	X
Ergasilus sp.	X	X	X	X	X	X	X	X
Eucyclops agilis (Koch)					X			
Mesocyclops edax (S. A. Forbes)	X	X	X	X	X	X	X	X
Tropocyclops prasinus (Fischer)	X	X	X		X			
Rotifera								
Asplanchna sp.			X	X	X	X	X	
Asplanchna herricki	X	X	X	X	X	X	X	
Branchionus angularis Gosse	X	X	X	X	X	X	X	X
Branchionus bidentata Anderson			X	X	X	X	X	
Branchionus budapestinensis Daday	X	X	X	X	X	X	X	X
Branchionus calcyciflorus Pallas	X	X	X	X	X	X	X	
Branchionus caudatus Barrois & Daday	X	X	X	X	X	X	X	X
Branchionus havanensis Rousselet		X	X					

Table 4.2-8 (Continued)

	Tennessee River Mile							
	278	284	289	292	294	296[a]	301[a]	308[a]
Branchionus quadridentatus Herman			X		X	X	X	
Cephalodella sp.						X		X
Collotheca sp.			X	X	X	X	X	
Conochiloides sp.	X	X	X	X	X	X	X	X
Conochilus hippocrepis (Schrank)	X	X	X	X	X	X	X	X
Conochilus unicornis Burckhardt	X	X	X	X	X		X	X
Epiphanes macroura Barrois & Daday	X	X	X	X	X	X		
Filinia sp.			X					
Filinia longiseta	X	X	X	X	X			X
Hexarthra sp.		X	X					
Kellicottia bostoniensis (Rousselet)				X				
Keratella cochlearis (Gosse)	X	X	X	X	X	X	X	X
Keratella crassa Ahlstrom	X			X		X		X
Keratella earlinae Ahlstrom	X	X	X	X	X	X	X	X
Lecane sp.					X			
Monostyla sp.						X	X	X
Platyias patulus (Muller)			X	X	X		X	X
Ploesoma sp.		X						
Ploesoma hudsoni	X	X			X			
Ploesoma truncata	X	X	X	X	X	X	X	X
Polyarthra sp.	X	X	X	X	X	X	X	X
Rotaria sp.				X	X	X	X	X
Rotaria neptunia						X		
Synchaeta stylata	X	X	X	X	X	X	X	X
Triochocera sp.	X	X	X	X	X	X	X	

a - Control Stations

The zooplankton community changed from cladoceran to rotifer domination immediately downstream of BFNP for all years studied, especially during 1978 and 1979 (Table 4.2-9). When group numbers are calculated from total zooplankton numbers (Table 4.2-10), it is apparent that this change resulted from very large increases in rotifer numbers. Cladocera increased moderately in number but decreased in proportion (percentage) of total zooplankton numbers because of the very large increase in rotifers. This suggests ideal conditions for rotifers, an important aspect of which is an abundant, high quality food supply. Most planktonic rotifers feed on algae or detritus. An abundant supply of phytoplankton was available, although most were blue-greens which are of relatively poor food value. A possible source of detritus could be the zooplankton entrained by BFNP intake, disintegrated during condenser passage, and returned to the reservoir through the diffusers (Taylor and Dycus 1980). Large increases in rotifer numbers in 1978 and 1979 (32.2^{o} C limit) but not in 1977 (30^{o} C standard) when phyroplankton numbers were also high suggest that thermal enrichment may increase reproductive success for rotifers. However, rotifer numbers increased in a downstream direction and became dominant during 1973, 1975, and 1976 sample periods when the plant did not operate. Therefore, if thermal "stimulation" is a factor it appears to only slightly accentuate an ongoing trend or process unrelated to the presence of BFNP. Data summarized in this section coupled with thermal plume dispersion data in section 4.1 show that operation of BFNP at a permanent 32.2^{o} C (90^{o} F) limit should not significantly affect Wheeler Reservoir zooplankton.

Table 4.2-9. Zooplankton composition (percent) for major groups during summer in Wheeler Reservoir, Alabama, by river mile and year.

			Operational 30° C Standard				Operational 32.2° C Standard	
		Preoperational	One Unit	Zero Unit		Three Unit	Three Unit	
Stations Below BFNP	Group	1973	1974	1975	1976	1977	1978	1979
TRM 277.98	Rotifera	83	66	91	91	14	84	76
	Cladocera	10	24	6	4	40	7	10
	Copepoda	7	10	3	5	46	9	14
TRM 283.94	Rotifera	88	85	98	91	58	95	94
	Cladocera	6	10	2	4	27	2	3
	Copepoda	6	5	1	5	12	3	3
TRM 288.78	Rotifera	86	82	78	96	82	99	98
	Cladocera	5	11	13	2	9	1	1
	Copepoda	9	7	9	2	9	1	1
TRM 291.76	Rotifera	81	78	75	89	53	69	97
	Cladocera	11	16	20	7	28	15	1
	Copepoda	9	6	5	4	19	16	2
TRM 293.70	Rotifera	73	78	68	91	21	77	91
	Cladocera	16	16	27	6	53	6	3
	Copepoda	7	6	5	3	26	17	6
Stations Above BFNP								
TRM 295.87	Rotifera	61	52	31	36	6	51	39
	Cladocera	30	42	62	49	59	17	19
	Copepoda	9	6	7	15	35	32	42
TRM 301.06	Rotifera	42	80	7	35	18	53	13
	Cladocera	47	14	89	42	61	15	54
	Copepoda	8	6	4	23	21	32	32
TRM 307.52	Rotifera	72	24	2	10	4	12	6
	Cladocera	24	68	92	73	74	19	58
	Copepoda	4	8	6	17	22	69	35

Table 4.2-10. Zooplankton numbers per cubic meter (all species combined) from 1973 to 1979 (summer months) in Wheeler Reservoir, Alabama. Mean of duplicate samples.

			Operational 30°C Standard				Operational 32.2° C Limit	
		Preoperational	One Unit	Zero Unit		Three Unit	Three Unit	
	TRM	1973	1974	1975	1976	1977	1978	1979
Stations	277.98	191,959	208,372	184,544	355,219	242,928	352,562	246,894
Below	283.94	100,572	203,530	212,561	114,543	232,123	410,442	421,236
BFNP	288.78	27,394	79,827	22,530	114,306	37,586	832,428	290,341
	291.76	11,835	53,560	28,829	39,343	46,140	184,043	263,271
	293.70	23,499	59,593	31,711	94,587	37,726	163,434	108,403
Control	295.87	8,744	33,335	11,842	9,431	41,864	51,112	13,799
Stations	301.06	5,077	18,640	14,204	8,114	50,934	41,688	8,011
	307.52	18,029	11,088	12,725	8,309	25,018	17,044	3,682

4.2.3 Ichthyoplankton

Larval fish and egg surveys in Wheeler Reservoir were initiated in 1971 as part of the overall monitoring program. Preoperational data were gathered to determine existing or baseline conditions and to assess the potential for effects of BFNP on these biota. Three previous TVA documents address ichthyoplankton investigations in detail. Baseline data (1971-1973) are summarized in the BFNP Preoperational Fisheries Resources Report, May 1978. Operational monitoring ichthyoplankton studies (1974-1977) are discussed in Biological Effects of Intake (BFNP), Volume 4, January 1978. The third document, "Fish Entrainment and Impingement at BFNP, Wheeler Reservoir, Alabama, for 1978 and 1979," updates larval fish and egg investigations.

Site specific rationales and state-of-the-art technology advances resulted in some methodology alterations during the 9-year monitoring period. These changes, as well as current sample and data analysis methodology, are described in detail in the above reports.

The two full years of larval fish data collected during the 90° F (32.2° C) limit period (1978-1979) showed species composition, density, and relative abundance to be similar to previous sample years (TVA 1978A, 1978B, and 1980). Table 4.2-11 shows relative abundance for dominant larval taxa collected during the complete monitoring period. Data from TRM 293 (plant transect) during 1978-1979 should show effects, or lack thereof, resulting

Table 4.2-11. Relative abundance (%) for dominant taxa of larval fish collected from Wheeler Reservoir, 1971-1972.

	FAMILY					
Date	Clupeidae	Catostomidae	Percichthyidae	Centrarchidae	Sciaenidae	Percidae
1971	93.72	<0.01	0.14	4.25	0.45	< 0.01
1972	92.88	<0.01	0.17	2.33	0.50	0.01
1973	91.53	4.86	0.32	0.36	1.21	0.18
1974	84.95	3.93	1.29	0.33	2.16	0.34
1975	92.00	1.20	0.68	0.50	0.40	0.20
1976	95.37	0.15	1.46	0.19	1.78	0.06
1977	94.25	1.43	0.99	0.73	1.62	0.07
1978	94.90	0.55	1.96	1.29	0.82	0.07
1979	91.07	0.94	3.58	0.51	2.12	0.18

from the increased river temperature allowed by the 90° F (32.2° C) limit. Density of dominant taxa and concurrent temperature data for TRM 293 (1978-1979) are shown in Figures 4.2-2 to 4.2-12.

Clupeids were the dominant taxa collected during the variance period. This was the case for all previous years sampled. Catostomids and percichthyids were the dominant early spawners and were not subjected to temperatures exceeding Alabama State standards for the Tennessee River drainage (Figures 4.2-3, 4.2-4, 4.2-8, and 4.2-9).

Spawning times for Stizostedion spp. (probably sauger) coincided with that of percichthyids and catostomids. Stizostedion spp. were the only larval "coolwater" taxa collected during the 9-year monitoring period and were present all years except 1971 and 1972 (Table 4.2-12). Highest densities occurred in 1973, 1974, 1975, and 1977 and were later reflected in large young-of-the-year numbers in cove samples and gill net catches (Table 4.2-21 in section 4.2.5) of adults in the plant vicinity. Larval Stizostedion spp. densities were low in 1976, 1978, and 1979. Their apparent absence in 1971 and 1972 was the result of initiating the sample program too late; i.e., after the period of larval Stizostedion spp. occurrence.

Temperature data gathered concurrently with larval samples show that water temperatures did not exceed 71.6° F (22° C) during periods when Stizostedion spp. larvae were present in Wheeler

Table 4.2-12. Total numbers, density, latest occurrence, and temperature data for Stizostedion spp. (probably sauger) larvae collected from Wheeler Reservoir, 1971-1979.

Year	Total Number	Density (No./1000 m3)	Latest Occurrence	Mean Temperature (C)*
1971**	0	0		
1972**	0	0		
1973	93	2.14	May 15	19.3
1974	107	1.60	May 15	21.0
1975	112	2.09	May 21	22.0
1976	13	0.22	May 6	19.7
1977	225	2.96	May 11	21.9
1978	2	0.07	May 8	19.9
1979	25	0.85	April 30	20.9

*Mean of day-night water temperature on date of latest occurrence.
**Sampling not begun until after the period of larval Stizostedion spp. occurrence.

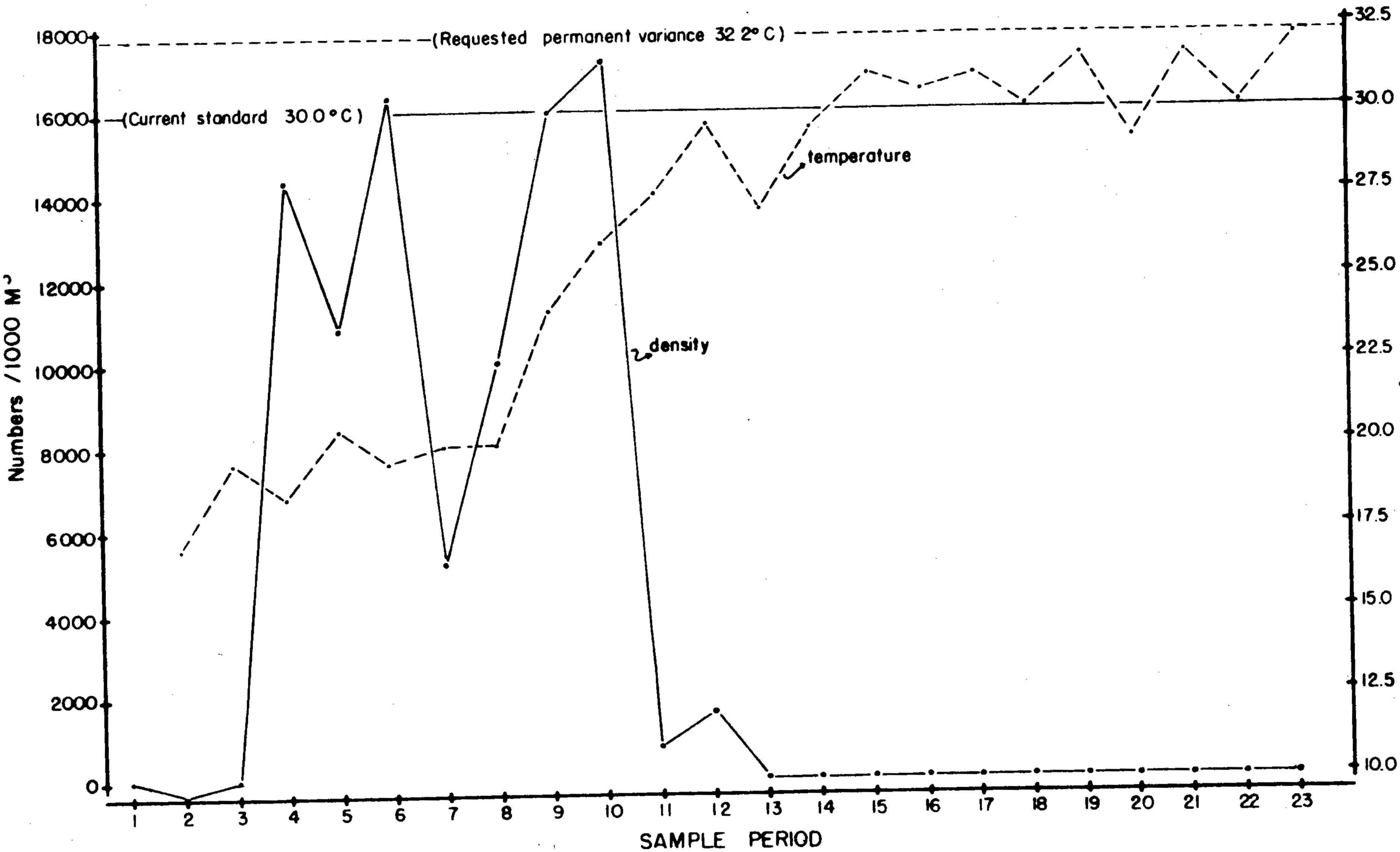


Figure 4.2-2. Water temperature and density (no./1000 m^3) of clupeid larvae collected from Wheeler Reservoir (TRM 293) during March through August, 1978.

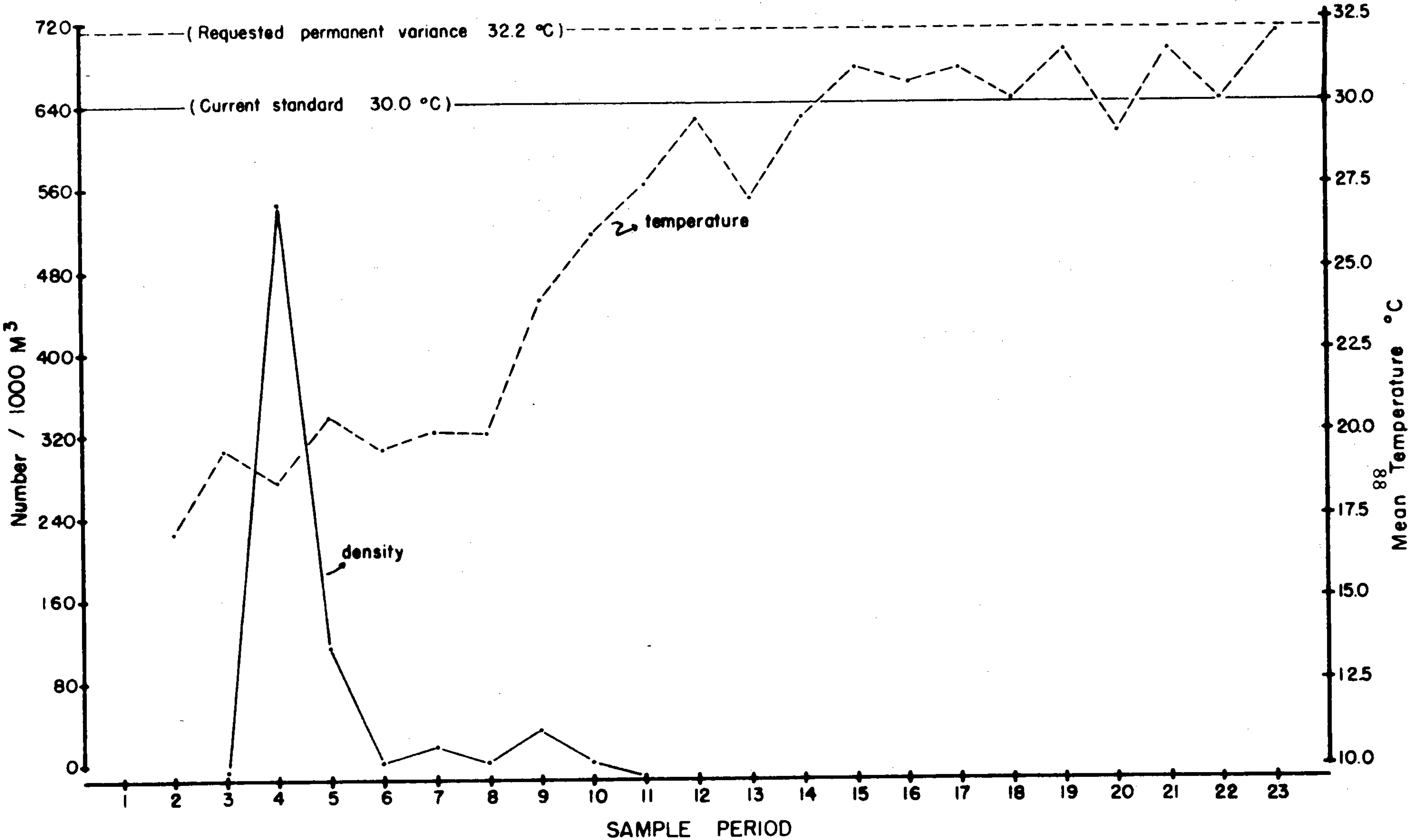


Figure 4.2-3. Water temperature and density (no./1000 m^3) of catostomid larvae collected from Wheeler Reservoir (TRM 293) during March through August 1978.

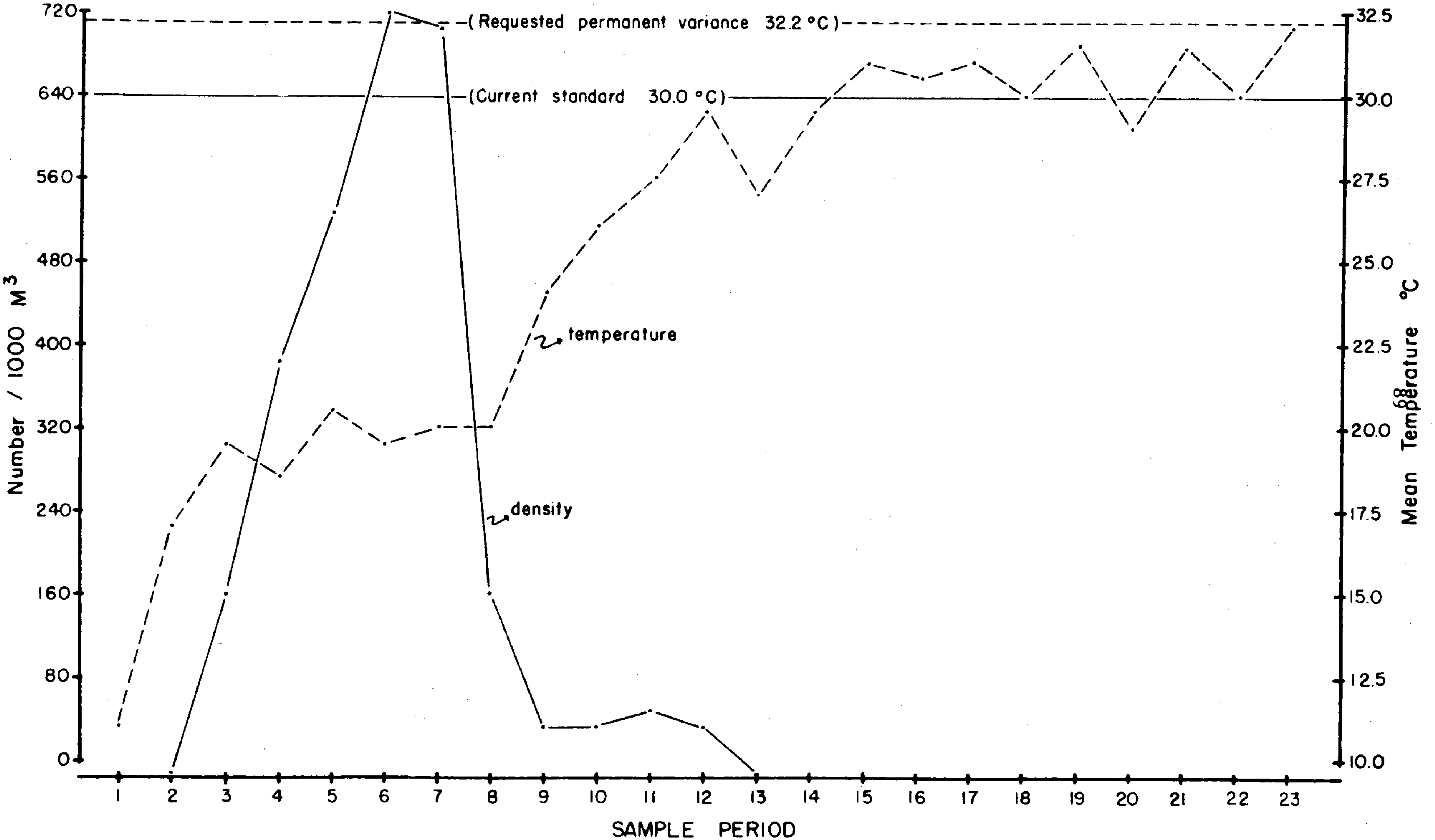


Figure 4.2-4. Water temperature and density (no./1000 m^3) of percichthyid larvae collected from Wheeler Reservoir (TRM 293) during March through August 1978.

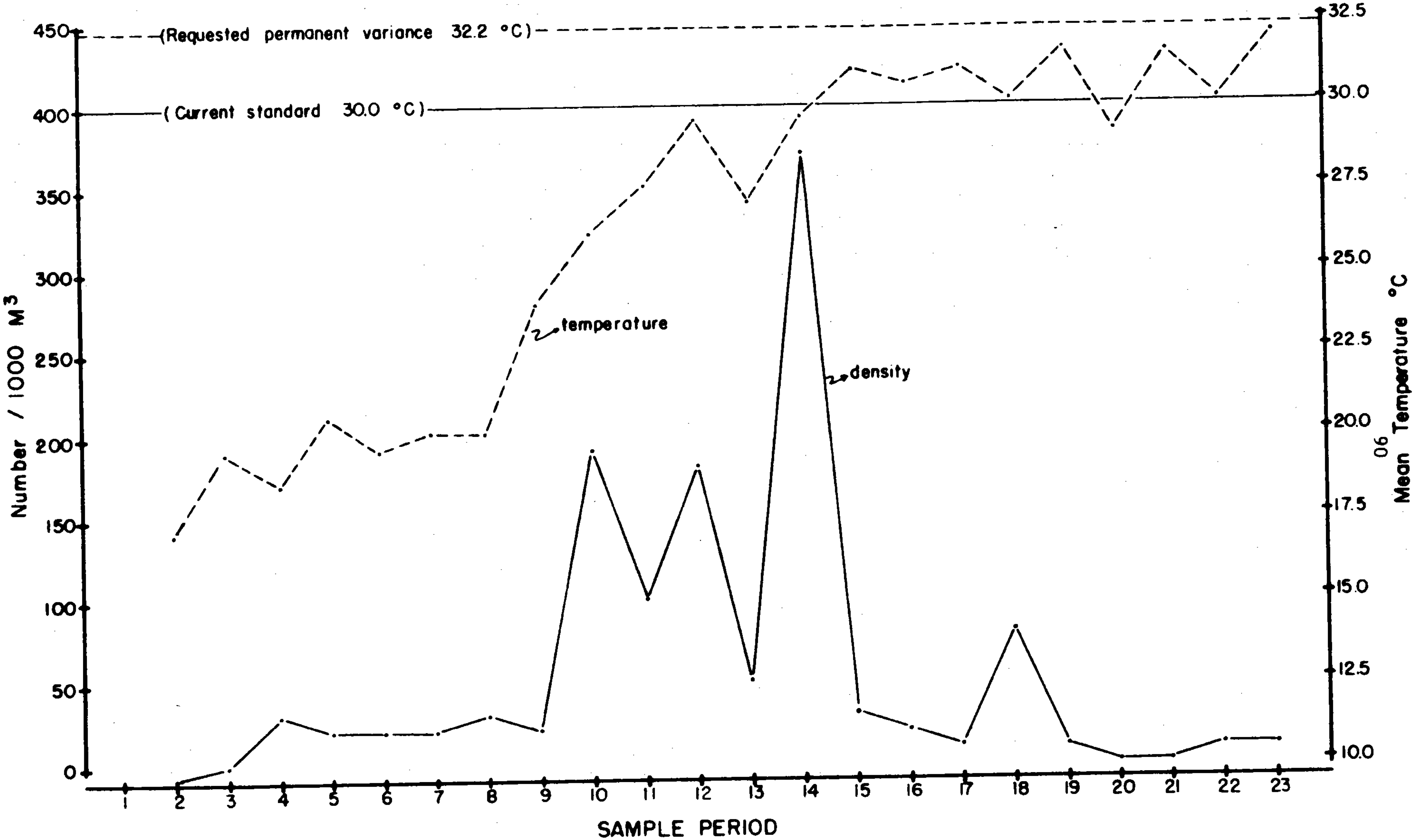


Figure 4.2-5. Water temperature and density (no./1000 m^3) of centrarchid larvae collected from Wheeler Reservoir (TRM 293) during March through August 1978.

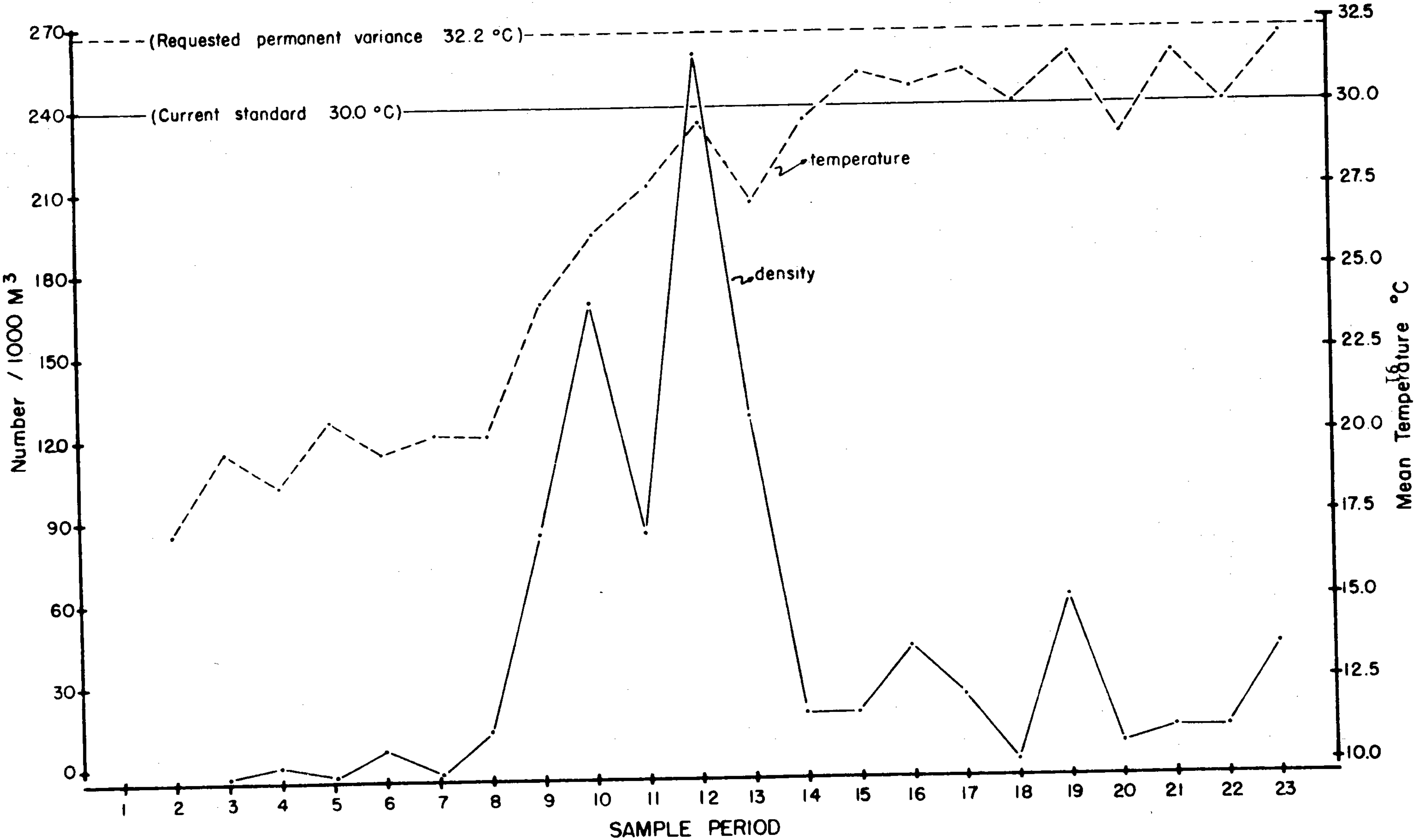


Figure 4.2-6. Water temperature and density (no./1000 m^3) of freshwater drum larvae collected from Wheeler Reservoir (TRM 293) during March through August 1978.

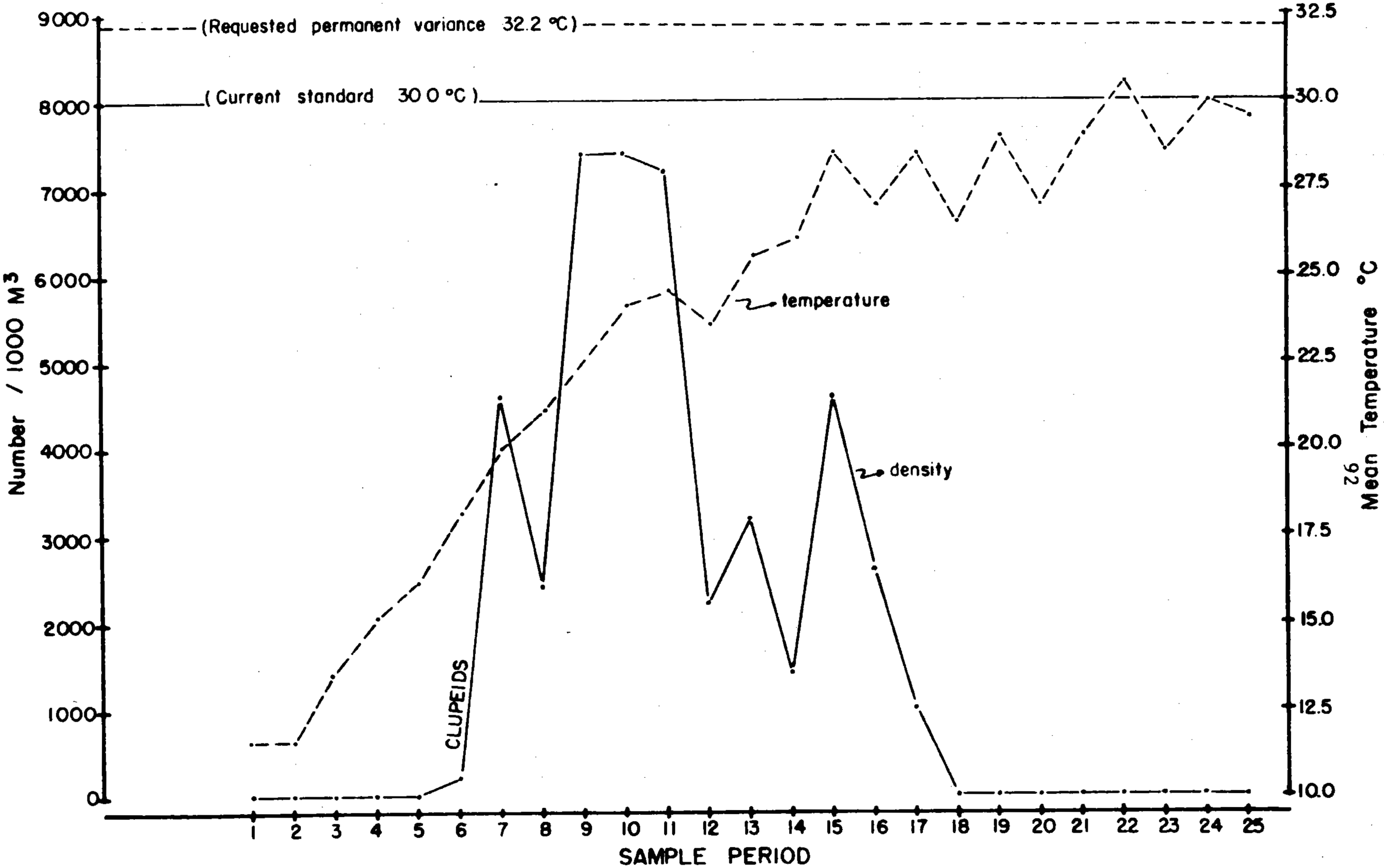


Figure 4.2-7. Water temperature and density (no./1000^3) of clupeid larvae collected from Wheeler Reservoir (TRM 293) during March through August 1979.

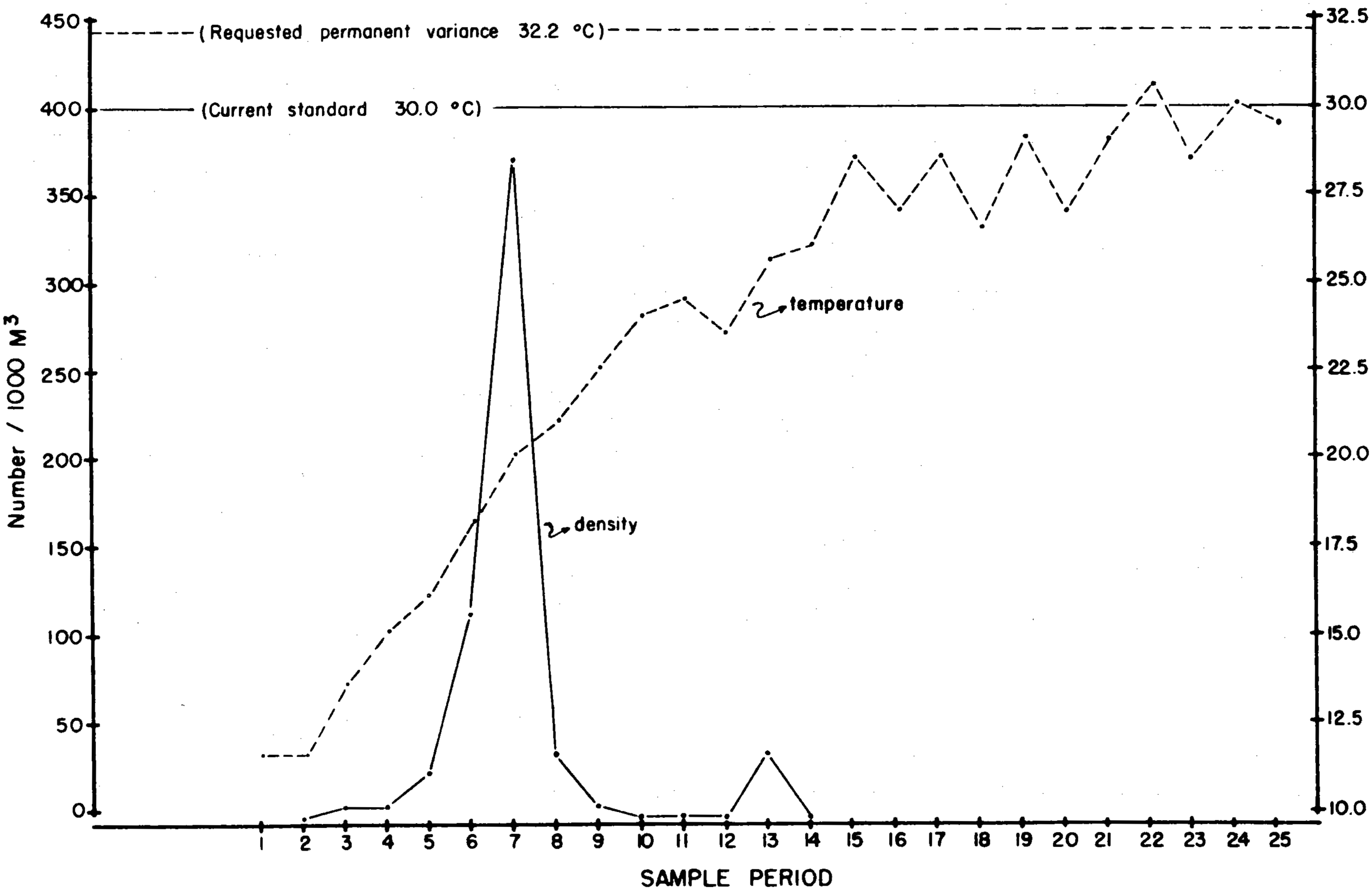


Figure 4.2-8. Water temperature and density (no./1000 m^3) of catostomid larvae collected from Wheeler Reservoir (TRM 293) during March through August 1979.

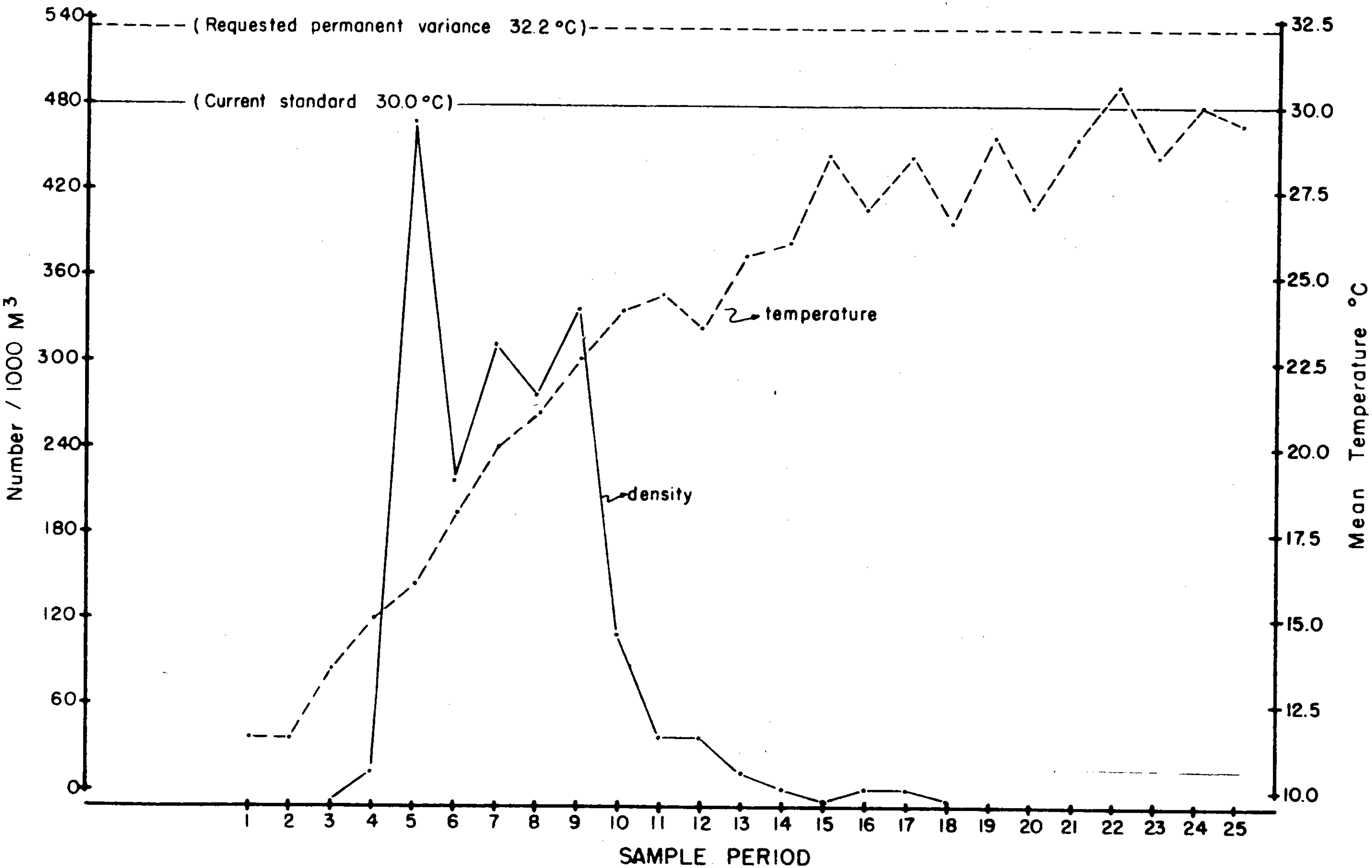


Figure 4.2-9. Water temperature and density (no./1000 m^3) of percichthyid larvae collected from Wheeler Reservoir (TRM 293) during March through August 1979.

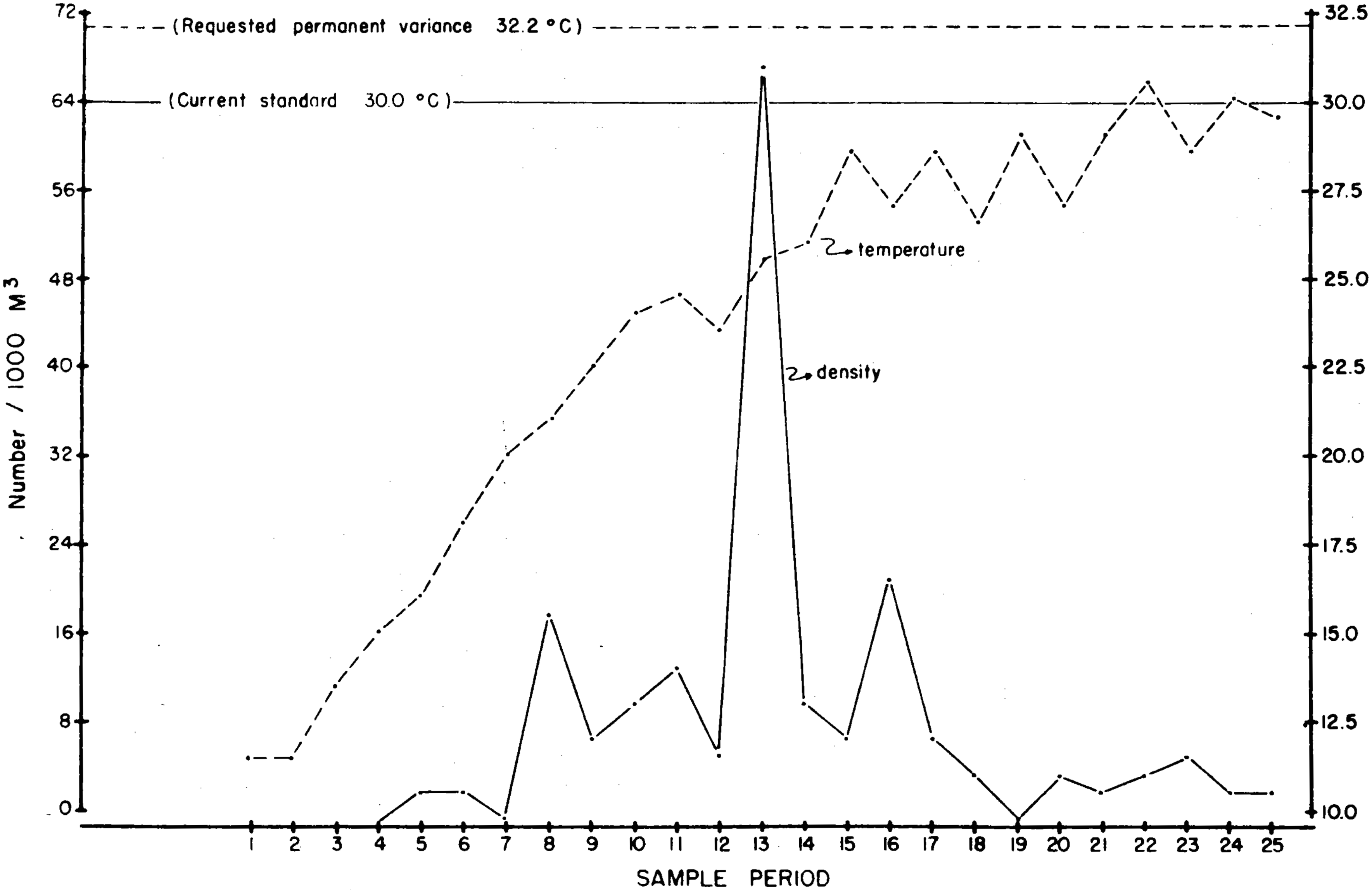


Figure 4.2-10. Water temperature and density (no./1000 m^3) of centrarchid larvae collected from Wheeler Reservoir (TRM 293) during March through August 1979.

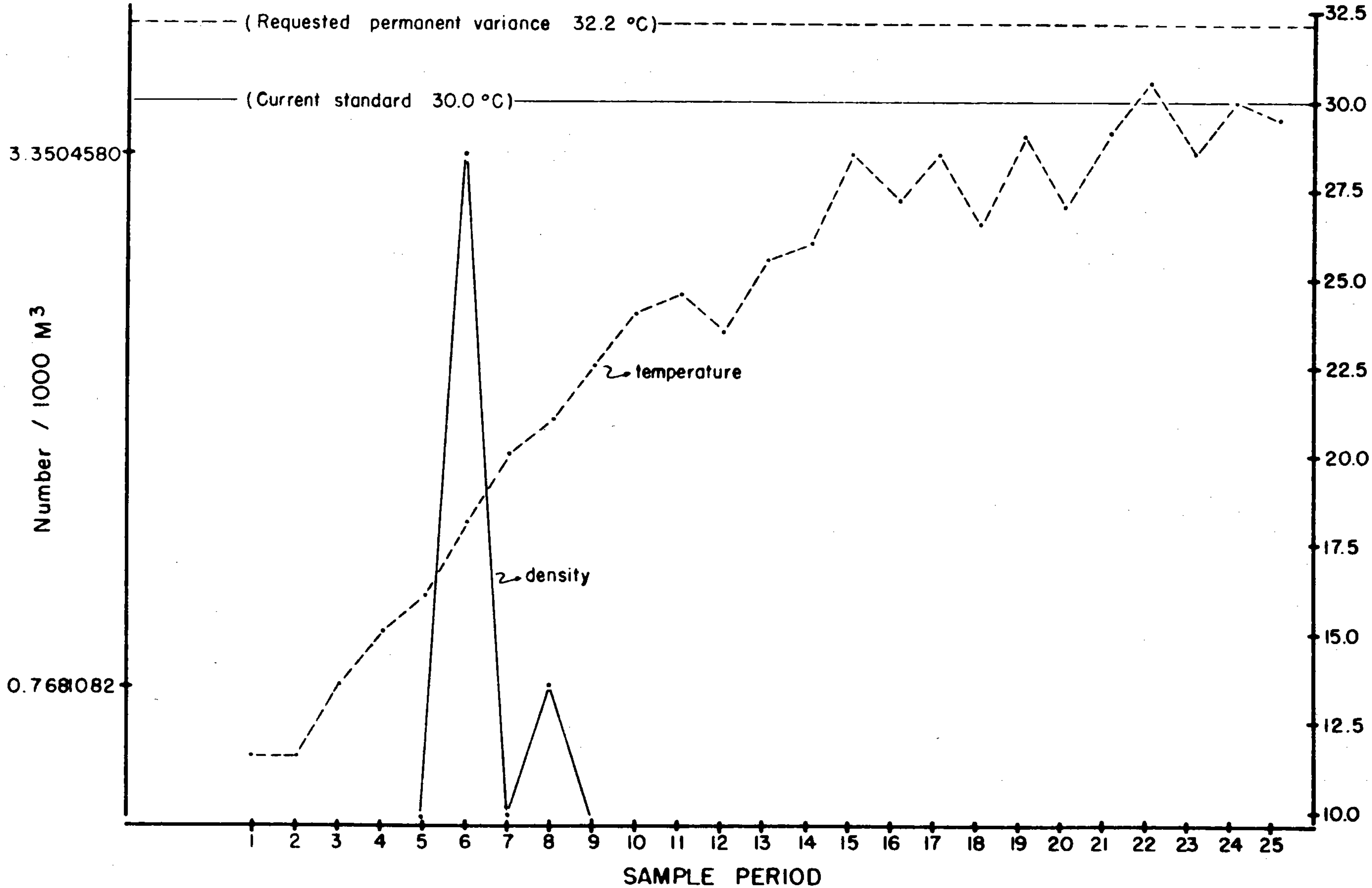


Figure 4.2-11. Water temperature and density (no./1000 m^3) of <u>Stizostedion</u> spp. larvae collected from Wheeler Reservoir (TRM 293) during March through August 1979.

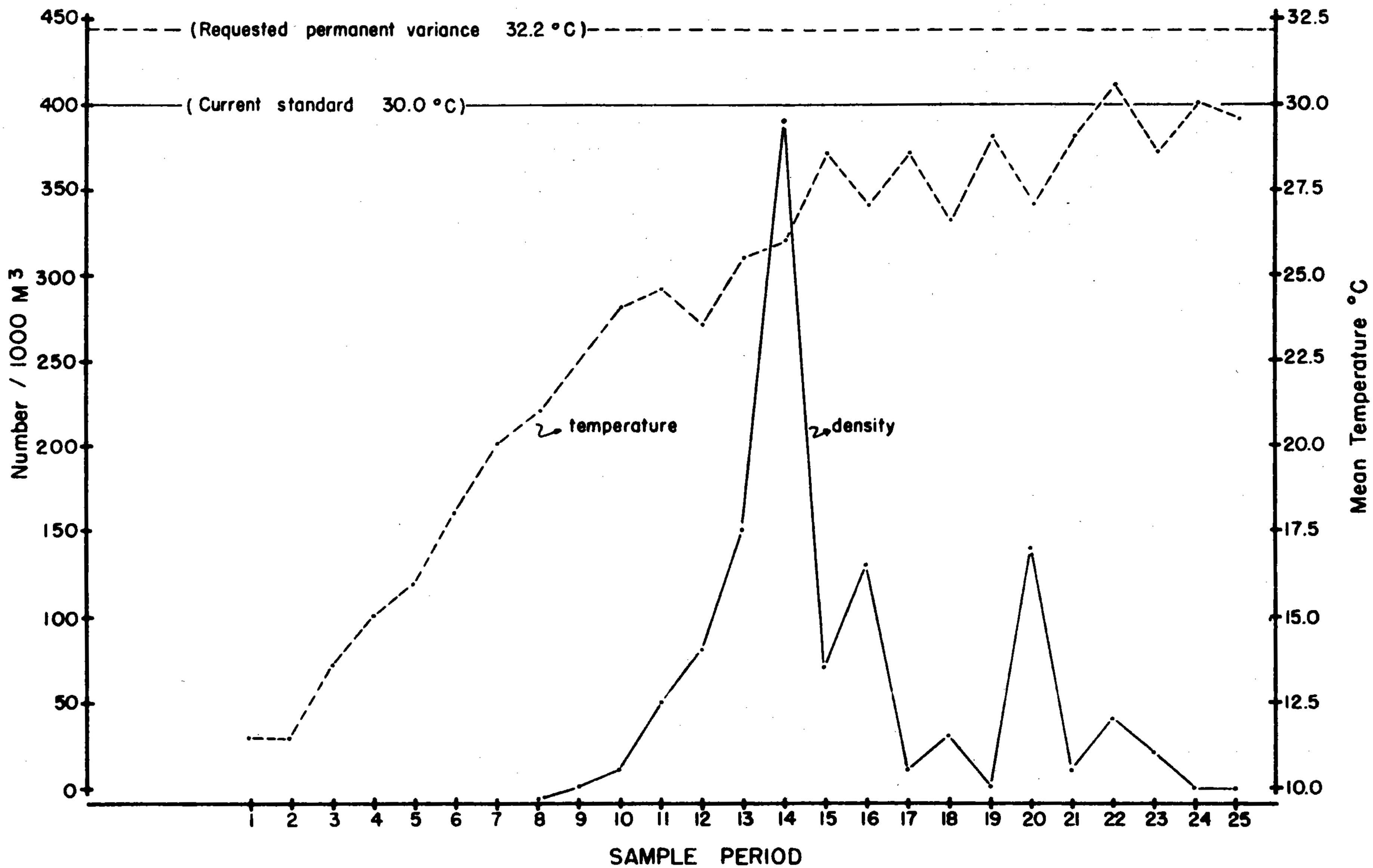


Figure 4.2-12. Water temperature and density (no./1000 m^3) of freshwater drum larvae collected from Wheeler Reservoir (TRM 293) during March through August 1979.

Reservoir. Since the permissible mixed temperature rise of 5° F (2.8° C) will be met as required by State standards and Stizostedion spp. larvae do not occur at temperatures greater than 71.6° F, they will be unaffected by a permanent limit of 90° F (32.2° C).

Centrarchids, clupeids, and freshwater drum were the dominant taxa collected from early to late summer during the 90° F (32.2° C) limit period. This pattern was typical for previous sample years (TVA 1978A, 1978B, and 1980).

Water temperatures taken at TRM 293 concurrently with larval samples did not exceed 86° F until mid-August in 1978 and 1979. Temperature extreme data derived from temperature monitors at TRM 275.0 and TRM 286.0 (Tables 3.1-6 and 3.1-7) show that water temperatures reached 86° F in June 1978 and 1979. Clupeids and freshwater drum were the dominant taxa collected when water temperatures were 86° F (30° C) or greater. Densities of Clupeids were on the decline at this time. These densities peaked on May 30, 1978, and May 7, 1979. Larval freshwater drum peak densities occurred during mid-June in both 1978 and 1979. Relative abundance of these larvae was 0.82 and 2.12 percent in 1978 and 1979, respectively. Therefore, entrainment in thermal plumes of greater than 86° F should be minimal and no effects are expected for a 90° F (32.2° C) limit.

4.2.4 Benthic Macroinvertebrates

Potential responses of the macrobenthic organisms in Wheeler Reservoir to temperatures ranging between 86° and 90° F include mortality, avoidance, community composition changes, and productivity rate changes.

1. Mortality. Temperatures at which benthic organisms are eliminated, presumably by mortality, from thermal discharge zones, rarely fall below 90° F (Wurtz 1961; Benda and Proffitt 1974; Durrett and Pearson 1975; and Miller *et al*. 1976). Lethal temperatures have been documented in laboratory studies for a variety of macroinvertebrate species. Those species whose lethal temperatures in short-term laboratory experiments are much less than 86° F do not occur in Wheeler Reservoir. In the Browns Ferry biothermal research channels, two organisms which occur in Wheeler Reservoir suffered population declines at temperatures lower than 90° F. In studies conducted in 1978, *Caenis* sp. declined approximately 90 percent in channels with mean daily temperatures ranging from about 89° to 96° F. *Corbicula manilensis* held in cages in the channels were completely eliminated when mean daily temperatures rose from 71° to 89° F. The whole macroinvertebrate community excluding Mollusca showed a significant decline in numbers (ca. 65%) at temperatures ranging between 87° and 93° F (Rogders, in press).

2. Avoidance. Certain organisms avoid temperatures between 86° and 90° F either by actively seeking or drifting to cooler areas.

The snail, *Lymnaea stagnalis*, moved from a 95° to 77° F area in a laboratory study gradient (Bovbjerg 1975).

3. Community composition changes. Species diversity and species composition are not likely to be significantly influenced by temperatures between 86° and 90° F. Alston *et al.*, (1978) noted reduced diversity of macroinvertebrates in artificial channels whose water temperature reached a maximum of 96° F, while in channels whose maximum temperature was 87° F diversity was not reduced. Shannon-Weaver (H^1) diversity was unrelated to temperature treatment in experiments in the biothermal channels with temperatures ranging to 93° F (Wrenn *et al.* 1979).

4. Productivity rate changes. There is little available literature relating benthic production to specific temperatures. Estimates of *Caenis* sp. production in the biothermal channels in 1978 indicated progressively less production with the addition of heat. *Caenis* production in channels experiencing 108 days at mean temperatures ranging from 86° to 97° F was 29 percent of that in ambient channels where temperatures did not reach 86° F.

Although these are potential responses, none are expected to occur because bottom temperatures in the mixing zone (the worst case area) are only elevated 1-2° F above upstream bottom temperatures (see section 4.1.1.). The most likely avenue of direct effect would be to drifting organisms or to insects which pass through the water column to emerge.

Evaluation of the effects of operating BFNP at a permanent 90° F (32.2° C) limit were based on community comparisons between up and downstream stations and between preoperational and operational years. Emphasis was placed on summer periods during the temporary variance (1978 and 1979). For discussion purposes, dominant macroinvertebrates have been grouped into two categories: Organisms which experience drift (*Hexagenia* and chironomid midges) and sedentary organisms (*Corbicula* and oligochaetes).

The burrowing mayfly (*Hexagenia bilineata*) inhabits soft sediments and emerges as the adult stage in large numbers, typically in late June and early July. Optimum habitat does not exist at Wheeler Reservoir forebay stations (TRM's 277.98 and 283.94) or riverine stations (TRM 301.06 and 307.52), and relatively low numbers were present in samples from these locations (Table 4.2-13). Largest populations typically were found at stations immediately upstream and up to six miles downstream of Browns Ferry Nuclear Plant during all plant operating regimes. Even though this trend was consistent throughout the study period, *Hexagenia* numbers were generally lower at stations within the six mile reach downstream of BFNP during 1977, 1978, and 1979 than in preceding years. This difference is thought to reflect emergence as adults prior to sample collection in these years since this species is known to be tolerant of relatively high temperatures. Studies at Cumberland Steam-electric Plant on Lake Barkley demonstrated that nymphs of *H. bilineata* survive thermal plume drift for prolonged periods (up to 4.5 hours) at temperatures of 94.6° F

Table 4.2-13. Mean benthic macroinvertebrate numbers per square meter (10 samples) collected at Tennessee River locations during 1974-1979, Wheeler Reservoir, Alabama.

TRM 277.98

	Operation 30° F Standard				Operation 32.2° C Limit	
	One Unit	Zero Unit		Three Unit	Three Unit	
	1974	1975	1976	1977	1978	1979
Diptera						
Chironomidae						
Ablabesmyia sp.	16	12	10			4
Chironomus sp.						
Coelotanypus sp.	92	131	71	136	181	161
Cryptochironomus sp.					2	
Epoicocladius sp.		2				
Procladius sp.		2	2	4	18	5
Culicidae						
Chaoborus sp.	42	28		176	80	16
Ephemeroptera						
Hexagenia bilineata	22	121	26			7
Heterodontida (Pelecypoda)						
Corbicula manilensis	92	173	97	13	138	107
Sphaerium sp.						4
Hirudinea		2				
Somatogyrus isogorus				2		
Oligochaeta						
Branchiura sowerbyi	56	242	89	4	56	70
Limnodrilus sp.	290	274	187	24	76	
Plumatellina						
Pectinatella magnifica					2	
Trichoptera						
Oecetis sp.						4

TRM 283.94

	1974	1975	1976	1977	1978	1979
Diptera						
Chironomidae						
Ablabesmyia sp.	26	20	8		1	11
Chironomus sp.	6	6			11	11
Coelotanypus sp.	56	64	50	92	163	31
Cryptochironomus sp.						47
Epoicocladius sp.	12	2	12	2		
Parachironomus sp.						9
Procladius sp.	6			24	11	25
Culicidae						
Chaoborus sp.	32	4		9	18	20
Ephemeroptera						
Hexagenia bilineata	40	83	423	2	38	5
Heterodontida (Pelecypoda)						
Corbicula manilensis	133	48	159	178	87	45

Table 4.2-13. (Continued)

	Operation 30° F Standard				Operation 32.2° C Limit	
	One Unit	Zero Unit		Three Unit	Three Unit	
	1974	1975	1976	1977	1978	1979
Pisidium sp.						7
Sphaerium sp.					105	4
S. Transversum						47
Hirudinea				5	7	9
Mesogastropoda (Gastropoda)						
Amnicola sp.				15		9
Compeloma sp.	6			2		
Lioplax sp.				49	54	72
Pleurocera (syn. Oxytrema) sp.				2		
Somatogyrus subglobosa isogenus				71	33	5
Viviparus sp.				15	87	246
Oligochaeta						
Branchiura sowerbyi	14	6	181	58	62	36
Limnodrilus sp.	306	403	423	147	76	522
Plumatellina						
Pectinatella magnifica					2	
Trichoptera						
Oecetis sp.						11
TRM 288.78						
Diptera						
Chironomidae						
Ablabesmyia sp.	44	64	16	83	13	31
Chironomus sp.				2	2	
Coelotanypus sp.	16	66	54	32	25	81
Cricotopus sp.						2
Cryptochironomus sp.	8	2		18		2
Epoicocladius sp.		14	14	4	5	5
Parachironomus sp.						2
Procladius sp.	6	4	2	12	9	5
Culicidae						
Chaoborus sp.			4	4	40	
Ephemeroptera						
Hexagenia bilineata	179	300	310	103	152	143
Heterodontida (Telecypoda		10				
Corbicula manilensis	453	195	387	89	252	22
Sphaerium sp.				18	2	11
Hirudinea				18	4	4
Mesogastropoda (Gastropoda)						
Amnicola sp.				4		
Campeloma sp.	2	4				
Lioplax sp.				36		
Somatogyrus isogorus				20		
Oligochaeta						
Branchiura sowerbyi	159	52	147	58	51	81
Limnodrilus sp.	386	405	346	101	109	246
Trichoptera						
Cyrnellus sp.				2		

Table 4.2-13. (Continued)

	Operation 30° F Standard				Operation 32.2° C Limit	
	One Unit	Zero Unit		Three Unit	Three Unit	
	1974	1975	1976	1977	1978	1979
TRM 291.76						
Diptera						
Chironomidae						
Ablabesmyia sp.	32	58	12	112	36	18
Chironomus sp.	2			11	4	
Coelotanypus sp.	18	24	77	47	25	25
Cryptochironomus sp.	4		2		2	
Epoicocladius sp.		4	6	13		4
Parachironomus sp.				2		
Procladius sp.	2	6	10	16	27	29
Culicidae						
Chaoborus sp.			8	38	34	2
Ephemeroptera						
Hexagenia bilineata	173	266	312	199	241	143
Heterodontida (Pelecypoda)						
Corbicula manilensis	318	139	264	154	247	11
Eupera sp.						2
Sphaerium sp.					20	22
S. Transversum						9
Mesogastropoda (Gastropoda)						
Amnicola sp.					2	2
Campeloma sp.	4	10				
Lioplax sp.			2	13	9	4
S. subglobosa isogenus			4		3	7
Viviparus sp.					2	
Nemata						
Paragordius sp.						5
Oligochaeta						
Branchiura sowerbyi	86	95	109	15	13	13
Limnodrilus sp.	356	314	280	147	116	90
Plumatellina						
Pectinatella magnifica					2	
TRM 293.87						
Diptera						
Chironomidae						
Ablabesmyia sp.	68	14	58	48	5	2
Chironomus sp.			2	4	2	
Coelotanypus sp.	18	18	16	36	4	13
Cryptochironomus sp.		2	4			4
Procladius sp.	18	2	2	6	5	22
Xenochironomus sp.					2	
Culicidae						
Chaoborus sp.		2		18	2	
Ephemeroptera						
Hexagenia bilineata	269	167	151	89	83	40

Table 4.2-13. (Continued)

	Operation 30° F Standard				Operation 32.2° C Limit	
	One Unit	Zero Unit		Three Unit	Three Unit	
	1974	1975	1976	1977	1978	1979
Heterodontida (Pelecypoda)						
Corbicula manilensis	288	185	240	117	136	69
Sphaerium sp.			8		4	
Hirudinea			2		2	
Mesogastropoda (Gastropoda)						
Amnicola sp.					2	
Campeloma sp.	2				2	
Lioplax sp.			18	28	13	
Pleurocera (syn. *Oxytrema*) sp.				2		
S. subglobosa isogenus				36	9	
Oligochaeta						
Branchiura sowerbyi	88	44	46	32	7	199
Limnodrilus sp.	439	272	16	143	27	
Plumatellina						
Pectinatella magnifica					2	
Tricladida						
Planariidae				36		
TRM 295.87						
Diptera						
Chironomidae						
Ablabesmyia sp.	30	10	26	18	11	41
Coelotanypus sp.	12		20	18	14	18
Cryptochironomus sp.			2		5	4
Epoicocladius sp.			2			
Procladius sp.	8	2	20	25	40	25
Xenochironomus sp.	10	6				
Culicidae						
Chaoborus sp.	6		8			4
Ephemeroptera						
Hexagenia bilineata	185	183	177	114	31	273
Heterodontida (Pelecypoda)						
Corbicula manilensis	223	131	153	47	98	110
Sphaerium sp.			2			
Hirudinea				5		
Mesogastropoda (Gastropoda)						
Lioplax sp.			2		5	2
Oligochaeta						
Branchiura sowerbyi	38	16	50	36	5	11
Limnodrilus sp.	195	131	149	91	60	121
Lumbriculidae				4		
Trichoptera						
Agraylea sp.					4	

Table 4.2-13. (Continued)

	Operation 30° F Standard				Operation 32.2° C Limit	
	One Unit	Zero Unit		Three Unit	Three Unit	
	1974	1975	1976	1977	1978	1979
TRM 301.06						
Diptera						
Chironomidae						
Ablabesmyia sp.			2		2	2
Chironomus sp.					2	
Coelotanypus sp.	2		6	2	2	
Cryptochironomus sp.			2		2	2
Glyptotendipes sp.					4	
Paracladipelnia sp.						4
Procladius sp.			6		4	2
Xenochironomus sp.	2			4		
Culicidae						
Chaoborus sp.			18		4	
Ephemeroptera						
Hexagenia bilineata		4	24	2	16	
Heterodontida (Pelecypoda)						
Corbicula manilensis	26	97	56	2	18	13
Hirudinea			2	2	2	
Mesogastropoda (Gastropoda)						
Lioplax sp.					2	
Pleurocera (syn. *Oxytrema*) sp.				7	2	
Oligochaeta						
Branchiura sowerbyi	44	18	71	2	2	2
Limnodrilus claparedianu	90	71	153	4	4	58
Trichoptera						
Cyrnellus sp.					11	
Oecetis sp.						2
TRM 307.52						
Diptera						
Chironomidae						
Ablabesmyia sp.		2	2		5	
Chironomus sp.			6		2	
Coelotanypus sp.		2		7		
Cryptochironomus sp.				2	2	
Glyptotendipes sp.					2	
Parachironomus sp.						4
Procladius sp.		6				5
Xenochironomus sp.	6	58	4		4	11
Culicidae						
Chaoborus sp.				2		
Coleoptera						
Dubiraphia sp.						2

Table 4.2-13. (Continued)

	Operation 30° F Standard				Operation 32.2° C Limit	
	One Unit	Zero Unit		Three Unit	Three Unit	
	1974	1975	1976	1977	1978	1979
Ephemeroptera						
Caenis sp.				18		
Hexagenia bilineata		4		9	5	
Heterodontida (Pelecypoda)						
Corbicula manilensis	36	52	71	16	27	25
Oliquaria reflexa					2	
Hirudinea	2					
Mesogastropoda (Gastropoda)						
Campeloma sp.					2	
Lioplax sp.					4	
Pleurocera (syn. *Oxytrema*) sp.					4	
Viviparus sp.						2
Oligochaeta						
Branchiura sowerbyi			10		2	
Limnodrilus sp.	66	34	30	18	2	5
Trichoptera						
Cyrnellus fraternus					7	22

(34.8° C) and higher (TVA 1977). Recent laboratory studies have documented that H. bilineata eggs will develop and hatch at 93.2° F (34° C) (Tennessen 1979). It therefore appears that thermal effluent from Browns Ferry Nuclear Plant does not affect the H. bilineata population for either a 86° F (30° C) standard or 90° F (32.2° C) limit.

Chironomid midges, depending upon species, may have two or more complete life cycles during summer. Hence, aquatic population densities are subject to marked natural variations. Fluctuations in population number occurred at both upstream and downstream stations under all plant operating regimes. These fluctuations showed no cause-effect relationship for plant operation at either the 86° F (30° C) or 90° F (32.2° C) limit.

Corbicula manilensis, the Asiatic clam, with the exception of a short initial semiplanktonic stage, is sedentary. Largest populations of C. manilensis were generally found at stations immediately upstream and up to six miles downstream of BFNP except for 1979 (Table 4.2-13). This distribution closely parallels that of H. bilineata. If thermal effluent affected this species, the station where changes would be expected to be most prominent was the station immediately downstream of the diffusers (TRM 293.70). The data do show reduced numbers at this station during 1977, 1978, 1979 compared to previous years. However, reductions were evident at other downstream stations not significantly affected by the plume. These reductions are not thought to indicate a

thermal effect, rather they are thought to reflect year-to-year sample variability caused by the contagious distribution pattern of this species.

Aquatic oligochaetes, depending upon taxon and abundance, may be classified as nuisance species and/or species indicative of organic pollution. Data in Table 4.2-13 show population fluctuations unrelated to BFNP with increases and decreases during periods of similar plant operation. Hence, it appears that the thermal effluent from Browns Ferry Nuclear Plant has not affected oligochaete populations.

Benthic macroinvertebrate data do not show that operation of Browns Ferry Nuclear Plant has affected maintenance of a balanced and indigenous benthic macroinvertebrate community for operation at either the 86° F (30° C) standard or 90° F (32.2° C) limit. These data, coupled with thermal data in section 4.1, show that a permanent 90° F (32.2° C) thermal limit should not significantly affect the benthic macroinvertebrate community in Wheeler Reservoir.

4.2.5 Juvenile and Adult Fish

Water temperatures that reach 90° F would not be lethal to important commercial, prey, and game fish species (including sauger and smallmouth bass). Recent studies show that the upper lethal temperature (50 percent mortality) for walleye is 94° F (Wrenn and Forsythe 1978; Wrenn *et al*. 1979; Hokanson 1979). Since sauger are reported to have a slightly higher thermal tolerance than walleye (Hokanson 1979), the lethal limit for sauger is at least 94°F. The upper lethal temperature for smallmouth bass is greater than 95° F (Horning and Pearson 1973; Stauffer *et al*. 1976; Wrenn, in press).

The most likely response under these temperature conditions would be avoidance by sauger, which generally avoid thermal discharge zones when the temperature exceeds 86° F (Wrenn 1975; Yoder and Gammon 1976). Most of the other species would be unaffected; some species would actually seek these temperature levels. For example, in the Ohio River, Yoder and Gammon (1976) reported that channel catfish, flathead catfish, gizzard shad, smallmouth buffalo, white crappie, bluegill, and largemouth bass frequently select temperatures equal to or greater than 90° F during summer. Also, smallmouth bass would not exhibit a strong avoidance response since the summer temperature preference for this species is 86-88° F (Barans and Tubb, 1973; Reynolds and Casterlin, 1976). Trembley (1960) collected smallmouth bass from heated discharge zones at temperatures up to 94° F. In Pickwick Reservoir (Tennessee River drainage),

temperatures that reached 92° F in a heated discharge channel did not create a thermal barrier to movement of smallmouth bass (Wrenn, 1976).

As indicated by the avoidance response of sauger and probably other species, local changes in the species composition of the fish community might occur. However, these changes would not have a significant or irreversible impact on the total fish community. In general, seasonal shifts in the composition of fish species in relation to thermal discharge zones are common (Wrenn 1975). These shifts occur without changing important community characteristics and only represent adaptations of the community along an environmental gradient (Teppen and Gammon 1976).

Historical fisheries data from Wheeler Reservoir date back to 1949 when cove rotenone surveys were first implemented to characterize this fish community. Rotenone surveys are effective for all species and sizes of fish but sample pelagic species less consistently because the surveys are typically taken in coves. Information for pelagic or open water species must be supplemented with data from entanglement and entrapment gear. Preoperational fisheries data included 18 years of reservoir standing stock surveys (from 1949 continuous through 1961 and from 1969 through 1973) and gill and trap net surveys (1970-1973). All these surveys have continued as part of the Browns Ferry Nuclear Plant fisheries monitoring program described

in the NRC technical specifications. Creel census surveys were implemented in 1970 to obtain information regarding the sport fishery in Wheeler Reservoir. Fish species and methodologies used to collect them are shown in Table 4.2-14.

4.2.5.1 Rotenone

Chemical sampling of fishes is an effective method of obtaining standing stock information such as densities, yearclass strength, reproductive success, species composition, and relative abundance. The majority of historical fisheries information for Wheeler Reservoir is cove rotenone data and sample procedures have remained relatively constant throughout the years.

Three locations (TRM 275, TRM 286, and ERM 2.7) were designated for preoperational and operational monitoring. The sites are all located downstream from BFNP (Figure 4.2-13); however, none are located within the expected zone of greatest thermal influence.

Historical data show natural cycles from year to year with a gradual escalating trend for total stock estimates from 1951 through 1960. Cove rotenone surveys were not conducted from 1962 through 1968. Standing stock estimates decreased progressively from 1969 through 1973. Stock estimates during the operation period of BFNP increased in a cyclic fashion from 349.05 kg/ha in 1974 to 745.33 kg/ha in 1977 with a peak of 821.5 kg/ha in 1976.

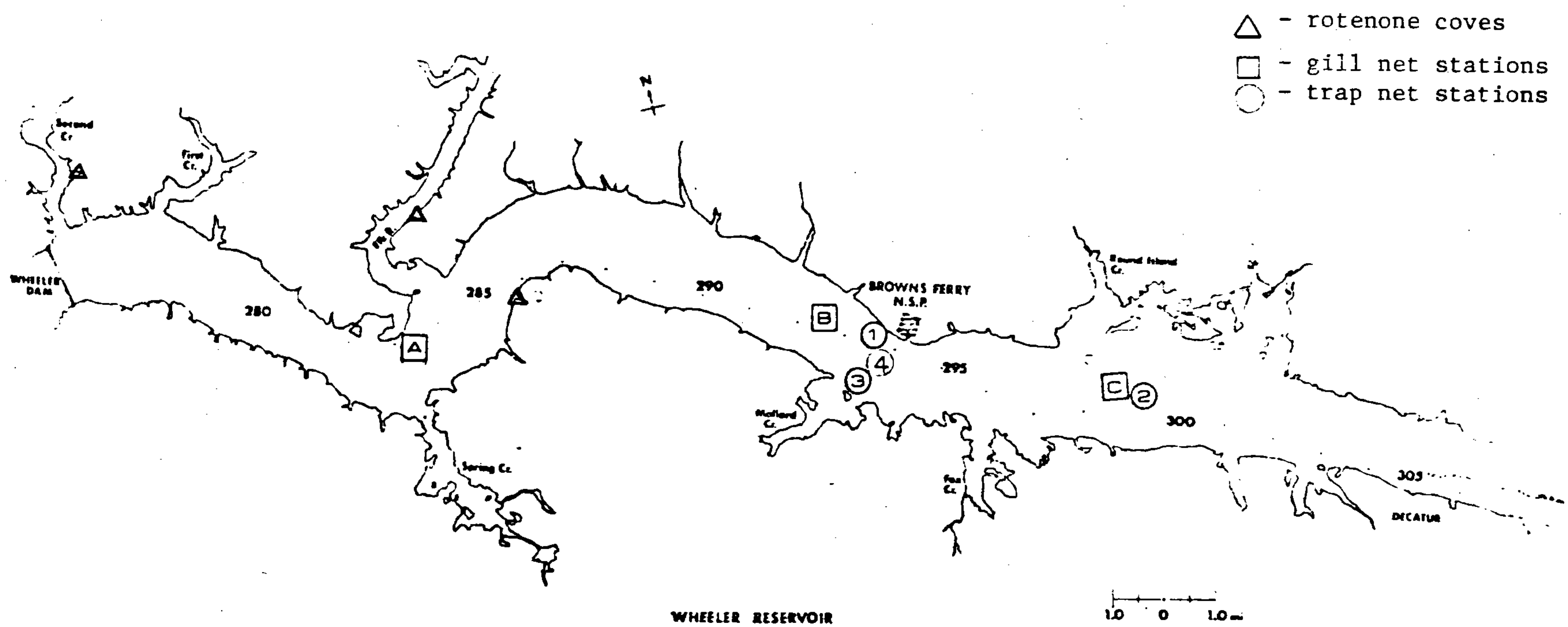


Figure 4.2-13. Location of gill net, trap net, and cove rotenone sample stations on Wheeler Reservoir near Browns Ferry Nuclear Plant.

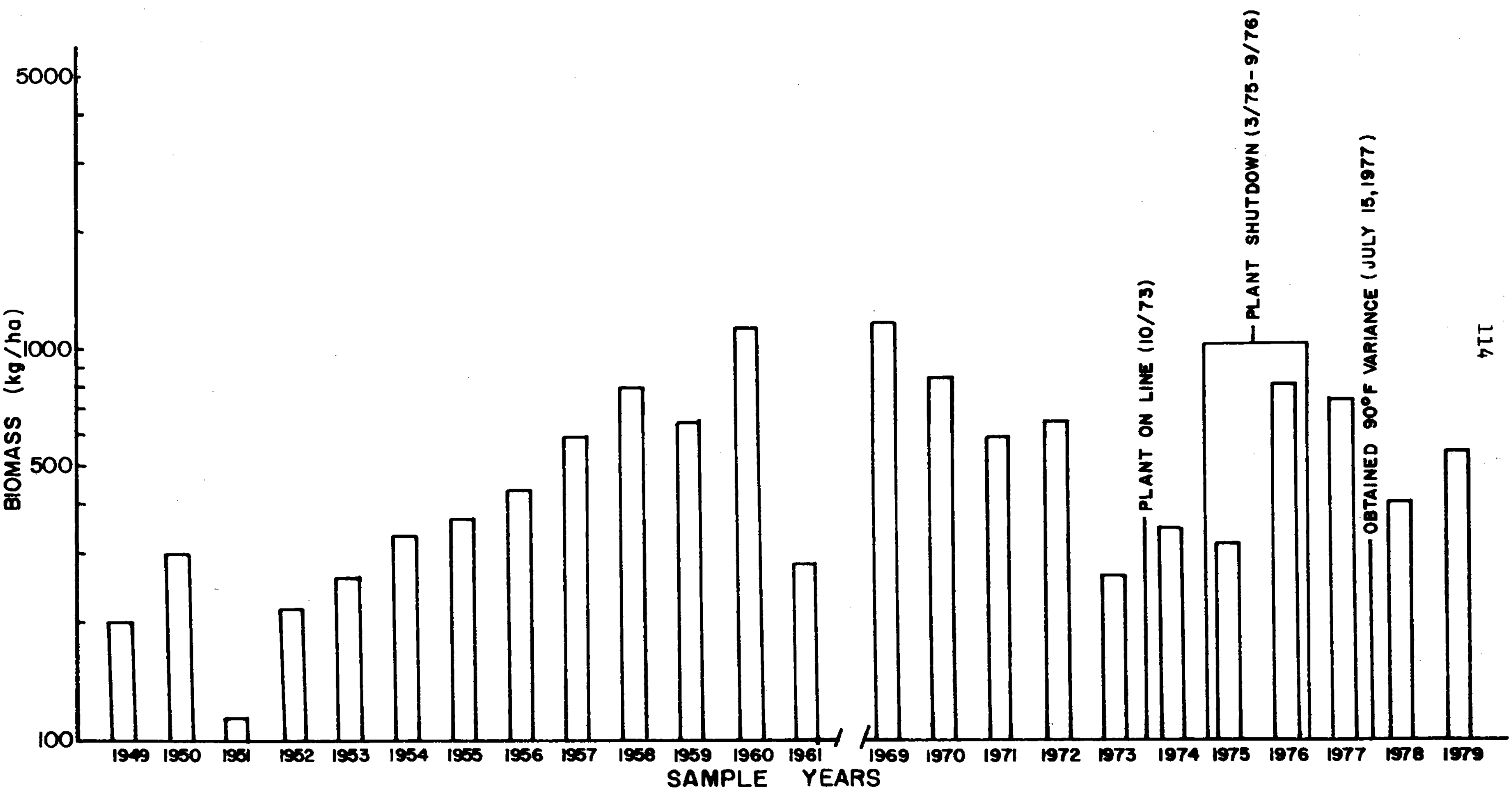


Figure 4.2-14. Cove rotenone estimates of total standing stock (kg/ha) of Wheeler Reservoir fishes, 1949-1979.

Table 4.2-14. Common and scientific names* of fishes collected from Wheeler Reservoir during 1969 to 1979, preoperational and operational monitoring for Browns Ferry Nuclear Plant.

Common Name	Scientific Name	Group**	Rotenone	Trap Nets	Gill Nets	Creel Census	Meter Netting
Paddlefish	Polyodon spathula	C		X	X		
Spotted gar	Lepisosteus oculatus	C	X	X	X		
Longnose gar	Lepisosteus osseus	C	X	X	X	X	X
Shortnose gar	Lepisosteus platostomus	C	X		X		
Skipjack herring	Alosa chrysochloris	C	X	X	X	X	X
Gizzard shad	Dorosoma cepedianum	P	X	X	X		X
Threadfin shad	Dorosoma petenense	P	X	X	X	X	X
Mooneye	Hiodon tergisus	C	X	X	X		X
Stoneroller	Campostoma anomalum	P	X				
Goldfish	Carrassius auratus	C		X	X		
Carp	Cyprinus carpio	C	X	X	X	X	X
Bigeyed chub	Hybopsis amblops	P	X				
Silver chub	Hybopsis storeriana	P					X
Golden shiner	Notemigonus crysoleucas	P	X	X	X		
Emerald shiner	Notropis atherinoides	P	X				X
Spotfin shiner	Notropis spilopterus	P	X				X
Bluntnose minnow	Pimephales notatus	P	X				
Bullhead minnow	Pimephales vigilax	P					X
River carpsucker	Carpiodes carpio	C		X			
Creek chubsucker	Erimyzon oblongus	P	X				
Northern hogsucker	Hypentelium nigricans	C	X	X	X		
Smallmouth buffalo	Ictiobus bubalus	C	X	X	X		X***
Bigmouth buffalo	Ictiobus cyprinellus	C	X	X			

*Taken from Common and Scientific Names of Fishes, American Fisheries Society Special Publication No. 6, Third Edition, 1970.
**Indicates prey (P), commercial (C), or game (G).
***Ictiobus sp. - larval fish; species not known.

Table 4.2-14. (Continued)

Common Name	Scientific Name	Group**	Rotenone	Trap Nets	Gill Nets	Creel Census	Meter Netting
Black buffalo	*Ictiobus niger*	C				X	
Spotted sucker	*Minytrema melanops*	C	X	X	X	X	
Silver redhorse	*Moxostoma anisurum*	C			X		
River redhorse	*Moxostoma carinatum*	C	X	X	X		
Black redhorse	*Moxostoma duquesnei*	C	X		X		
Golden redhorse	*Moxostoma erythrurum*	C	X	X	X	X	
Shorthead redhorse	*Moxostoma macrolepidotum*	C	X		X		
Blue catfish	*Ictalurus furcatus*	C		X	X	X	X
Black bullhead	*Ictalurus melas*	C	X	X	X		
Yellow bullhead	*Ictalurus natalis*	C		X		X	
Brown bullhead	*Ictalurus nebulosus*	C		X	X		
Channel catfish	*Ictalurus punctatus*	C	X	X	X	X	X
Madtom	*Noturus* sp.	P	X				
Flathead catfish	*Pylodictis olivaris*	C	X	X	X	X	X
Blackstripe topminnow	*Fundulus notatus*	P	X				
Mosquitofish	*Gambusia affinis*	P	X				
Brook silverside	*Labidesthes sicculus*	P	X				X
White bass	*Morone chrysops*	G	X	X	X	X	X
Yellow bass	*Morone mississippiensis*	G	X	X	X	X	X
Rock bass	*Ambloplites rupestris*	G	X			X	
Green sunfish	*Lepomis cyanellus*	G	X			X	
Warmouth	*Lepomis gulosus*	G	X	X	X	X	
Orangespotted sunfish	*Lepomis humilis*	P	X				
Bluegill	*Lepomis macrochirus*	G	X	X	X		X
Longear sunfish	*Lepomis megalotis*	G	X	X	X		X
Redear sunfish	*Lepomis microlophus*	G	X	X	X		X
Smallmouth bass	*Micropterus dolomieui*	G	X	X	X	X	
Spotted bass	*Micropterus punctulatus*	G	X	X	X		X

Table 4.2-14. (Continued)

Common Name	Scientific Name	Group**	Rotenone	Trap Nets	Gill Nets	Creel Census	Meter Netting
Largemouth bass	Micropterus salmoides	G	X	X	X	X	X
White crappie	Pomoxis annularis	G	X	X	X	X	X
Black crappie	Pomoxis nigromaculatus	G	X	X	X	X	
Darter	Etheostoma sp.	P					X
Logperch	Percina caprodes	P	X				X
Sauger	Stizostedion canadense	G	X	X	X	X	
Yellow perch	Perca flavescens	G	X				
Walleye	Stizostedion vitreum vitreum	G		X	X	X	
Freshwater drum	Aplodinotus grunniens	C	X	X	X	X	X

Standing stock (rotenone) data gathered during the period (1978-1979; samples in 1977 were taken efore the variance was in effect) BFNP was operated with a 90° F (32.2° C) limit showed a decrease to 404.44 in 1978 and an increase to 549.45 kg/ha in 1979. This is thought to be a natural cycle unrelated to the current interim variance at BFNP. This hypothesis is supported by historical data which show similar cyclic fluctuations (Figure 4.2-14). Standing stock biomass values for 1978 and 1979 were not significantly different from the 24-year average (577.42 kg/ha) for all data.

Fish species occurrence, mean numbers, and mean weights for 1979 are shown in Table 4.2-15. Dominant taxa found during preoperational and operational monitoring are shown in Figure 4.2-15. Gizzard shad (*Dorosoma cepedianum*) were always dominant in terms of biomass. The second most abundant species by weight was bluegill (*Lepomis macrochirus*), and carp (*Cyprinus carpio*) was the third most abundant taxon in 1979. Smallmouth buffalo (*Ictiobus bubalus*) and freshwater drum (*Aplodinotus grunniens*) were also abundant.

The arbitrary categories of game, commercial, and prey species are shown during the 10-year monitoring period in Figure 4.2-16. Standing stocks for all three groups tend to vary in parallel, showing a definite trend. Game species had a gradual but significant decline until the initiation of

Table 4.2-15. Estimated number and weight (kg) of fish per hectare in three samples in Wheeler Reservoir, 1979.

Species	Young of Year		Intermediate		Harvestable		Total	
	Number	Weight	Number	Weight	Number	Weight	Number	Weight
				Game				
White bass	14.62	0.26	2.24	0.12	0		16.86	0.37
Yellow bass	66.33	0.24	0.33	0.02	0		66.67	0.26
Warmouth	183.59	0.66	73.16	1.22	17.02	1.30	273.76	3.18
Green sunfish	174.84	0.55	89.84	1.53	16.22	0.88	280.90	2.95
Bluegill	2,342.83	7.84	1,807.51	31.40	484.60	30.67	4,684.94	69.91
Longear sunfish	1,193.94	4.02	1,206.76	21.64	56.00	2.64	2,456.70	28.30
Redear sunfish	214.41	1.01	80.00	1.35	82.33	11.25	376.75	13.61
Smallmouth bass	24.57	0.17	15.24	0.37	4.90	0.84	44.71	1.38
Spotted bass	40.22	0.24	13.22	0.24	2.46	0.47	55.90	0.95
Largemouth bass	74.65	0.50	82.10	2.33	21.37	10.39	178.11	13.22
White crappie	0		8.70	0.44	15.51	2.26	24.21	2.70
Black crappie	0		0		0.67	0.11	0.67	0.11
Yellow perch	0		0.56	T	0		0.56	T
Sauger	3.43	0.08	1.90	0.20	1.00	0.20	6.33	0.48
Group Total	4,383.43	15.57	3,381.56	60.86	702.08	61.00	8,467.06	137.43
				Commercial				
Spotted gar	2.25	0.15	0.67	0.18	5.68	4.69	8.60	5.02
Longnose gar	0		0.67	0.10	0.33	0.99	1.00	1.09
Skipjack herring	0.71	0.01	5.29	0.26	0.24	0.04	6.24	0.32
Carp	0		0		1.19	4.10	1.19	4.10
Smallmouth buffalo	0		1.76	0.67	42.62	57.30	44.38	57.96
Bigmouth buffalo	0		0		2.71	5.06	2.71	5.06
Spotted sucker	0		3.16	0.39	84.49	34.36	87.65	34.76
Silver redhorse	0		0		7.86	5.45	7.86	5.45
Golden redhorse	0		0.79	0.12	38.70	20.31	39.49	20.43
Channel catfish	1.00	0.01	0		7.56	4.49	8.56	4.51
Flathead catfish	3.33	0.02	6.86	0.52	5.49	3.34	15.68	3.89
Freshwater drum	60.95	0.61	76.08	3.34	66.27	23.30	203.30	27.35
Group Total	68.25	0.80	95.27	5.59	263.14	163.44	426.67	169.83

Table 4.2-15. (Continued)

Species	Young of Year Number	Young of Year Weight	Intermediate Number	Intermediate Weight	Harvestable Number	Harvestable Weight	Total Number	Total Weight
				Prey				
Gizzard shad	315.11	2.71	0		7,357.03	217.09	7,672.14	219.79
Threadfin shad	4,329.97	20.63	0		0		4,329.97	20.63
Stoneroller	0.24	T	0		0		0.24	T
Silver chub	2.81	0.02	0		0		2.81	0.02
Golden shiner	13.05	0.42	0		0		13.05	0.42
Emerald shiner	11.05	0.02	0		0		11.05	0.02
Bullhead minnow	64.22	0.13	0		0		64.22	0.13
Tadpole madtom	0.33	T	0		0		0.33	T
Blackspotted topminnow	25.84	0.06	0		0		25.84	0.06
Mosquitofish	1.67	T	0		0		1.67	T
Orange spotted sunfish	0.24	T	22.71	0.09	1.35	0.01	24.30	0.10
Fantail darter	0.71	T	0		0		0.71	T
Stripetail darter	2.56	T	0		0		2.56	T
Logperch	132.27	1.01	0		0		132.27	1.01
River darter	0.24	T	0		0		0.24	T
Brook silverside	7.32	0.01	0		0		7.32	0.01
Group Total	4,907.62	25.00	22.71	0.09	7,358.38	217.10	12,288.71	242.19
Final Total	9,359.30	41.38	3,499.54	66.54	8,323.60	441.53	21,182.44	549.45

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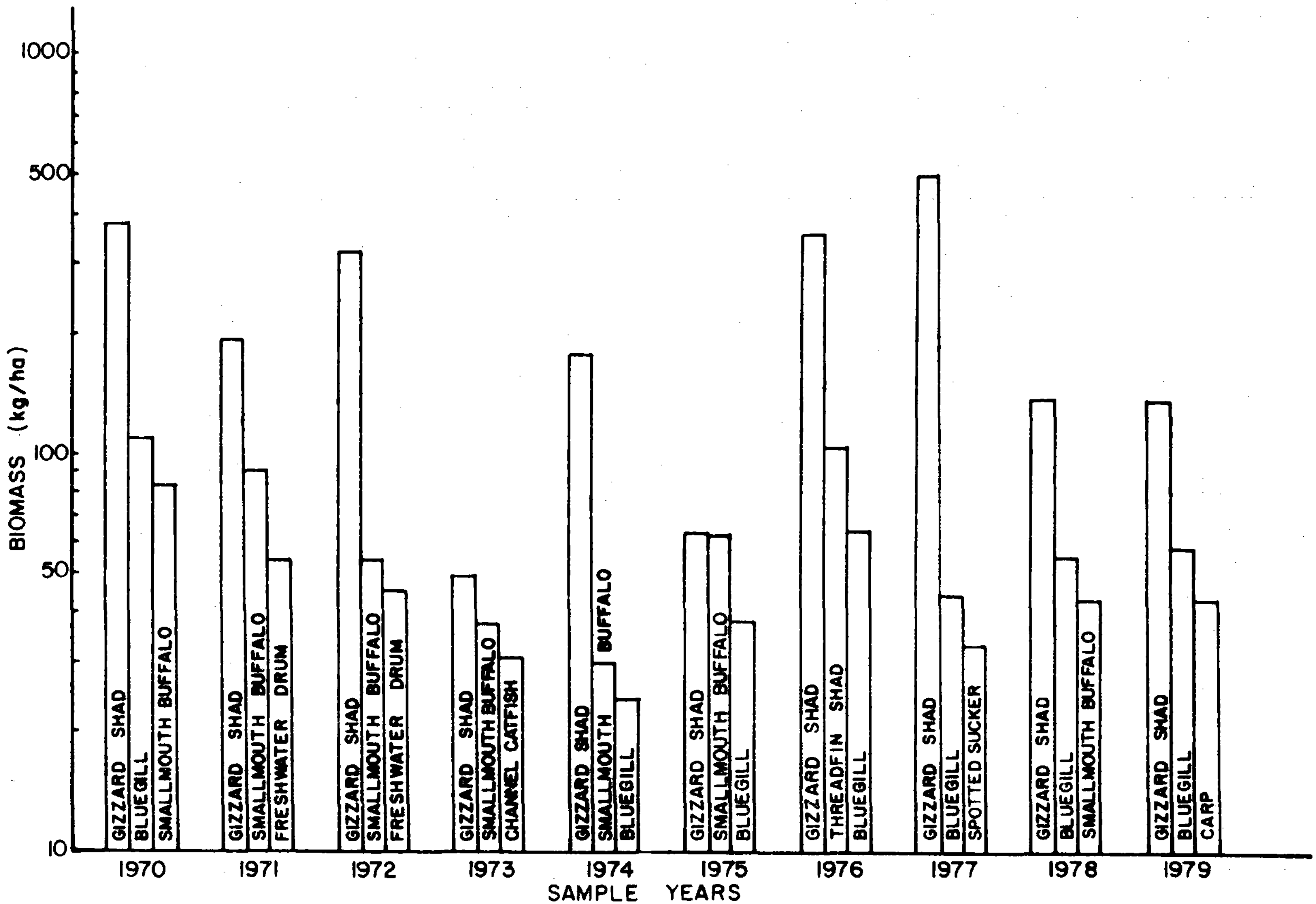


Figure 4.2-15. Dominant taxa (by weight) of fishes collected from Wheeler Reservoir cove rotenone surveys (1970-1979).

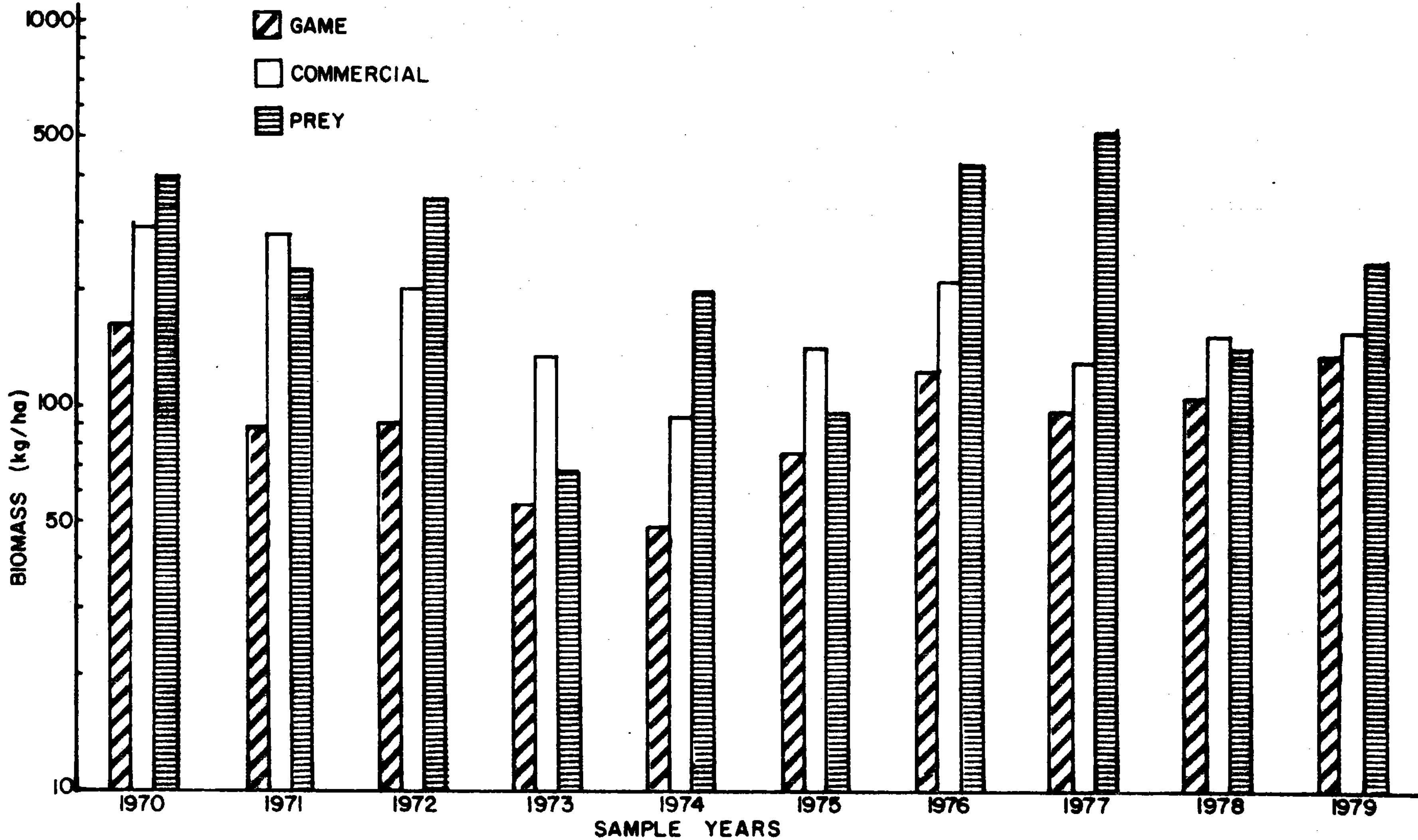


Figure 4.2-16. Biomass (kg/ha) of game, commercial, and prey fishes taken in Wheeler Reservoir cove rotenone surveys from 1970-1979 (average of three coves).

generation by BFNP and an equally gradual and significant increase during operation of the plant. Warmwater centrarchids (e.g., bluegill, redear, sunfish, and largemouth bass) were the dominant game fishes. Stocks of commercial and prey species showed similar trends, the prey species being somewhat more variable than the other two groups.

Density and distribution patterns for sauger and smallmouth bass are key to determining any adverse impact of the 90°F (32.2° C) thermal limit. Walleye have not been collected in cove rotenone samples since 1954 and are sufficiently rare to preclude potential impact from thermal enrichment; however, smallmouth bass frequently occur at all sample locations. Sauger are common in the two coves sampled off the Tennessee River proper but occur infrequently at the Elk River cove (ERM 2.7).

Biomass data and species composition for sauger and smallmouth bass are shown in Figures 4.2-17 and 4.2-18. The mean standing stock for smallmouth bass during the 10-year monitoring period was 1.77 kg/ha. Smallmouth bass standing stocks from 1970 through 1972 were greater than the 10-year mean. The extremely high biomass in the TRM 275 cove in 1971, a definite outlier, accounted for this relatively high average. Sauger biomass was greatest in 1976 and 1977, 2.61 and 2.55 kg/ha, respectively. Although these data show a decrease in 1978 and 1979, biomass during these two years was greater than

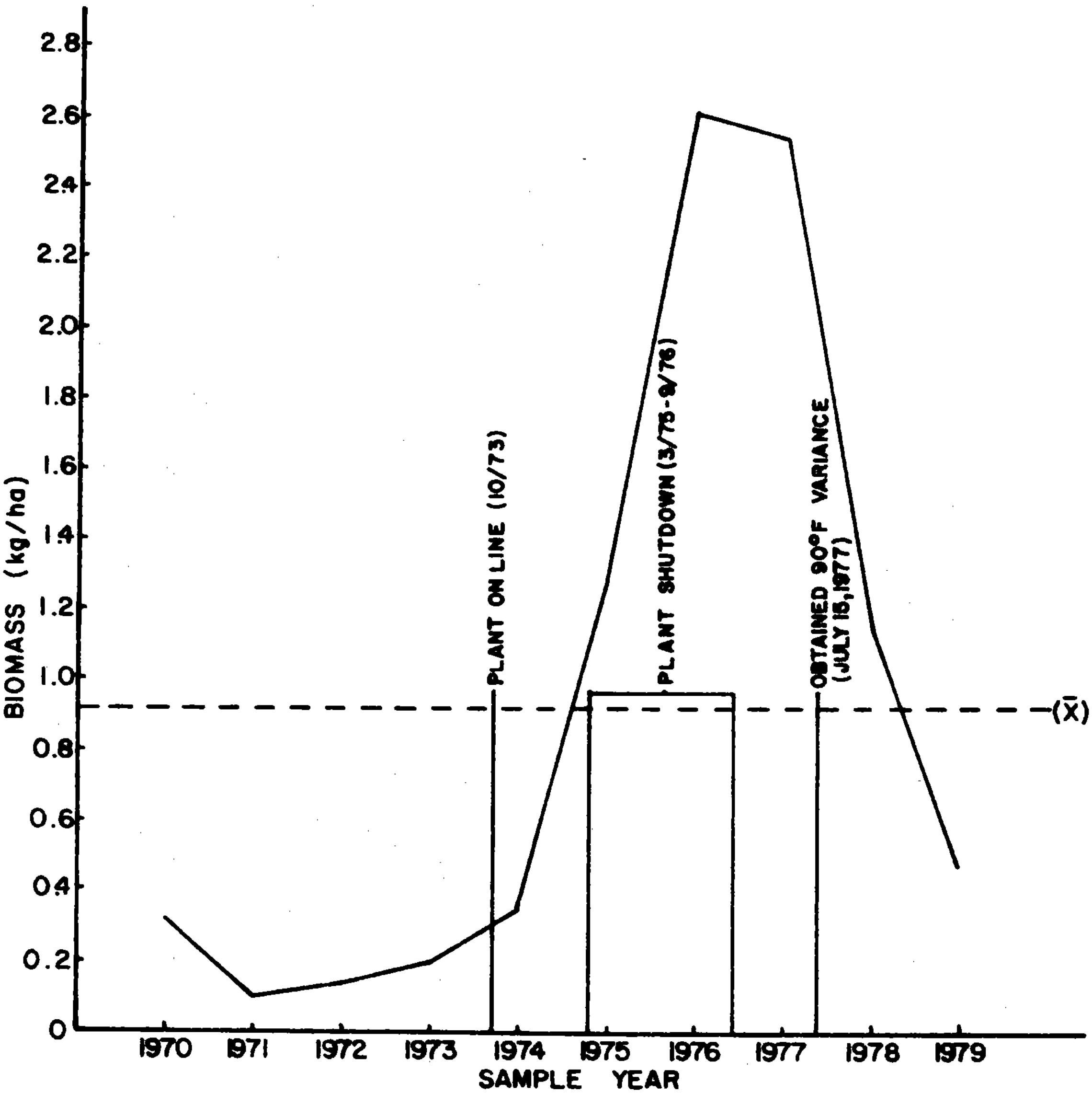


Figure 4.2-17. Sauger biomass (kg/ha) in cove rotenone samples from Wheeler Reservoir (average of three coves).

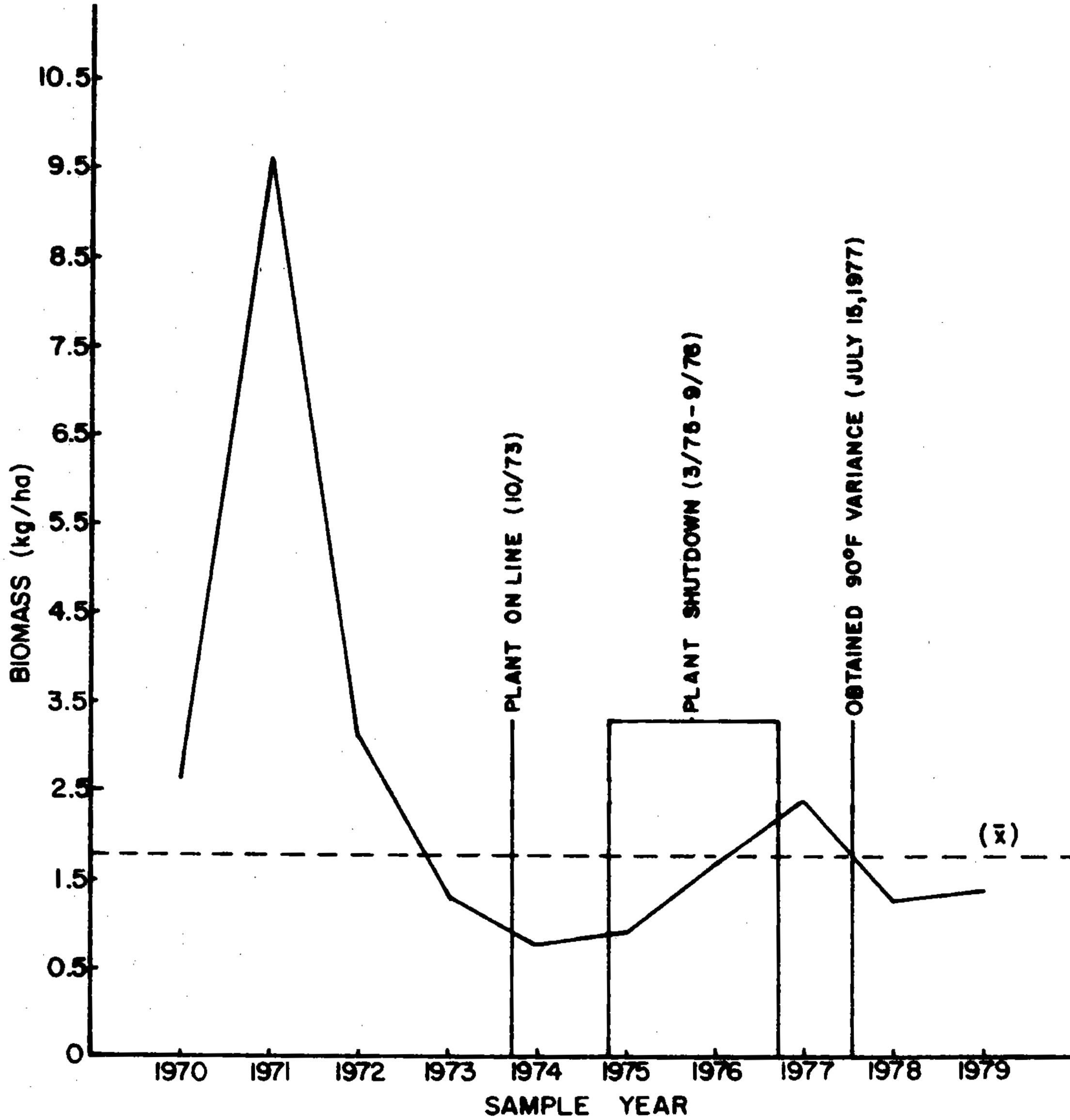


Figure 4.2-18. Smallmouth bass biomass (kg/ha) in cove rotenone samples from Wheeler Reservoir (average of three coves). Mean ($\bar{x}$) excludes the one unusual sample at TRM 275 in 1971.

that of the first five years of monitoring (1970-1974). It is unlikely that this reduction was due to higher mixed-river temperatures, but was probably related to low recruitment.

Largemouth bass stocks showed greater variation during the 10-year monitoring period than did smallmouth bass and sauger (Figure 4.2-19). Number, biomass, and sizeclass data for sauger and smallmouth bass at three coves are shown in Tables 4.2-16 and 4.2-17. The greatest number of young-of-the-year sauger found was in 1977 at TRM 275 and 286. No increase in the harvestable sizeclass was noted at either station in 1978 and 1979. Number and biomass of smallmouth bass increased markedly during 1977-1979 at TRM 286. Data from TRM 275, except for the unusually high biomass in 1971, were the most consistent throughout all years sampled for all sizeclasses. Standing stock of smallmouth bass at the Elk River cove was relatively low for all years.

Standing stocks of prey fishes were variable throughout the 10-year monitoring period (Figure 4.2-16). Clupeids (threadfin and gizzard shad) were the dominant prey species collected. Biomass estimates decreased from 515.71 kg/ha in 1977 to 143.39 kg/ha in 1978, but increased to 242.19 kg/ha in 1979.

Adult or harvestable sizeclasses were the major portion of total biomass collected (Figure 4.2-20). Figure 4.2-21 shows stock levels for dominant young-of-the-year taxa during the

Table 4.2-16. Numbers and biomass of sauger per hectare taken in cove-rotenone samples, Wheeler Reservoir. YOY = young of year (<200 mm TL); I = intermediate (200-300 mm); H = harvestable (>300 mm). Coves at TRM 275, 286, and ERM (Elk River) 2.7 are preoperational and operational monitoring sites for BFNP.

		Sauger - YOY		I		H	
Location	Year	N	kg	N	kg	N	kg
TRM 275	1970	5	0.13	0		0	
	1971	0		1	0.29	0	
	1972	5	0.35	0		0	
	1973	16	0.60	0		0	
	1974	5	0.15	0		1	0.21
	1975	14	0.37	5	0.62	1	0.11
	1976	6	0.31	5	0.88	0	
	1977	86	1.85	1	0.14	4	0.87
	1978	7	0.21	16	1.80	3	0.81
	1979	1	0.03	0		3	0.60
TRM 286	1970	18	0.69	0		0	
	1971	0		0		0	
	1972	1	0.03	1	0.05	0	
	1973	9	0.30	0		1	0.17
	1974	8	0.16	1	0.12	1	0.28
	1975	27	0.74	10	1.56	0	
	1976	21	0.99	24	2.48	7	2.45
	1977	124	2.76	0		14	4.38
	1978	4	0.07	8	0.66	1	0.29
	1979	9	0.21	6	0.60	0	
ERM 2.7	1970	0		0		0	
	1971	0		0		0	
	1972	0		0		0	
	1973	0		0		0	
	1974	5	0.17	0		0	
	1975	3	0.06	5	0.59	0	
	1976	0		8	0.77	2	0.60
	1977	3	0.09	0		0	
	1978	0	0.00	0		2	0.23
	1979	0	0.00	0		0	

Table 4.2-17. Number and biomass of smallmouth bass per hectare taken in cove-rotenone samples, Wheeler Reservoir. YOY = young of year (<125 mm TL); I = intermediate (125-200 mm); H = harvestable (>200 mm). Coves at TRM 275, 286, and ERM (Elk River) 2.7 are preoperational and operational monitoring sites for BFNP.

Location	Year	YOY		I		H	
		N	kg	N	kg	N	kg
TRM 275	1970	95	0.36	19	1.02	12	4.66
	1971	85	0.86	32	1.35	32	18.69
	1972	80	0.64	31	2.56	17	3.39
	1973	36	0.41	7	0.57	8	1.34
	1974	146	0.87	11	0.69	6	0.85
	1975	84	0.68	11	0.67	3	0.87
	1976	108	1.46	19	0.91	24	3.35
	1977	71	0.29	25	1.26	23	4.77
	1978	153	0.72	39	0.97	9	1.24
	1979	48	0.31	40	1.03	14	2.37
TRM 286	1970	86	0.15	13	0.55	2	0.38
	1971	135	1.13	83	2.36	5	0.71
	1972	8	0.05	1	0.09	1	0.18
	1973	1	0.01	0		0	
	1974	1	0.01	0		0	
	1975	3	0.04	0		0	
	1976	7	0.10	1	0.03	7	1.13
	1977	40	0.15	11	0.51	11	0.47
	1978	45	0.23	5	0.11	0	
	1979	26	0.18	6	0.10	1	0.14
ERM 2.7	1970	20	0.21	2	0.23	0	
	1971	141	1.31	38	1.01	6	0.99
	1972	9	0.10	9	0.75	11	1.61
	1973	0		0		0	
	1974	16	0.13	0		0	
	1975	9	0.10	3	0.18	3	0.35
	1976	0		0		0	
	1977	2	0.01	10	0.23	5	1.18
	1978	9	0.06	5	0.11	5	1.11
	1979	0		0		0	

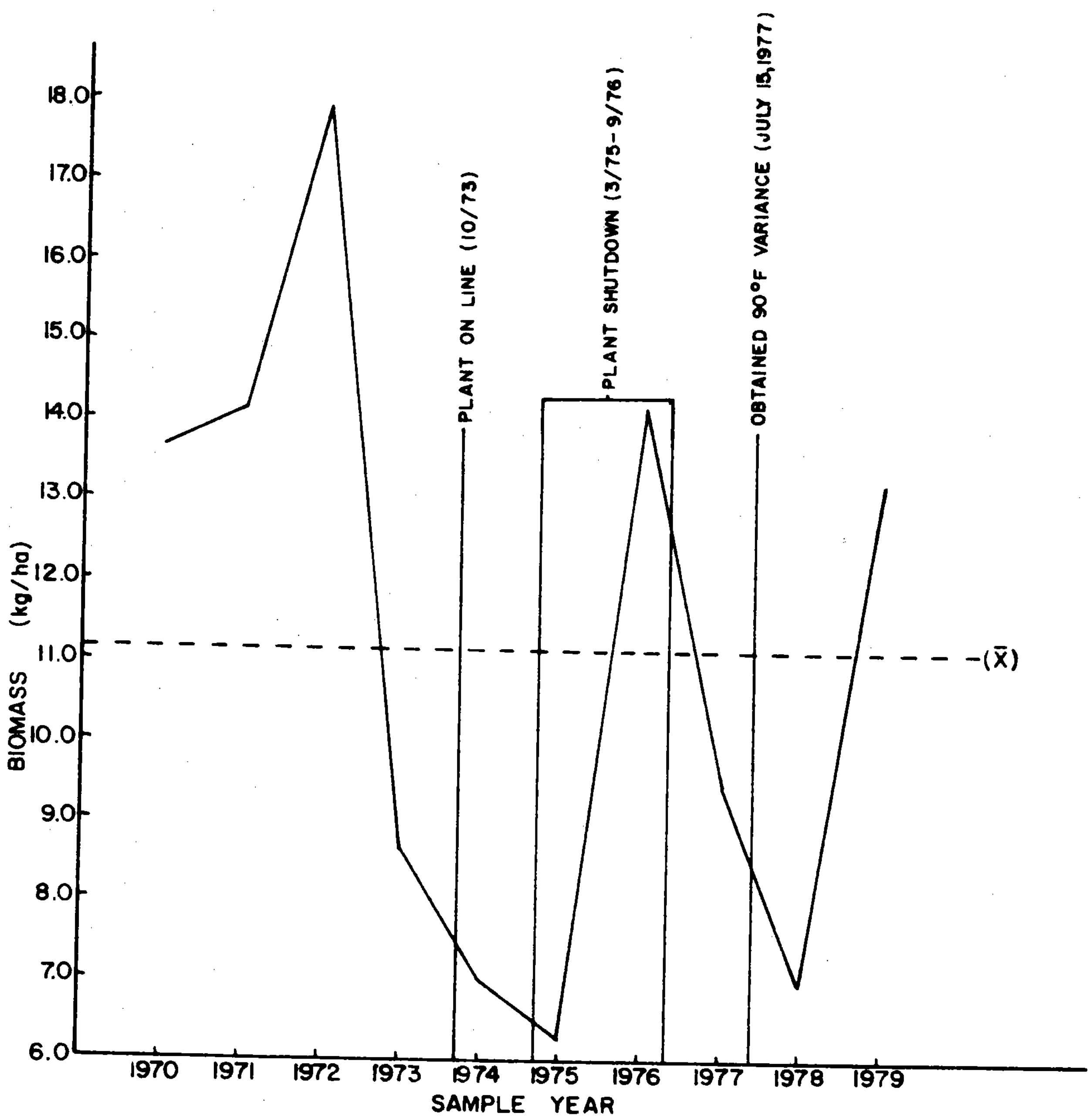


Figure 4.2-19. Largemouth bass biomass (kg/ha) in cove rotenone samples from Wheeler Reservoir (average of three coves).

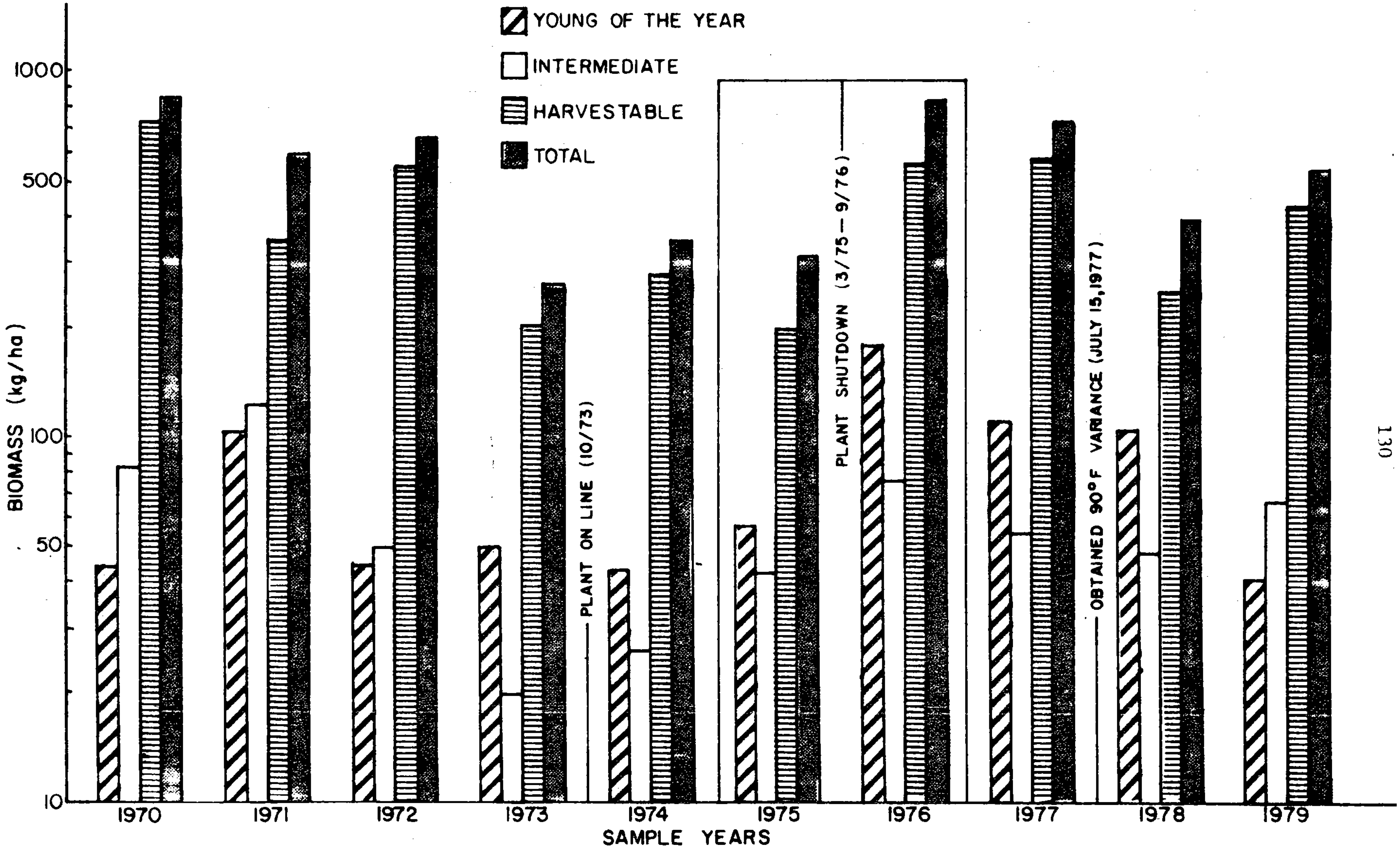


Figure 4.2-20. Standing stock estimates (kg/ha) by size class of fishes taken in Wheeler Reservoir cove rotenone surveys from 1970-1979 (average of three coves).

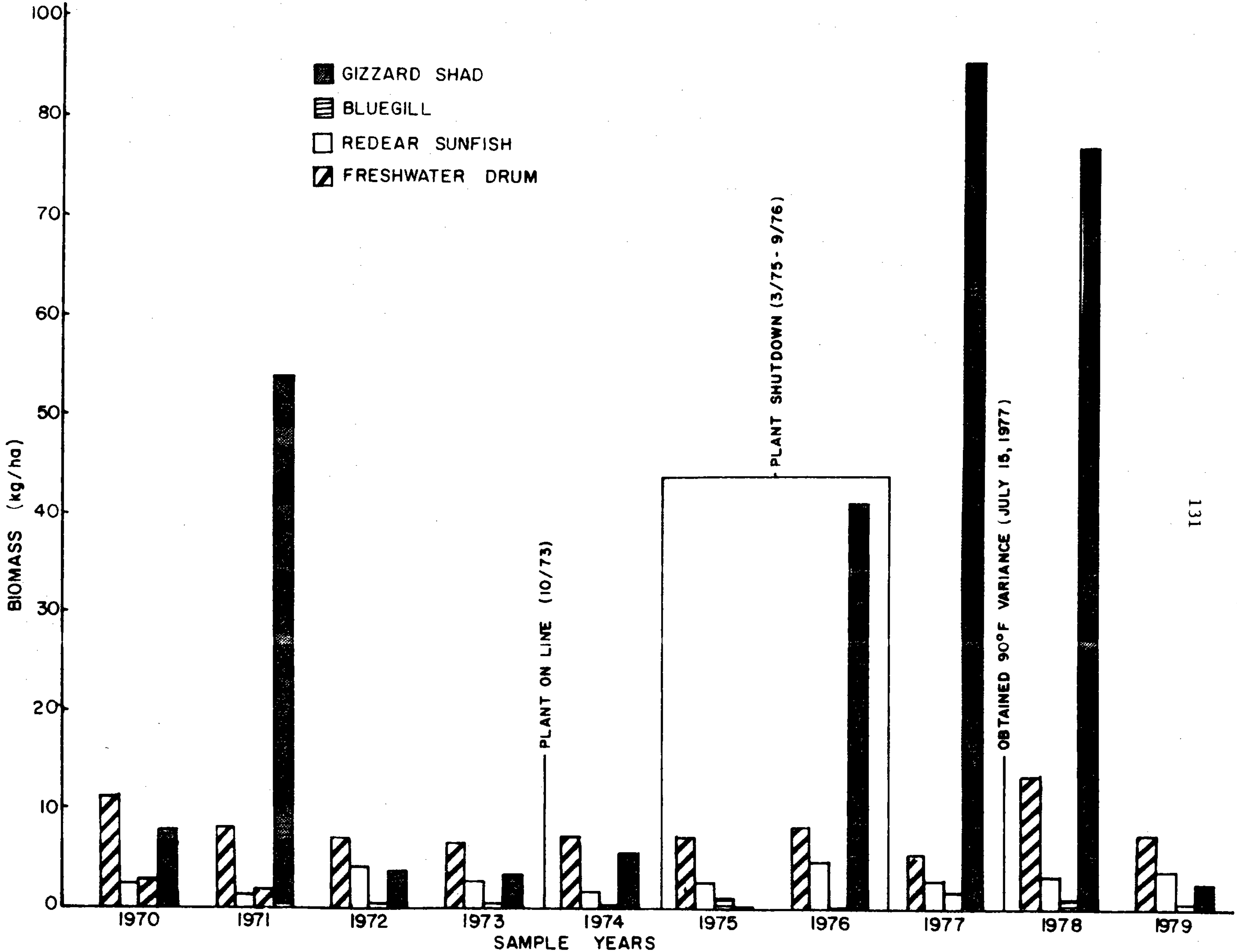


Figure 4.2-21. Four dominant young-of-the-year taxa collected in Wheeler Reservoir cove rotenone surveys during 1970-1979 (average of three coves).

10-year monitoring period. Bluegill, redear sunfish, and freshwater drum were very consistent in their occurrence and showed no effect of plant operation. Young-of-the-year gizzard shad were more variable with several highs and lows, the greatest deviations occurring during the period of plant operation.

Figure 4.2-22 shows relative abundance of adult and young-of-the-year gizzard shad. Adult gizzard shad constituted from 46 to 88 percent of the fish community biomass during the 10-year monitoring period. Clupeids dominated the total standing stock consistently throughout all sample years. In 1975, extremely low numbers of young-of-the-year gizzard shad were found. This was possibly due to: (1) Interspecific competition with threadfin shad young-of-the-year since they comprised 40.6 percent of total fish collected in 1975; and (2) patchiness; i.e., rotenone samples in 1975 simply may not have been in areas where young gizzard shad were abundant.

Historical rotenone data clearly illustrate recurrent stock fluctuations in Wheeler Reservoir during the period records are available. Fluctuations during the period of plant operation were indiscernible from those of the twenty-five year period preceding operation of BFNP, and any impact to the fish community of Wheeler Reservoir owing to the operation of this facility is judged to be nonsignificant.

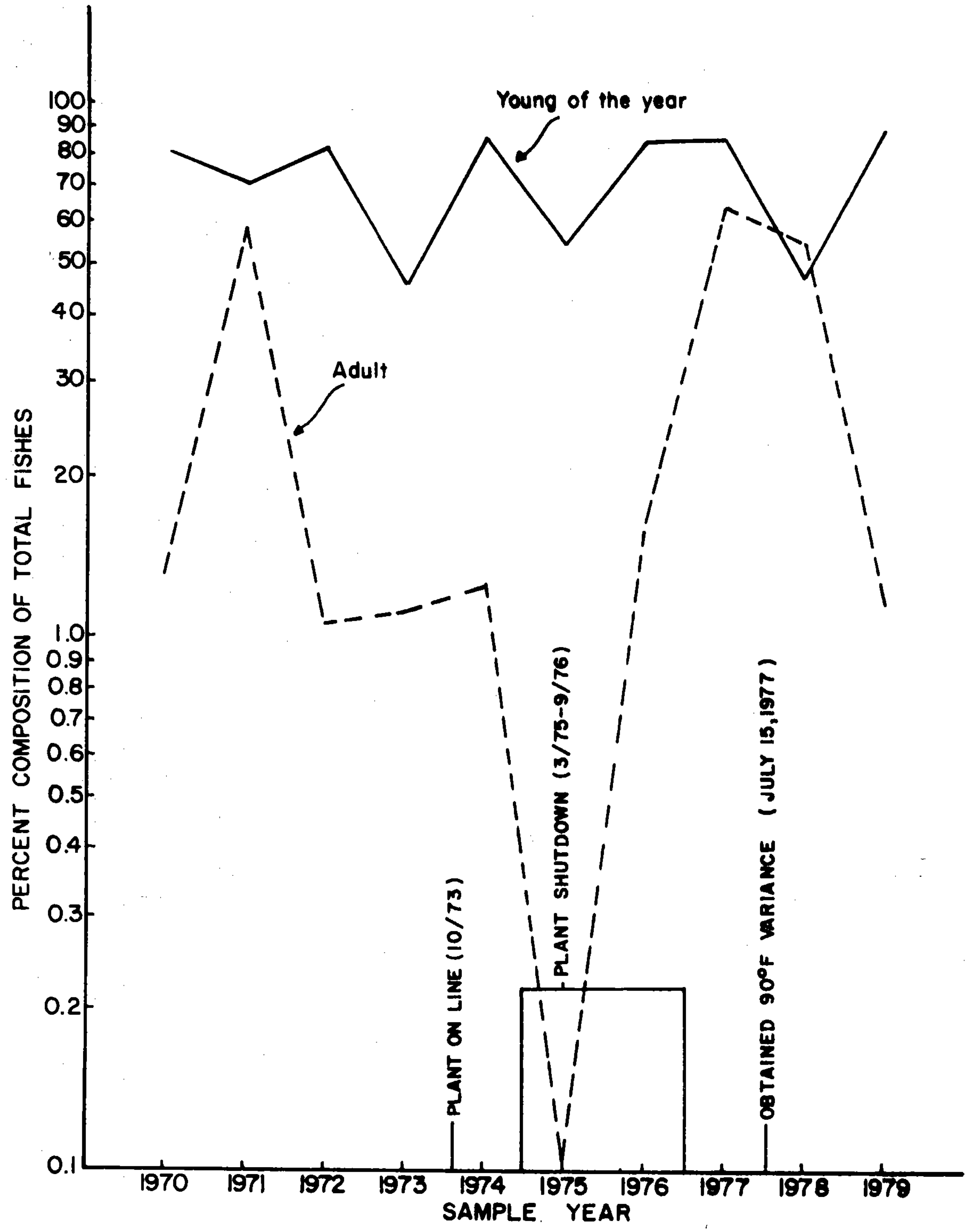


Figure 4.2-22. Percent composition of young-of-the-year and adult gizzard shad in cove rotenone samples from Wheeler Reservoir (average of three coves).

4.2.5.2 Gill Nets

Quarterly gill net surveys were conducted at Browns Ferry Nuclear Plant as part of preoperational and operational monitoring requirements in the NRC technical specifications for BFNP. Gill nets used in these surveys were standard 3.8 centimeter bar mesh, 2.4 meters deep by 30.4 meters long. Gill nets are highly selective for harvestable size fish but allow different physical areas of a water body (channel, pelagic zones, overbanks, etc.) to be sampled. Sample locations in Wheeler Reservoir are shown in Figure 4.2-13.

Sampling at station 4, located at the diffuser discharge, began in 1975. This is the only location sampled within the zone of maximum thermal influence. Figure 4.2-23 shows catch per unit effort (c/f) for all species combined during the 10-year monitoring period. Plotted values are means for spring and summer surveys combined. Comparisons between operational periods were made from surveys taken between May 1 and September 30 of each year. Fall and winter quarter surveys were excluded from these comparisons since there is no potential for thermal impacts during those periods. Table 4.2-18 summarizes summer quarter gill net data from 1969 to 1979.

The c/f at station 1 (TRM 293) was consistent through the 10-year monitoring period, ranging during plant operation from a low of 16 in 1974 to a high of 23 fish per net night

Table 4.2-18. Summary of summer quarter gill net sampling, preoperational (1969-1973) and operational monitoring (1973-1979) at BFNP, Wheeler Reservoir.

		STATIONS							
		1		2		3		4*	
		N	c/f	N	c/f	N	c/f	N	c/f
Preoperation	1969-1973	1146	28.65	306	8.18	1158	29.87		
Unit 1 on Line	1973-1974	316	7.90	85	2.83	643	16.08		
Shutdown	1975-1976	816	20.89	14	4.13	1051	26.27	173	9.06
90° F Variance	1977-1979	621	15.70	306	8.22	1706	42.65	191	12.07

*Sampling at station 4 began in 1975.

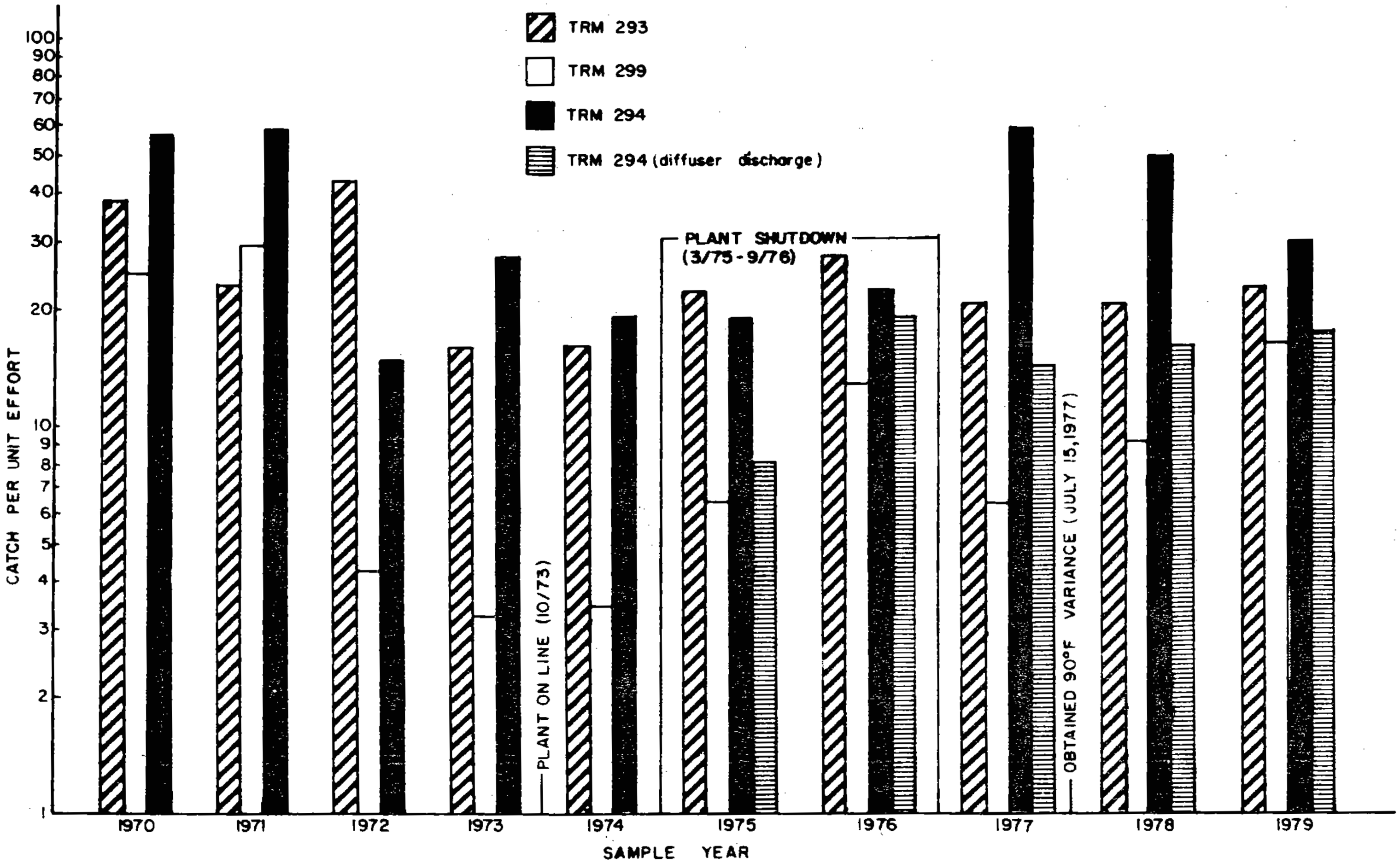
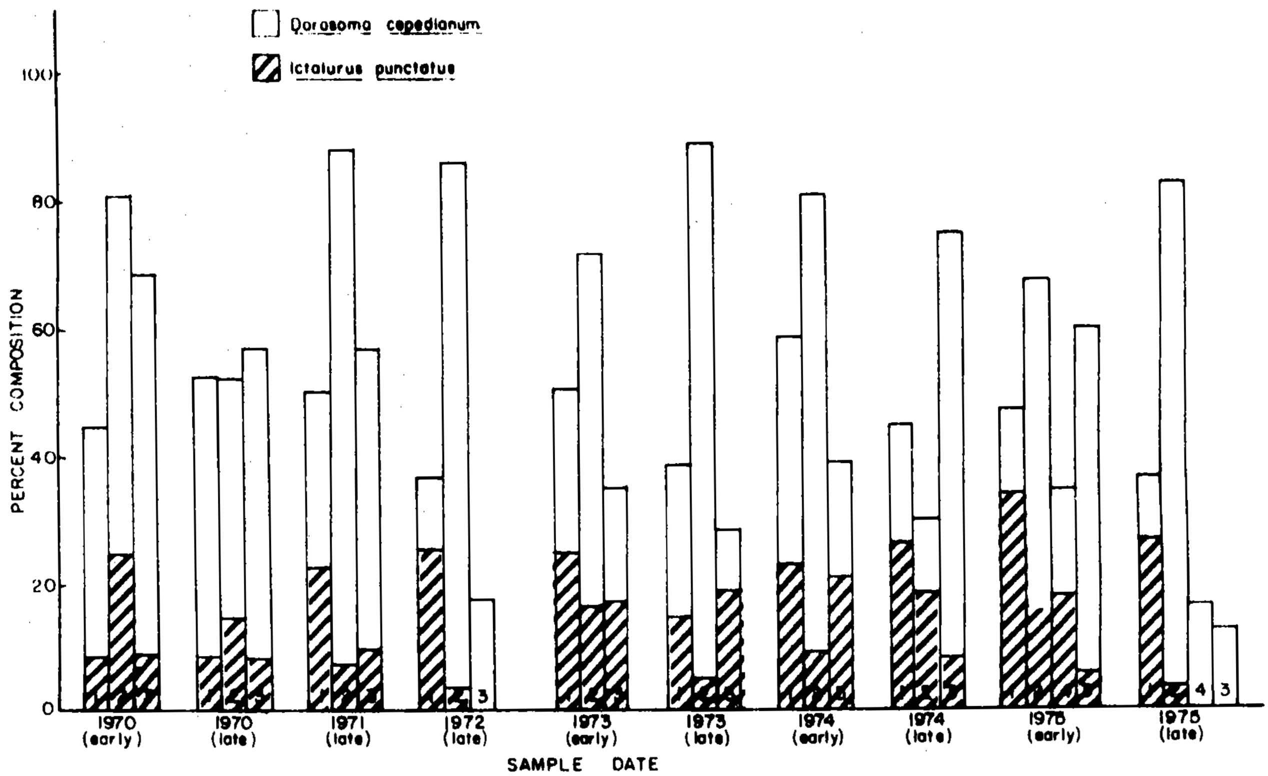


Figure 4.2-23. Catch per unit effort of gill net surveys conducted in the vicinity of BFNP during the years 1970-1979. Data include surveys taken between May 1 and September 30 for each year.

in 1979. The c/f at station 3 (TRM 294) decreased to a low of 14.9 in 1972 but increased progressively to a peak of 60 fish per net night in 1977. The c/f for 1978 and 1979 remained high at 51.92 and 31.52 fish per net night, respectively. Differences between station 1 and station 3 may reflect thermal effects; i.e., relatively high c/f during 1977-1979 suggests that station 3 might serve as a refuge from the thermal plume. However, c/f at station 4 (TRM 294), located in the discharge, was higher from 1977-1979 during spring-summer than in 1975 and 1976 when the plant was not operating. The c/f ranged from 14.53 to 19.57 fish per net night during the 4-year operational period. Surprisingly, the control station (station 3, TRM 299) showed greater variation in c/f than any other station. At no time was the control station subjected to the thermal plume. Variations in data from the control station corresponded more closely to those of rotenone standing stock estimates. Consistency of the c/f data observed at station 4 may be due to attraction to the discharge structure. Physical structures in aquatic habitats have long been known to attract fish, particularly game or sport species. Extensive fish attractor placement activities, presently ongoing in TVA, have this as their basis.

Gizzard shad was consistently the dominant taxon collected at stations outside the thermal plume zone (stations 2 and 3). From 1977 through 1979, channel catfish dominated the catch at station 1 during May 1 to September 30 (Figure 4.2-24).



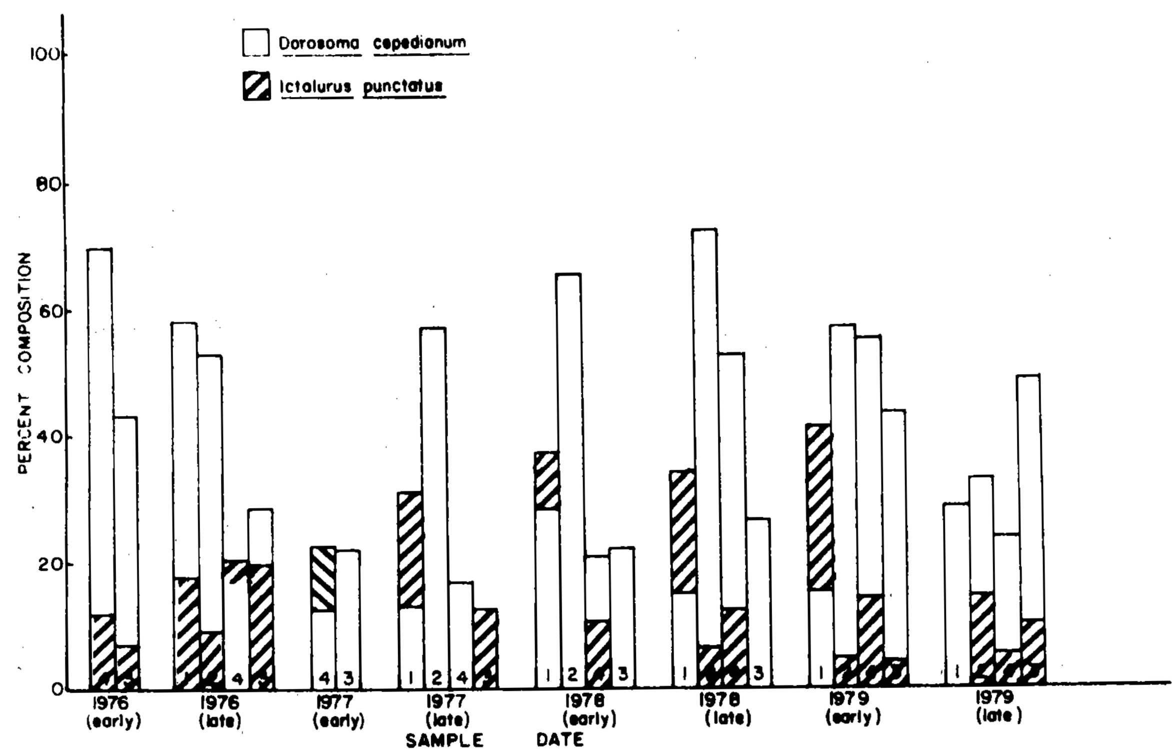


Figure 4.2-24. Percent composition of two dominant taxa (gizzard shad and channel catfish) at gill net stations in the vicinity of BFNP. Data are samples taken between May 1 (early) and September 30 (late) for each year.
Station 1 = TRM 293 (right shoreline overbank)
Station 2 = TRM 299 (right shoreline overbank)
Station 3 = TRM 294 (left shoreline overbank) and
Station 4 = TRM 294 (diffuser discharge)

During summer samples in 1975, 1976, and 1977, ictalurids (blue and channel catfish) were the dominant taxa collected at station 4. In 1978 and 1979, gizzard shad were the dominant taxon at station 4 with catfish the second most abundant taxa. This apparent decrease was the result of an increase in numbers of gizzard shad, not a reduction in catfish abundance. Species occurrence in gill net samples may be found in previous quarterly and annual reports (TVA 1969-1979).

Gill net samples of sauger, walleye, and smallmouth bass are shown in Tables 4.2-19 and 4.2-20. Gill nets are apparently effective for sauger but not smallmouth bass. Walleye are too rare to be encountered with any degree of regularity.

Sauger catches from gill nets at the discharge station show large numbers present in fall and winter; however, substantial numbers were present during spring and summer months (Table 4.2-20). The c/f for sauger during summer at station 4 was higher than at station 1, with fall and winter c/f much higher at station 4 than station 1. Sauger are evidently attracted to this area (diffuser discharge), even in summer. This is probably due to attraction to the diffuser structure, concentration of prey species, and related turbulence of the water; however, it is clear that plant-induced temperature maximums have not caused this species to avoid even the mixing zone.

Table 4.2-19. Summary of catch (N) and catch per unit of effort (c/f) for smallmouth bass, walleye, and sauger during preoperational and operational monitoring at Browns Ferry Nuclear Plant. Data are from gill net catches at station 1, TRM 293.

		Autumn		Winter		Spring		Summer	
Year	Species	N	c/f	N	c/f	N	c/f	N	c/f
1968-69	SMB[1]	0		0		0		0	
	W[1]	0		0		0		0	
	S[1]	6	0.20	2	0.05	5	0.13	3	0.08
1969-70	SMB	4	0.10	0		1	0.03	0	
	W	0		0		0		0	
	S	8	0.20	0		3	0.08	4	0.10
1970-71	SMB	3	0.08	0		0		0	
	W	0		0		0		0	
	S	2	0.05	4	0.10	0		0	
1971-72	SMB	0		0		2	0.05	0	
	W	0		0		0		0	
	S	2	0.05	4	0.10	0		0	
1972-73	SMB	0		0		0		0	
	W	0		0		0		0	
	S	0		0		0		1	0.03
1973-74	SMB	2	0.05	0		1	0.03	0	
	W	0		0		0		0	
	S	7	0.18	0		2	0.05	0	
1974-75	SMB	0		0		0		0	
	W	2	0.05	0		0		0	
	S	10	0.25	0		16	0.40	4	0.10
1975-76	SMB	0		0		0		0	
	W	0		0		0		0	
	S	25	0.62	26	0.65	31	0.77	11	0.27
1976-77	SMB	1	0.03	0		0		0	
	W	0		0		0		0	
	S	83	2.07	2	0.05	7	0.18	4	0.10

Table 4.2-19. (Continued)

Year	Species	Autumn N	Autumn c/f	Winter N	Winter c/f	Spring N	Spring c/f	Summer N	Summer c/f
1977-78	SMB	0		0		0		0	
	W	0		0		0		0	
	S	7	0.18	9	0.22	14	0.369	5	1.135
1978-79	SMB	0		0		0		0	
	W	0		0		0		0	
	S	30	0.75	1	0.035	16	0.40	5	0.135
1979-80	SMB	0		0		*[2]		*	
	W	0		0		*		*	
	S	33	0.850	0		*		*	

1 SMB = smallmouth bass, *Micropterus dolomieui*
W = walleye, *Stizostedion v. vitreum*
S = sauger, *S. canadense*

2 Data not available

Table 4.2-20. Summary of catch (N) and catch per unit effort (c/f) of sauger by season at Browns Ferry Nuclear Plant. Data are from gill net catches at station 4 (diffuser discharge), TRM 294, 1975-1979.

	Autumn		Winter		Spring		Summer	
Year	N	c/f	N	c/f	N	c/f	N	c/f
1974-75	15	0.94	1	0.05	4	0.23	6	0.35
1975-76	46	2.55	13	0.65	1	0.05	4	0.20
1976-77	200	10.00	38	2.77	4	0.23	16	0.89
1977-78	82	4.10	38	1.90	24	1.20	12	1.09
1978-79	72	4.23	49	3.06	15	0.88	30	1.87
1979-80	99	5.50	*	*	*	*	*	*

*Data not available

Table 4.2-21 shows ten years of gill net data collected during spring and summer quarters (May 1-September 30). From 1970 to 1974, the presence of sauger at all stations was low. From 1975 to 1979, number and c/f of sauger increased progressively at all stations. Both the highest numbers and c/f for sauger were found at the diffuser station (station 4) during the 1977-1979 period.

Gill net catch was plotted against standing stock data for a test of bivariate correlation. The degree of correlation is a statistical measure of the relationship between variables. Figures 4.2-25 through 4.2-28 show gill net-standing stock correlations. A positive correlation was observed at all stations and increased gill net catches clearly reflected population changes observed in rotenone samples. Correlation coefficients ranged from 0.42 at the left overbank (station 3) to 0.71 at station 4; however, none were statistically significant at the 95-percent level of confidence. These correlations (gill net with cove rotenone) were positive as expected for the two sampling methodologies and, although not statistically significant, the two sampling methods are apparently a measure of the same attributes in the fish community; however, use of one to predict the other is unwarranted because of the lack of significance in a statistical sense.

Table 4.2-21. Number (N) and catch per unit effort (c/f) of sauger, walleye, and smallmouth bass in gill nets at BFNP from 1970-1979 annual surveys. Only data from spring and summer quarters (May 1-September 30) are included.

Year	Station*	Sauger N	Sauger c/f	Walleye N	Walleye c/f	Smallmouth Bass N	Smallmouth Bass c/f
1970	1	4	0.100	0		1	0.025
	2	1	0.030	0		0	
	3	1	0.025	0		0	
1971	1	0		0		0	
	2	1	0.025	0		0	
	3	0		0		0	
1972	1	0		0		0	
	2	1	0.025	0		0	
	3	0		2	0.059	0	
1973	1	1	0.025	0		0	
	2	1	0.025	0		0	
	3	2	0.050	0		0	
Plant on line							
1974	1	4	0.100	0		1	0.025
	2	1	0.025	0		0	
	3	2	0.058	0		0	
Plant off line							
1975	1	8	0.205	0		0	
	2	10	0.250	0		0	
	3	23	0.575	0		0	
	4	10	0.588	0		0	
1976	1	11	0.275	0		0	
	2	26	0.714	0		1	0.030
	3	75	1.875	0		0	
	4	5	0.250	0		0	
Plant back on line							
1977**	1	4	0.103	0		0	
	2	4	0.106	0		0	
	3	13	0.325	0		0	
	4	20	1.124	0		0	
1978**	1	19	0.484	0		0	
	2	10	0.250	2	0.050	0	
	3	24	0.600	1	0.025	0	
	4	36	2.290	0		0	
1979**	1	21	0.425	0		0	
	2	9	0.260	0		0	
	3	17	0.425	0		0	
	4	45	2.757	0		0	

*Station 1 = TRM 293
2 = TRM 299
3 = TRM 294
4 = TRM 294 (Diffuser)

**Obtained 90° F variance from NRC on July 15, 1977; earlier gill net samples during 1977 were collected before obtaining the 90° F variance.

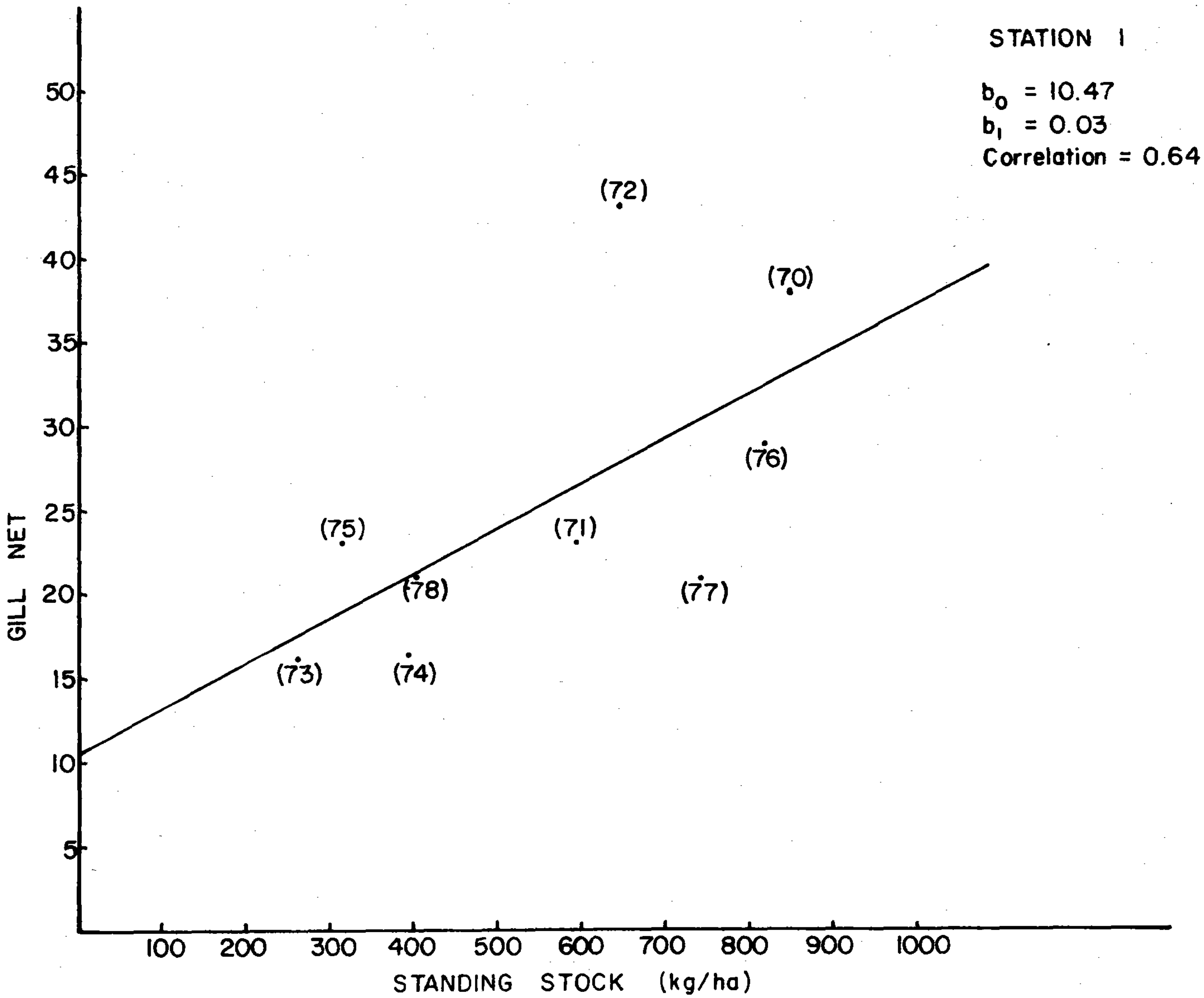


Figure 4.2-25. Correlation of gill net catches at Station 1 (TRM 293) with cove rotenone standing stock estimates (average of three coves) in the vicinity of BFNP during the years 1970-1978.

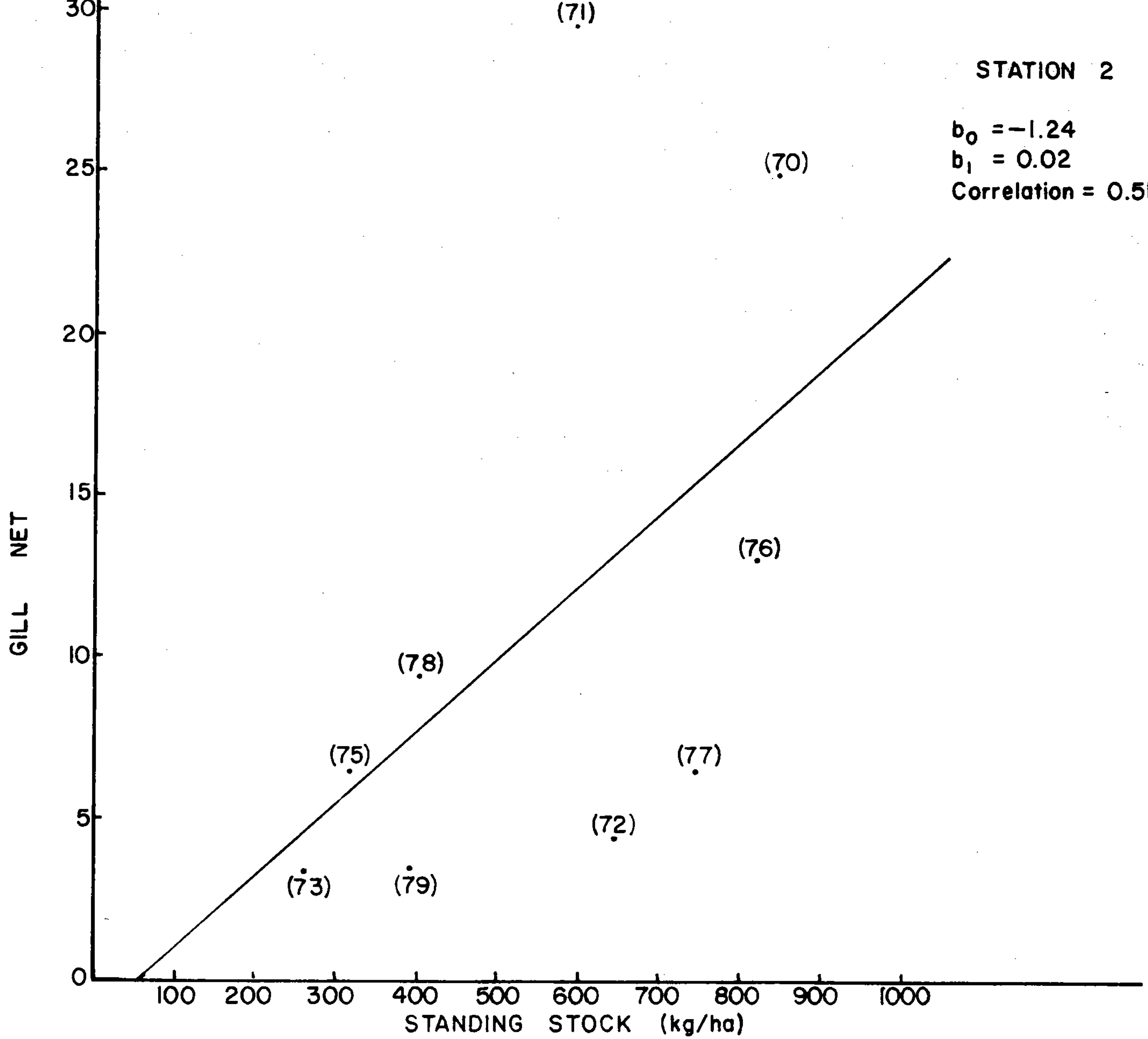


Figure 4.2-26. Correlation of gill net catches at Station 2 (TRM 299) with cove rotenone standing stock estimates (average of three coves) in the vicinity of BFNP during the years 1970-1979.

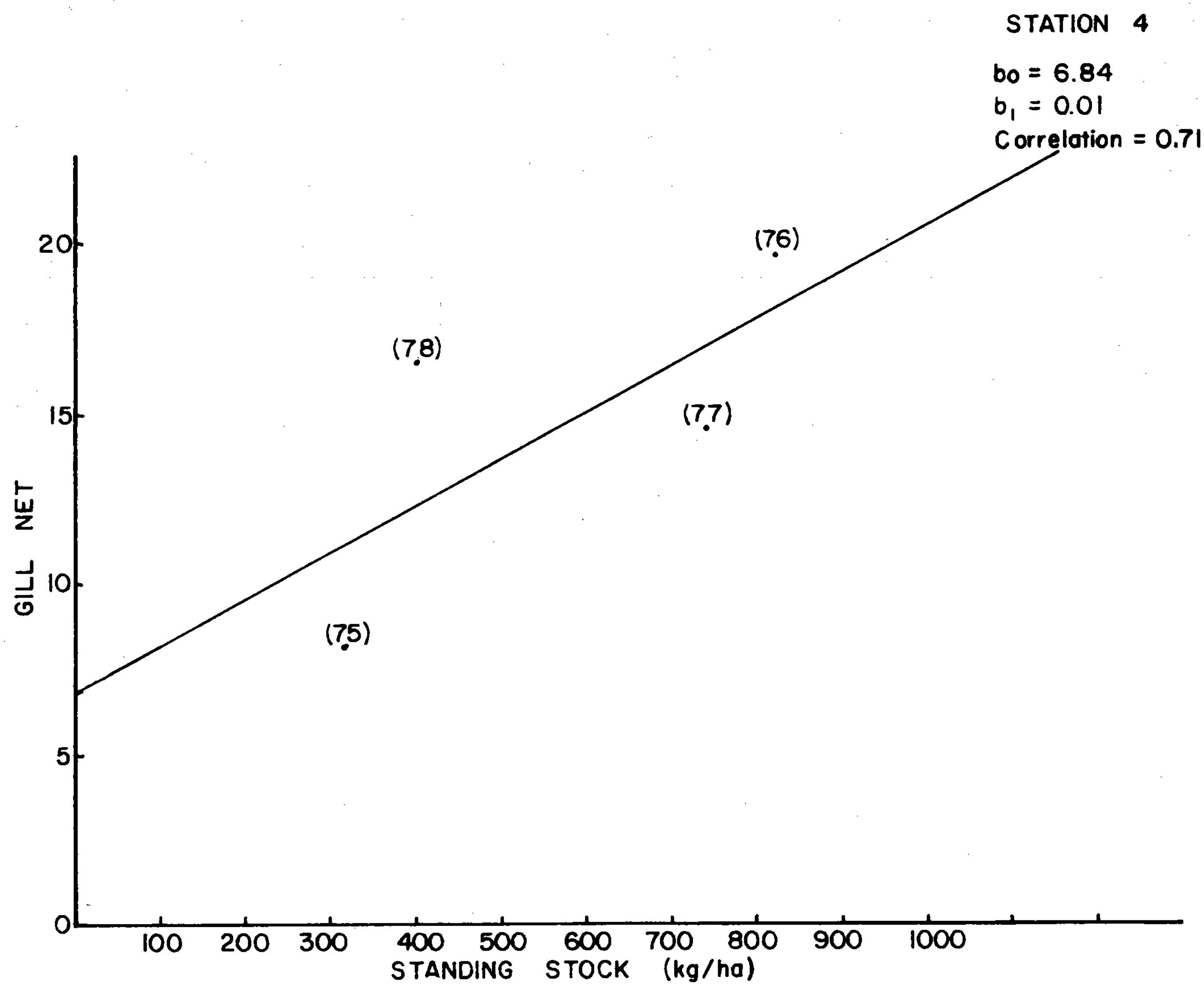


Figure 4.2-28. Correlation of gill net catches at Station 4 (diffuser discharge, TRM 294) with cove rotenone standing stock estimates (average of three coves) in the vicinity of BFNP during the years 1975-1978.

Analyses of data from the ten-year gill net monitoring program at BFNP indicate no adverse impacts to local fish populations owing to thermal enrichment during periods when either the 86° F (30.0° C) standard or 90° F (32.2° C) limit was in effect. Species composition and c/f data from these gill net surveys for sample locations outside zones of greatest thermal influence showed little or no difference from stations in zones of maximum thermal influence. Attraction of sauger to the diffuser discharge was observed even during warmest water temperatures.

4.2.5.3 Trap Nets

Trap netting was initiated on Wheeler Reservoir in 1969 as part of the preoperational fisheries investigations at BFNP. Trap net locations are shown in Figure 4.2-13. No trap net data were collected in 1973 and 1974. Trap net sampling resumed in 1975 and has continued as part of the BFNP fisheries monitoring program. Data of catch per effort are shown in Figure 4.2-29.

An attempt was made to correlate these data with standing stock rotenone estimates in concurrent years (Figures 4.2-30 through 4.2-32). Rotenone data were compared to each of three trap net stations. Stations A and B were located downstream from the plant and a control station (station C) was located 9.7 kilometers upstream from the plant. Correlation coefficients for stations A and B were 0.49 and 0.64, respectively.

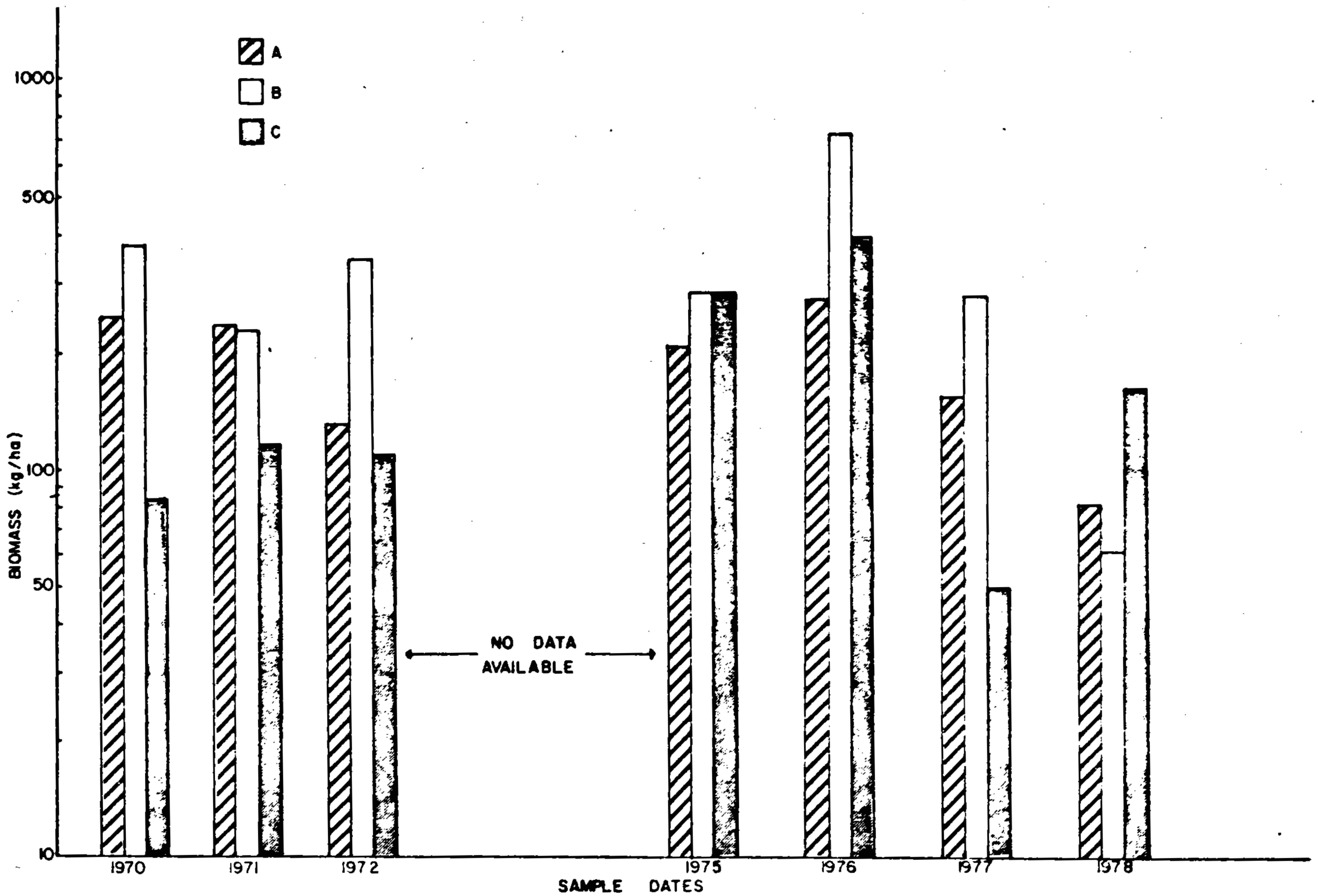


Figure 4.2-29. Biomass (kg/ha) of total fishes taken in Wheeler Reservoir trap net surveys from 1970-1978. Data include surveys taken between May 1 and September 30 for each year.
Station A = TRM 293
Station B = TRM 299
Station C = TRM 284

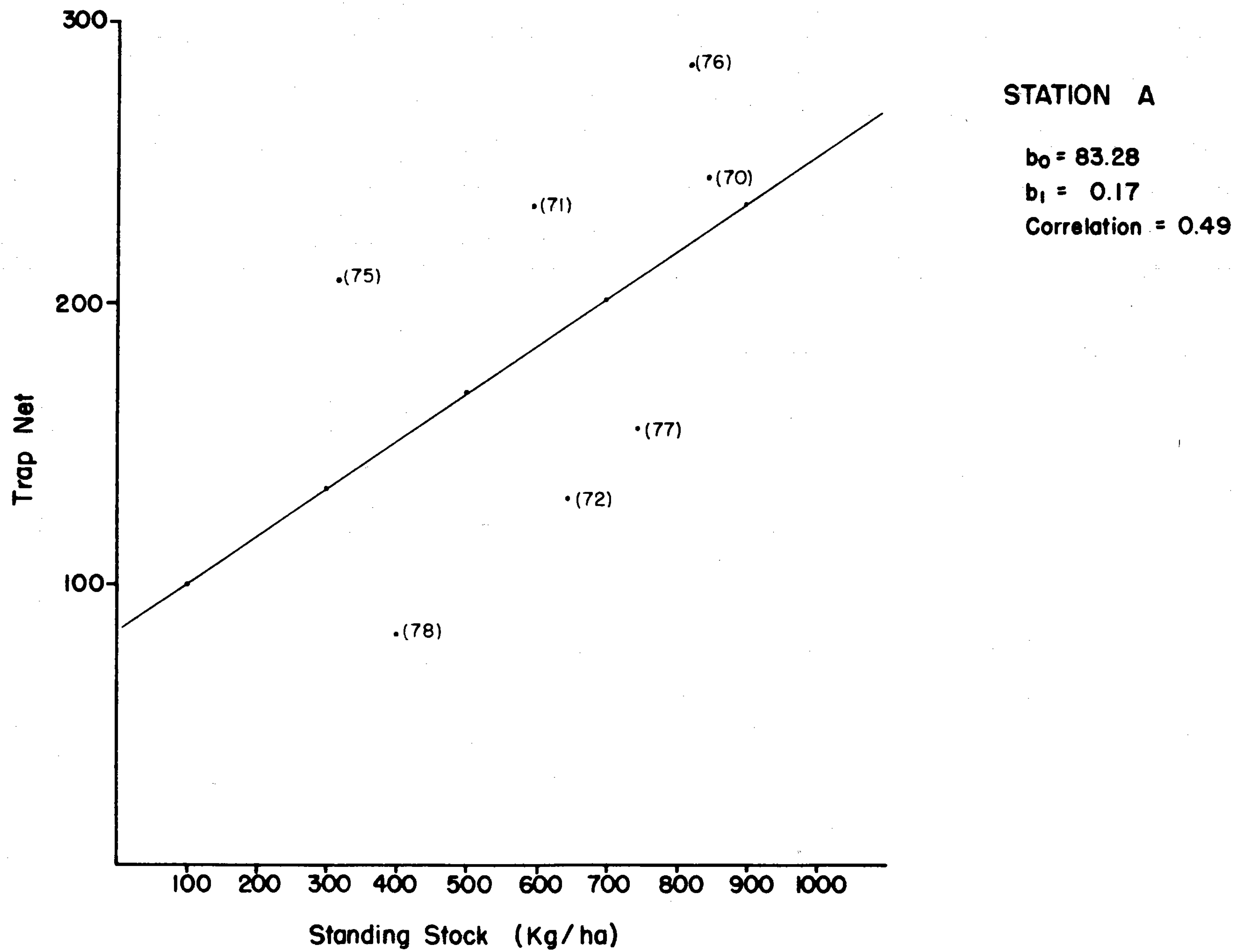


Figure 4.2-30. Correlation of trap net catches at Station A (TRM 284) with cove rotenone standing stock estimates (average of three coves) in the vicinity of BFNP during the years 1970-1978.

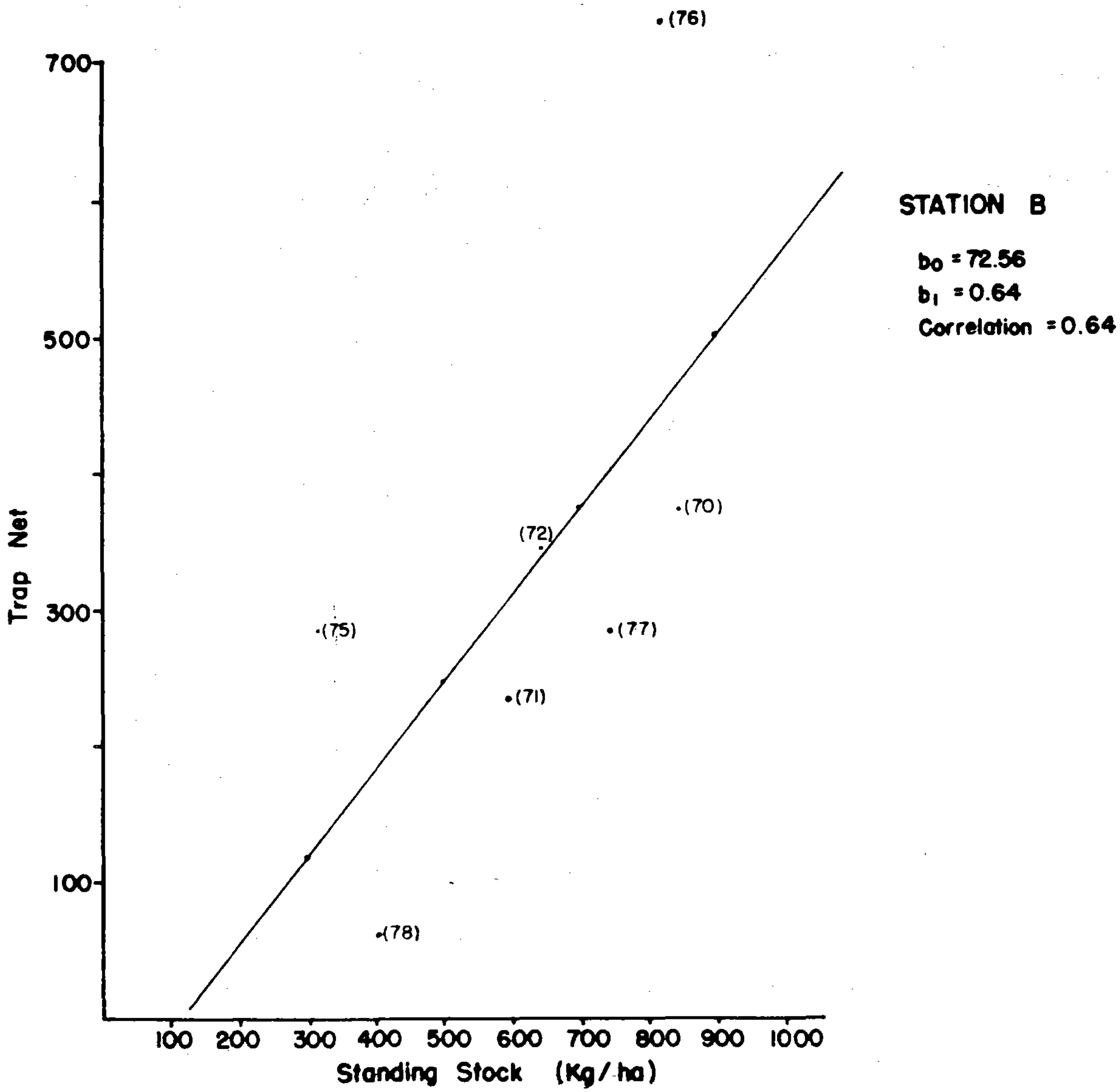


Figure 4.2-31. Correlation of trap net catches at station B (TRM 293) with cove rotenone standing stock estimates (average of three coves) in the vicinity of BFNP during the years 1970-1978.

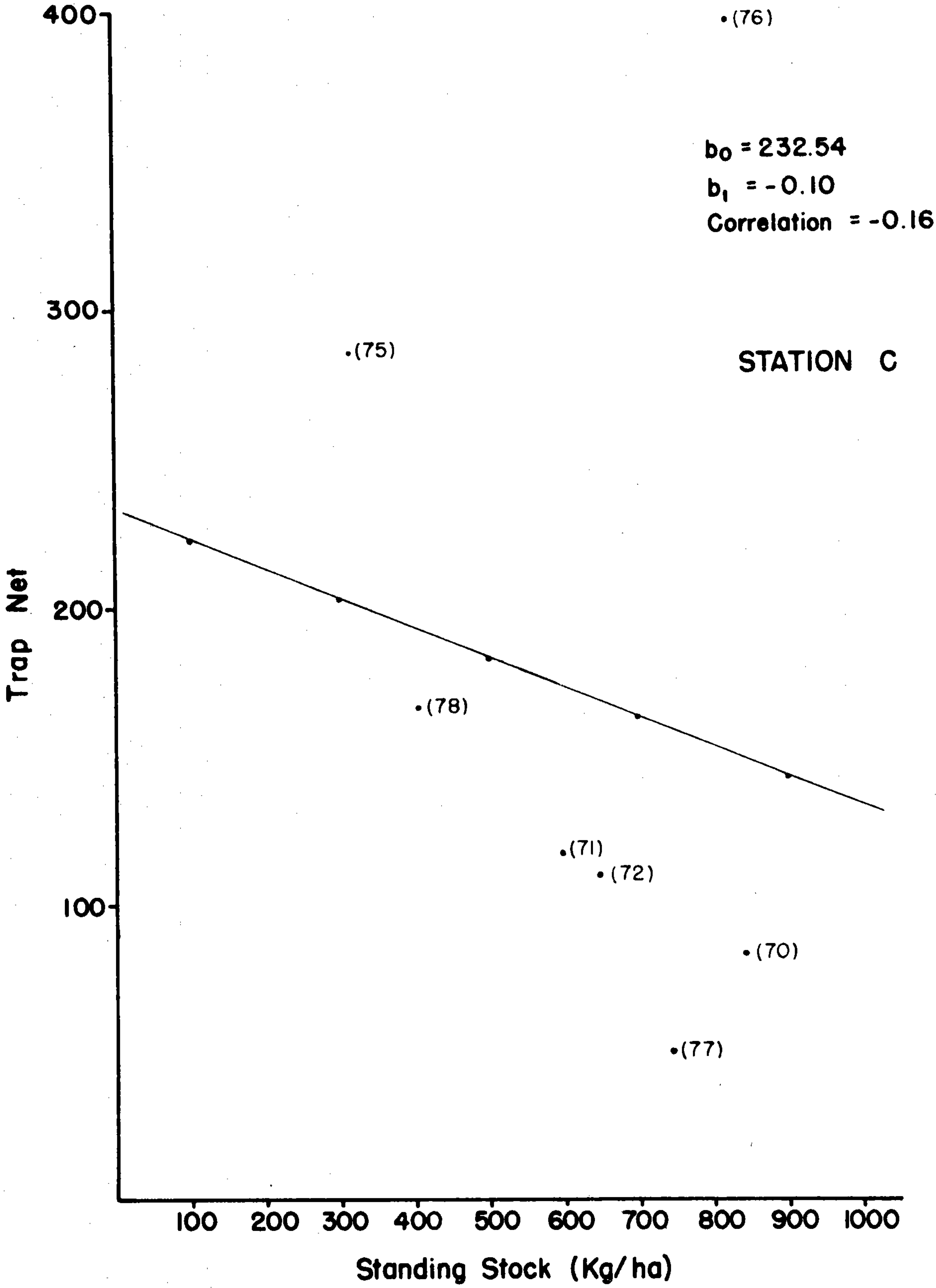


Figure 4.2-32. Correlation of trap net catches at Station C (TRM 299) to cove rotenone standing stock estimates (average of three coves) in the vicinity of BFNP during the years 1970-1978.

Positive correlation was observed as expected but neither value was statistically significant. Station C had a negative r value. Trap nets are extremely selective and are not well suited to general stock assessment. Additionally, high variability of BFNP trap net data precludes a valid assessment of fish populations in the vicinity of this plant.

4.2.5.4 Creel Census

Wheeler Reservoir creel census surveys began in July 1970, as one segment of monitoring investigations at BFNP. Figure 4.2-33 shows the survey area. Bank and boat fishermen surveys were conducted at randomly chosen times during the census period. Counts of fishermen were used to derive estimates of fishing pressure (hours) for each census period. Quarterly and total fishing pressure for the 19,800 ha of Wheeler Reservoir surveyed is shown in Table 4.2-22. Fishing pressure was highest during 1970-1973. The mean number of hours for 1971-1973 was 449,446 hours. Data from 1970 included the summer and fall quarters only. In 1974, fishing pressure decreased to 178,234 estimated hours, more than a 50 percent reduction. In 1975, the spring fishing pressure increased greatly to bring the total for the year to 398,157 hours. In 1976, spring fishing pressure was the lowest recorded in eight years; consequently, a decrease in fishing pressure for the year was observed (169,904 hours). In 1977 and 1978, fishing pressure was 407,957 and 299,198 hours, respectively. Maximum effort occurred during spring (April-June) in every

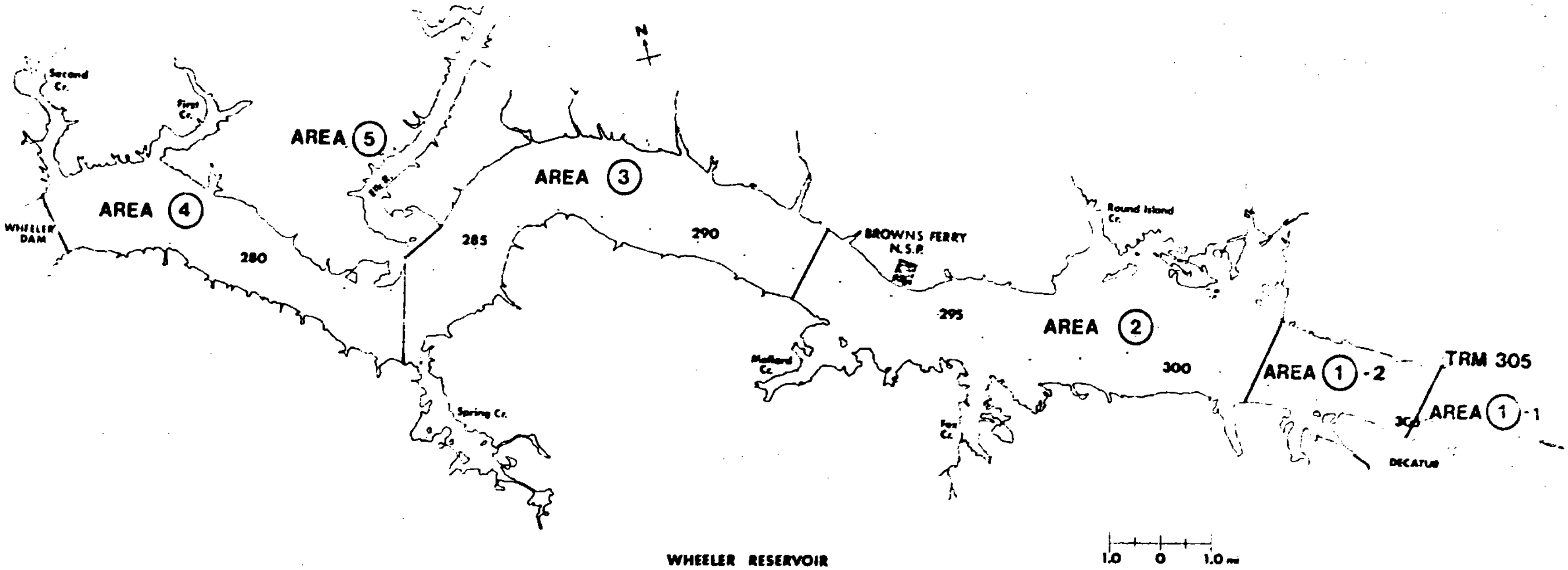


Figure 4.2-33. Location of the six creel survey areas on Wheeler Reservoir.

Table 4.2-22. Estimated quarterly fishing pressure[t], July 1, 1970, through December 30, 1978, Wheeler Reservoir, Alabama.

	Calendar Year								
	1970	1971	1972	1973	1974	1975	1976	1977	1978
Winter (Jan.-Mar.)		40,606	155,221	135,016	22,077	68,386	19,988	57,761	53,132
Spring (Apr.-June)		247,771	152,658	238,257*	89,653	229,070	85,405	189,829	145,584
Summer (July-Sept.)	102,864	113,477	71,549	105,883	43,570	76,532	52,393	91,844	57,018
Fall (Oct.-Dec.)	47,577	31,946	36,412	19,601	22,934	24,164	12,118	68,523	43,464
Total	150,441	433,800	415,840	498,757	178,234	398,152	169,904	407,957	299,198

* Beginning of creel survey procedures as described by the Institute of Statistics, North Carolina State University, Raleigh, North Carolina.

t Hours fished.

year except in 1972 when pressure was higher in winter (January-March).

White crappie was the most common species harvested in terms of number and biomass. For sauger, smallmouth bass, and walleye, estimated harvest showed only the smallmouth to be important in the census area (Table 4.2-23). Smallmouth bass and sauger harvest by area is shown in Tables 4.2-24 and 4.2-25. Only a single walleye was censused in the harvest, fall of 1970.

Smallmouth bass were collected every quarter surveyed from 1970-1979, except in the fall of 1973. Estimated numbers taken per quarter ranged from 85 to 6,424. From 1973 to 1979, smallmouth bass harvest from areas 1 and 2 was sporadic and numbers taken were relatively low except in fall of 1970.

Sauger harvest during this same period was sporadic. From 1970 to mid-1974, sauger harvest was found during only two quarters. From 1974 through 1977, numbers harvested ranged from 52 to 336 per quarter. During 1978 and 1979, sauger harvest was found only in one quarter (fall 1978) when an estimated 414 sauger were harvested. This was consistent with cove rotenone estimates of trends in the sauger stock, but was the highest number recorded during the 10-year census. Sauger harvest was greatest at areas 4, 1, and 3. No sauger were harvested during the first eight months of 1979.

Table 4.2-23. Estimated smallmouth bass, sauger, and walleye sportfishing harvest, Wheeler Reservoir, July 1970 through July 1979.

Season		Smallmouth Bass		Sauger		Walleye	
		No.	lb.	No.	lb.	No.	lb.
1970	S	6,424	4,537	0		0	
	F	4,674	4,700	21	8	48	37
1971	W	101	133	0		0	
	S	2,505	2,580	0		0	
	S	2,614	2,579	0		0	
	F	268	281	0		0	
1972	W	638	493	0		0	
	S	2,279	1,937	28	28	0	
	S	850	852	0		0	
	F	156	85	0		0	
1973	W	5,304	2,061	0		0	
	S	1,135	630	0		0	
	S	616	460	0		0	
	F	0		0		0	
1974	W	85	116	0		0	
	S	357	701	0		0	
	S	112	168	153	117	0	
	F	114	168	84	42	0	
1975	W	330	257	0		0	
	S	394	225	336	256	0	
	S	351	271	0		0	
	F	68	37	52	42	0	
1976	W	180	217	0		0	
	S	611	887	286	249	0	
1977	S	1,353	2,241	250	265	0	
	F	2,517	6,069	79	110	0	
1978	W	1,435	2,282	0		0	
	S	4,897	6,480	0		0	
	S	2,317	2,783	0		0	
	F	2,241	3,674	414	200	0	
1979	W	185	304	0		0	
	S	1,292	1,604	0		0	
	S	282	532	0		0	

Table 4.2-24. Estimated smallmouth fishing harvest by area, Wheeler Reservoir, April 1973 through August 1979.

		Areas 1-1 and 1-2		Area 2-1		Area 3-1		Area 3-2		Area 4-1		Totals	
		No.	lb.	No.	lb.	No.	lb.	No.	lb.	No.	lb.	No.	lb.
1973	Apr - June	0		52		620	457	429	149	34	24	1135	630
	July - Aug	0		139	93	69	53	310	246	98	68	616	460
	Sept - Dec	0		0		0		0		0		0	
1974	Jan - Mar	0		0		0		34	60	51	56	85	116
	Apr - June	0		0		0		333	639	24	62	357	701
	July - Aug	0		0		0		47	88	65	80	112	168
	Sept - Dec	0		9	9	36	62	32	45	37	52	114	168
1975	Jan - Mar	0		0		0		209	197	121	60	330	257
	Apr - June	0		77	54	101	60	90	36	126	75	394	225
	July - Aug	28	17	0		57	40	26	118	240	96	351	271
	Sept - Dec	0		0		0		68	37	0		68	37
1976	Jan - Mar	10	10	10	5	0		20	20	140	182	180	217
	Apr - June	0		23	36	31	31	338	509	219	311	611	887
1977	Jul - Aug	0		0		275	399	878	1569	200	273	1353	2241
	Sept - Dec	0		0		506	1645	852	1561	1159	2863	2517	6069
1978	Jan - Mar	0		0		172	601	73	312	1190	1369	1435	2282
	Apr - June	71	78	0		2205	3640	393	435	2228	2327	4826	6402
	July - Aug	0				683	968	564	752	1070	1063	2317	2783
	Sept - Dec	343	515	659	1057	605	1060	350	525	284	517	2241	3674
1979	Jan - Mar	0		0		80	120	51	102	54	82	185	304
	Apr - June	50	50	79	198	0		980	1150	183	206	1292	1604
	July - Aug	0		0		187	343	0		95	189	282	532
	Total	502	670	930	1452	5627	9479	6077	8350	7567	9889	20,801	30,028

Table 4.2-25. Estimated sauger sportfishing harvest by area, Wheeler Reservoir, April 1973 through August 1979.

		Areas 1-1 and 1-2		Area 2-1		Area 3-1		Area 3-2		Area 4-1		Totals	
		No.	lb.	No.	lb.	No.	lb.	No.	lb.	No.	lb.	No.	lb.
1973	Apr - June	0		0		0		0		0		0	
	July - Aug	0		0		0		0		0		0	
	Sept - Dec	0		0		0		0		0		0	
1974	Jan - Mar	0		0		0		0		0		0	
	Apr - June	0		0		0		0		0		0	
	July - Aug	39	31	18	13	82	62	14	11	0		153	117
	Sept - Dec	84	42	0		0		0		0		84	42
1975	Jan - Mar	0		0		0		0		0		0	
	Apr - June	91	54	28	19	88	71	51	10	78	102	336	256
	July - Aug	0		0		0		0		0		0	
	Sept - Dec	52	42	0		0		0		0		52	42
1976	Jan - Mar	0		0		0		0		0		0	
	Apr - June	77	115	99	107	110	27	0		0		286	249
1977	July - Aug	0		82	66	0		101	132	67	67	250	265
	Sept - Dec	0		0		79	110			0		79	110
1978	Jan - Mar	0		0		0		0		0		0	
	Apr - June	0		0		0		0		0		0	
	July - Aug	0		0		0		0		0		0	
	Sept - Dec	103	96	0		0		0		311	104	414	200
1979	Jan - Mar	0		0		0		0		0		0	
	Apr - June	0		0		0		0		0		0	
	July - Aug	0		0		0		0		0		0	
	Total	446	380	227	205	359	270	166	153	456	273	1,654	1,281

Creel census data show no effect of BFNP on the Wheeler Reservoir fishery. However, the data are sufficiently imprecise to preclude the possibility of detecting subtle changes in stock densities.

4.2.6 Expected Hydrothermodynamic and Fish Interactions

Based on the size of the mixing zone and the infrequent occurrence of temperatures that approach 90° F at the five-foot depth, no significant impact to the fish community, including sauger and smallmouth bass, in Wheeler Reservoir is expected. For example, in July when maximum temperatures are most likely to occur, mixed river temperatures will exceed 88° F only about two percent of the time in a small pelagic zone less than one percent of the volume of Wheeler Reservoir. Surface temperatures (0.5 ft) within this zone, or elsewhere in the reservoir, that occasionally exceed 90° F are not thought to cause any unnatural fish distributions. Fish species, such as shad, that inhabit the pelagic zone would readily tolerate these temperatures. Sauger would not be expected to occur in this zone, regardless of prevailing temperatures since they are bottom-dwelling. However, even the heated plume should have no significant impact on the distribution of this species as shown by the presence of sauger in the summer gill net catch in the immediate vicinity of the diffuser. Although smallmouth bass readily tolerate 90° F waters, this species normally inhabits the littoral zone or off-shore rocky shelves.

5.0 Summary and Conclusions

The intent of thermal discharge limitations is the protection and propagation of balanced and indigenous populations of aquatic organisms in the receiving water body. According to protocol established by EPA, this is best accomplished by protecting the most temperature sensitive fish species judged important, desirable or both. For the Tennessee River drainage basin, sauger, smallmouth bass, and walleye were initially classified as coolwater species. Recent data show that smallmouth bass do not warrant this classification. Walleye are rare in Wheeler Reservoir and are of minimal concern. However, sauger are common and the potential for thermal impact to this species was investigated at length.

Extensive preoperational and operational monitoring investigations of adult fish stocks identified natural flucuations in fish stocks in the vicinity of BFNP. Data gathered prior to operation and during operation under both the 86°F standard and 90°F limit were similar. The attraction of some species, including sauger, to the discharge structure was observed during all seasons. Surface water temperatures in the zone of thermal influence occasionally exceed 90°F, a temperature which occurs naturally in both overbank and channel surface areas in summer months. Coolwater species could avoid these areas but cove rotenone data do not document such an avoidance. The presence of sauger and smallmouth bass in areas with surface temperatures that exceed 90°F naturally and sauger near the diffusers during all periods suggest that there were no adverse thermal effects for either the 86°F standard or 90°F limit.

Stizostedion spp. (probably sauger) were the only "coolwater" ichthyoplankton collected during the 9-year monitoring period. Temperature data gathered concurrently with larval samples showed that water temperatures did not exceed 71.6°F (22°C) during periods when Stizostedion larvae were present in Wheeler Reservoir. As a consequence, they would be unaffected by a permanent 90°F variance.

Clupeids and freshwater drum were the dominant ichthyoplankters collected when water temperatures were 86°F or greater. Densities of both taxa were at naturally low levels in these temperature regimes because these temperatures occur after peak spawning. Therefore only a minor portion of clupeids and freshwater drum larvae are subjected to entrainment in thermal plumes exceeding 86°F and no effects to either would be expected for a permanent 90°F thermal limit.

Phytoplankton data revealed that slightly eutrophic conditions in Wheeler Reservoir during early and mid-1970's changed to eutrophic conditions during the late 1970's. Available data for all years except 1979 indicate this was the result of factors not related to operation of BFNP since parallel changes occurred throughout the reservoir upstream and downstream of the plant. In 1979, a wetter and cooler year than average, there were indications of stimulation of phytoplankton at stations downstream of BFNP. If this was the case, there was no substantial difference in the phytoplankton community downstream of BFNP from that in 1977 when the 86°F standard was in effect.

The zooplankton assemblage was diverse but changed from Cladocera to Rotifera domination immediately downstream of BFNP, especially during 1978 and 1979. Whereas Cladocera abundance also increased downstream of the plant, a disproportionate increase in rotifer numbers resulted in Rotifera becoming dominant. Available data suggested that thermal enrichment may have increased reproductive success for rotifers in 1978 and 1979 when the 90°F limit was in effect. However, if thermal enrichment was a factor, it appeared to only somewhat accentuate an ongoing trend or process unrelated to the presence of BFNP.

Data for benthic macroinvertebrates tended to be variable. Because known thermal tolerances for these organisms are higher than bottom temperatures measured in Wheeler Reservoir, population fluctuations were thought to reflect emergence of adults prior to sample collections and/or sample variability caused by contagious distribution patterns. Benthic macroinvertebrate data do not show that operation of Browns Ferry Nuclear Plant has affected maintenance of a balanced and indigenous benthic macroinvertebrate community during operation at either the 86°F standard or 90°F limit.

The proposed mixing zone for Browns Ferry Nuclear Plant is 1800 feet wide and extends 2200 feet downstream of the diffusers over the entire water depth. The mixing zone is often paritally stratified. Mixed temperatures greater than 90°F do not occur at the downstream edge of the mixing zone at the five foot depth for open mode cooling when ambient river temperatures are less than 85°F or for helper mode cooling when ambient river temperatures are less than 88°F. A mixed temperature rise in excess of 5°F will

not occur for most river flow conditions. If low or reverse river flows persist for sustained periods, re-entrainment of the diffuser plume may result. In this case, increased river flows or decreased plant heat discharge will prevent plume re-entrainment.

If the Browns Ferry Nuclear Plant is required to meet the 86°F maximum mixed-reservoir temperature, two round mechanical draft cooling towers would need to be constructed to lessen plant load reductions required during summer months. However, assuming a 90°F thermal variance, tower additions can be avoided by increasing existing tower performance by about 6 percent. Adoption of a 90°F thermal limit along with increased tower performance is the preferred option and has a cost advantage of $33 million over the next lowest option.

TVA, following extensive evaluation of data collected before and during the 90°F variance period, now believes that permanent relaxation of the 86°F thermal standard to a 90°F limit would assure the protection and propagation of aquatic biota in Wheeler Reservoir. In addition, such a relaxation would avoid the necessity to either take large load reductions or install additional cooling towers at the plant. Environmental losses would not accrue for a 90°F limit whereas economic advantages to TVA and its customers would be substantial.

6.0 References

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