LPL-233

Amacoy Lake Restoration Project
Baseline Fishery and Comparative Water Quality Surveys Spring - Fall 1994 Final Report

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and
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Table of Contents

Tables

Figures

Amacoy Lake Restoration Project
Baseline Fishery and
Comparative Water Quality Surveys
Spring - Fall 1994 Final Report

Background

Amacoy Lake is a 287-acre, shallow, eutrophic lake located in Rusk County, Wisconsin (Brakke, 1993). Historically, the lake communicated directly with the Chippewa River via an approximately one-mile-long outlet stream. As a result, annual variations in the surface elevation of the lake reflected flood flow conditions in the nearby Chippewa River, and the lake functioned essentially as a flowage system under frequently occurring flood conditions.

In the years prior to 1970, local residents observed several flood events that apparently caused considerable flood damage to riparian dwellings along the lake's shoreline. As a result, a road with a flood-control structure was built over the outlet stream at a point approximately 100 meters upstream from its confluence with the Chippewa River. The structure consists of two 40-inch-diameter corrugated metal culverts that run under River Road and are fitted with uni-directional steel "flap" gates at the downstream end of the culverts. The flap-gates allow water to leave the Amacoy Lake system at all times and prevent periodic Chippewa River flood waters from entering the system. The elevation of the road bed at the stream crossing exceeds the 100-year flood elevation of the Chippewa River at that point by more than 7 feet. In conjunction with the flap-gate structure, River Road effectively denies flood communication with Amacoy Lake and has raised its elevation by 2 feet (0.5 meters). The effect of these changes has been to eliminate stage fluctuations in Amacoy Lake, creating a stable-stage lake system.

Further observations by long-time residents suggest that since the installation of the flood-control structures, both the water quality and fish resources within the lake have been steadily degrading relative to original conditions. To address concerns relative to these apparent declines, a multiphased study approach was developed, which involved the following components:

- Establishing a current baseline data set regarding water quality in Amacoy Lake (completed June 1993).
- Establishing a baseline fishery data set for the lake and to implement continuous water quality monitoring in both the lake and the Chippewa River during high-flow events (the primary focus of this report).
- Integrating data from the first two phases into a hydrographic study of both the Chippewa River and the immediate Amacoy Lake basin, including the outlet stream.

The final phase of study will determine alternatives that will allow for bi-directional movement of fish and water between Amacoy Lake and the Chippewa River and still provide the flood control required to protect various riparian concerns along the lake.

This report describes the current fishery of Amacoy Lake in terms of species composition, relative abundance among species, length-frequencies and population estimates. Methods and study results are discussed in the context of Amacoy Lake as a previously functional flowage system that has apparently undergone a significant perturbation in the form of flood-control structures. Relative water quality in the lake and in the Chippewa River during the spring and fall runoff periods is also discussed.

Baseline Fishery Survey

Introduction

Historical information regarding the fishery in Amacoy Lake suggests that prior to 1970, the lake was home to a wide variety of both lacustrine and riverine fish species. The alleged presence of riverine species such as lake sturgeon, channel catfish, and redhorse suckers was likely due to the fact that these fish were allowed unrestricted movement between the lake and the Chippewa River during common flood events. Since the installation of flood-control structures within the outlet stream in 1970, it has become apparent that nearly all of the typically riverine species have become increasingly uncommon within the lake. Attrition from both natural and angler effects as well as the ability for fish to move only out of, and not back into, the lake are the likely primary causes for such declines.

Prior to this study, relatively little empirical data existed regarding the fishery within the lake, although considerable anecdotal data existed. The primary purpose of this study was to evaluate the current fishery of Amacoy Lake, to determine the overall structure and composition of the lake's fishery, and to establish a baseline data set. Data from this survey will be used to evaluate future management alternatives to restore fish populations. These are expected to consist of either modification of the flood-control structure to reestablish communication with the Chippewa River, or a program of in-lake fish management efforts such as artificial spawning structures or special angler harvest options.

Methods

Amacoy Lake was fyke netted for 17 days in spring of 1994 beginning on April 17 (approximately 5 days after ice-off) and ending on May 3. Nine nets were deployed at various locations along the lakeshore throughout the 17 days, resulting in a total netting effort of 153 net-nights (i.e., 17 nights of netting times 9 nets = 153 net-nights). Five nets had 4- by 6-foot rectangular openings and were constructed with half-inch bar mesh; the remaining four nets had 3- by 6-foot rectangular openings and were also constructed with half-inch bar mesh. Only center-leads and no wing nets were used during deployment. The lengths of center-leads used for individual nets varied as a function of shoreline configuration; that is, long leads were necessary for shallow, gently sloping shorelines and short leads were required for abrupt, steep shorelines.

All nets were moved to new shoreline locations at least once (some were moved multiple times) during the 17-day netting period. As a general rule, nets remained in one location as long as they continued to produce substantial catches each day. If the daily catch began to diminish quickly for more than one day, the net was redeployed in a new location to optimize catch efficiency.

All individual fish were removed from each net daily. Fish were transferred to an aerated holding tank where they were kept until processed. Individual fish were identified, enumerated, and recorded on field sheets. Walleye and northern pike were given individual, coded T-bar (FLOY) tags as part of a long-term fish movement study. This study was initiated at the suggestion of Mr. Frank Pratt, the Wisconsin Department of Natural Resources (WDNR) Fisheries Manager in the Hayward area office. These same walleye and northern pike were also given a temporary clip of the left pectoral fin to monitor long-term tag loss and short-term recapture rate during this survey. All other species were only given a left pectoral fin-clip to monitor recapture rates. An exception to the left pectoral fin-clip was for yellow perch; due to their relatively small average size and very high numbers, it was substantially more efficient to give these individuals a fin-clip on the top lobe of the caudal (tail) fin. After individual fish were processed, they were returned alive to the lake. Fish mortality as a result of sampling stress was minimal.

Approximately 3 weeks after the conclusion of fyke netting operations, electrofishing operations began. This phase of the survey was a cooperative effort between the WDNR's Hayward area fisheries manager and Mead & Hunt, Inc., and was designed to function as a recapture mechanism for fish tagged during netting operations. Data recorded during shocking operations and data from netting operations were both used to generate population estimates for certain species.

Actual electrofishing dates were May 25 (by WDNR) and June 1 and 2 (by Mead & Hunt, Inc.). On May 25, there was a total of 3.0 hours of electrode "on-time," while on June 1 and 2, there were 3.0 and 3.5 hours of "on-time," respectively. During each night of electrofishing, approximately one full circuit was made around the lake shore. Actual electrical outputs were continuously optimized during shocking operations as a function of apparent spatial shifts in lake water conductivity. For example, some embayments clearly exhibited more dissolved solids in the water than others and, as a result, minor adjustments in electrical output were necessary to prevent injury to fish.

During electrofishing operations, fish were netted continuously by two netters until the live-well on the boat became full, when time shocking activities ceased temporarily until all fish were processed. Fish species that were well represented in terms of length-frequency distributions from the netting phase of the study were only enumerated and recorded, while those that were poorly represented during netting operations were measured to the nearest 1.0 millimeter, counted, and recorded. As with netting, walleye and northern pike were given a coded T-bar tag. At WDNR's request, all largemouth bass collected during shocking operations were given a fin-clip on the top lobe of the caudal fin as a mark for future WDNR fishery surveys of the lake. A separate record of recaptured individuals by species was also maintained. All individual fish were returned alive to the lake following processing.

Results

Species Composition

A list of all fish species collected from Amacoy Lake during both fyke netting and electrofishing operations is shown in Table 1. A synonymy of common and scientific names is given in Table 2.

TABLE 1
Amacoy Lake Fishery Survey - Spring 1994
Fish Species Relative Abundance

Species	No. Caught	Relative Abundance (%)
Yellow perch	11,131	74.59
Walleye	229	1.53
Largemouth bass	96	0.64
Bluegill	2,028	13.59
Pumpkinseed	115	0.77
Green sunfish	34	0.23
Black crappie	360	2.41
Muskellunge	74	0.50
Golden shiner	548	3.67
White sucker	256	1.72
Black bullhead	8	0.05
Yellow bullhead	12	0.08
Northern pike	31	0.21
Shorthead redhorse	*	
Silver redhorse	*	
Creek chub	*	
Central mudminnow	*	
Emerald shiner	*	
Total	14,922	100

* *Less than five individuals caught.*

TABLE 2
Amacoy Lake Fish Species Composition from Electroshocking and Fyke Netting Data

Common Name	Scientific Name
	Cyprinidae
Golden shiner	*Notemigonus crysoleucas*
Emerald shiner	*Notropis atherinoides*
Creek chub	*Semotilus atromaculatus*
	Catostomidae
White sucker	*Catostomus commersoni*
Silver redhorse	*Moxostoma anisurum*
Shorthead redhorse	*Moxostoma macrolepidotum*
	Ictaluridae
Black bullhead	*Ameiurus melas*
Yellow bullhead	*Ameiurus natalis*
	Esocidae
Northern pike	*Esox lucius*
Muskellunge	*Esox masquinongy*
	Umbridae
Central mudminnow	*Umbra limi*
	Centrarchidae
Green sunfish	*Lepomis cyanellus*
Pumpkinseed	*Lepomis gibbosus*
Bluegill	*Lepomis macrochirus*
Largemouth bass	*Micropterus salmoides*
Black crappie	*Pomoxis nigromaculatus*
	Percidae
Yellow perch	*Perca flavescens*
Walleye	*Stizostedion vitreum*

Relative Abundance

Table 1 shows the relative abundance of all fish species collected during both fyke netting and electrofishing operations. Yellow perch were the numerically dominant species and accounted for nearly 75 percent of all fish collected. Second in numerical dominance were bluegill, accounting for approximately 14 percent of all fish collected. Walleye and muskellunge accounted for 1.53 percent and 0.5 percent, respectively, while golden shiner, white sucker and black crappie accounted for 3.67 percent, 1.72 percent and 2.41 percent, respectively. All other species accounted for less than 1 percent each.

Length Frequency

Figures 1 - 10 show length-frequency distributions in millimeters (mm) (1 inch = approximately 25 mm) of a number of fish species from Amacoy Lake. These distributions were generated only for those species where sufficient numbers were captured to allow for a meaningful distribution.

Walleye ranged in length from 180 to 720 mm (7 to 29 inches) and demonstrated relatively strong length classes in the 200-, 500- and 640-mm (9-, 20-, and 25-inch) ranges. Males and females were represented about equally within the population, though females dominated the 540- to 720-mm (22- to 29-inch) range.

Muskellunge ranged in length from 220 to 1300 mm (8 to 52 inches), with a majority of them being longer than 760 mm (30 inches). Approximately 70 percent of all individuals sampled were greater than the current state legal size limit (810 mm or 32 inches).

Northern pike ranged in length from 240 to 1100 mm (9 to 44 inches) with a majority of them in the 580- to 680-mm (23- to 27-inch) class.

Bluegill ranged in length from 80 to 210 mm (3 to 8.5 inches). Yellow perch ranged in length from 100 to 195 mm (4 to 7.5 inches), with an average size of approximately 125 mm (5 inches). Pumpkinseed ranged from 90 to 175 mm (3.5 to 7 inches) and black crappie ranged from approximately 120 to 340 mm (5.5 to 13.5 inches). Largemouth bass showed a wide size range from 150 to 450 mm (6 to 18 inches).

Only two forage fish species were sampled in sufficient numbers to generate meaningful length-frequency distributions. Golden shiner ranged from 60 to 235 mm (2.5 to 9.5 inches) and averaged approximately 150 mm (6 inches), and white sucker ranged from 110 to 480 mm (4.5 to 18.5 inches).

Population Estimates

Population estimates for a number of species collected during sampling are shown in Table 3 and include 95 percent confidence limits.

TABLE 3
Amacoy Lake Fish Population Estimates - Spring 1994

Species	M	C	R	Population Estimate*	95% Confidence Limits (±)	Variance
Yellow perch	10,310	964	51	191,330	51,615.80	6.66E+08
Walleye	118	174	5	3,442	2,761.52	1.91E+06
Largemouth bass	10	140	4	282	247.72	1.53E+04
Bluegill	1,127	1,175	8	147,261	97,797.83	2.39E+09
Pumpkinseed	73	63	3	1,168	1,130.91	3.20E+07
Black crappie	77	299	1	11,550	16,279.63	6.63E+07
White sucker	54	225	1	6,102	8,591.26	1.85E+07
Muskellunge	69	7	0	552	1,032.70	2.67E+05
Northern pike	31	3	0	124	214.77	1.15E+04
Green sunfish	13	21	0	286	558.85	7.81E+04
Golden shiner	448	68	0	30,912	61,374.36	9.42E+08

* All estimates generated using Baily formula: $N = \frac{M(C+1)}{R+1}$

where:
M = number of fish captured during spring netting operations
C = total number of fish captured during spring shocking operations
R = total number of fish recaptured during spring shocking operations

Discussion

The fish species composition of Amacoy Lake is consistent with similar land-locked lakes within the same geographic region. However, since Amacoy Lake was formerly connected to the nearby Chippewa River, the current fish assemblage is likely very different from the historic fishery. For example, there were no lake sturgeon or channel catfish found during this sampling effort and very few shorthead and silver redhorse—species that would be expected to be present in at least limited abundance if they were able to readily enter the lake system from the Chippewa River.

Amacoy Lake is numerically dominated by a large population of stunted yellow perch with an average length of 5 inches. According to local anglers having long-term experience with the fishery, the perch population used to show a wide range of sizes, with individuals in the 10- to 13-inch class commonly harvested. The changeover to the current population of stunted fish has occurred within the past 20 to 30 years. The longest perch sampled during this study measured only 7.5 inches.

Recent trends indicated in the yellow perch population may be explained as follows. When yellow perch spawn, the female releases a long, spiral, gelatinous mass of eggs. These masses adhere readily to virtually any underwater structure, especially submerged woody debris. Historically, when the lake functioned as a flood-flowage system, the shoreline was largely a wide, periodically inundated sand flat with relatively little to offer in the way of woody material in the near-shore zone. It's likely that when the current flood-control structures were installed and the lake level was raised approximately 0.5 meters, it resulted in the constant submergence of shoreline brush and stumps that were previously only inundated for brief periods during spring and fall. The addition of this potential perch spawning habitat may have contributed considerably to their relative success within the lake.

A considerable amount of potential perch spawning habitat was observed along the shoreline of the lake during the course of this study. Large numbers of perch egg masses were seen attached to submerged woody snags even as close as 1 inch from the water's edge. It may be possible to significantly reduce the total amount of perch spawning habitat by reestablishing direct communication between Amacoy Lake and the Chippewa River through modification or removal of the current flood-control structure. Consequent lowering of the lake stage by 2 feet (0.5 meters) to historical levels could significantly reduce recruitment to the perch population by eliminating portions of their spawning habitat.

Reduction of yellow perch may also enhance lake water quality by changing trophic relationships within the system. Recent research indicates that overgrazing of zooplankton by fish such as yellow perch may reduce zooplankton to such low levels that they are no longer able to exert significant control of algal populations. When zooplankton are no longer able to help keep algae in check, heavy algae blooms may occur and degrade water quality.

Historically, Amacoy Lake was well known for its productive walleye fishery, which has also been observed to be declining in quality over the past two decades. The results of this study support this belief, as it appears that the lake walleye population is dominated by a relatively small number of old, large individuals while the only small fish (i.e., 1-, 2-, and 3-year olds) are apparently those that have been stocked recently by either WDNR or local resource conservation organizations.

In contrast to the walleye fishery, however, the population of muskellunge is quite dense and has a well-distributed age structure at and above the legal size limit. The density of the population distinguishes Amacoy Lake from other similar lakes in the region (WDNR, 1994). The population appears to be dominated by relatively large individuals, all of which sampled during this survey appeared to be very healthy and vigorous, probably due to their reliable forage base of yellow perch and golden shiner.

It is difficult to know with any degree of certainty whether walleye historically spawned directly within Amacoy Lake, migrated out of the lake into the Chippewa River to spawn, or some combination of both. However, it does appear that the walleye reproduction rate in the lake is at a level far below what it was in the past. If, in fact, walleye historically spawned in the Chippewa River and moved back into the lake, the current situation is readily explained, as individuals can only move out of the lake and not back into it under the current flood-control structure design. The alternative hypothesis (walleye spawning primarily in the lake) may also explain the decline in the walleye fishery. As stated above, the installation of the current flood-control structures effectively raised—and more importantly in this situation, stabilized—lake levels. It is possible that historical (pre-flood control) annual fluctuations in lake levels due to flood and baseflow events in the Chippewa River could have effectively maintained a near-shore zone that was kept relatively free of organic material and other detritus due to rapid flushing and cyclical change in the wave-scour zone. Once the lake level was stabilized, fine organic and particulate materials may have begun to settle in the interstitial spaces between larger particles of gravel and cobble, a favored walleye spawning habitat. Over time, the majority of these gravel/cobble areas may have been silted in, rendering them largely unfit for successful walleye reproduction.

In either of the above scenarios regarding walleye spawning, the presence of the current flood-control structures may have had a negative impact on the walleye population.

Supplemental Water Quality Survey

Introduction

As mentioned previously, anecdotal information from long-term residents describes visual deterioration of water quality since the installation of the flood-control structure and elimination of flushing floods. The first Amacoy Lake grant study included a comprehensive water quality evaluation of the lake and concluded that it is in a state of eutrophication indicated by elevated levels of chlorophyll, nutrients, and shallow secchi depths (Brakke 1993) . Potential watershed nutrient sources were highlighted by sampling of inlet streams, but no data were collected from the Chippewa River. The report recommended implementation of controls on watershed sources and further study of the potential role of the Chippewa River through comparison of nutrient levels with those of the lake and its inlets. The following data act on the latter recommendation and, as such, supplement the Brakke report.

Methods

Investigation methods comprised continuous monitoring of temperature and dissolved oxygen (DO) within the Chippewa River and the main inlet to Amacoy Lake, site INL-1 (Brakke, 1993), and shallow grab samples for analysis of water chemistry at these same locations. Grab samples of Amacoy Lake were taken by Craig Roesler of the WDNR Northwest District Office. All chemical analyses were conducted by the State Laboratory of Hygiene.

The purpose of continuous monitoring was to evaluate the relative water quality in each location during the time of year when the river was most likely to communicate directly with the lake via back-flushing as a result of spring flooding. Monitoring of phosphorous levels from analysis of the grab samples was intended to help evaluate the potential impact to nutrient levels in Amacoy Lake from reestablishment of flushing flows.

Two HydroLab DataSonde III continuous water quality monitors were deployed at different locations on April 19, 1994. One was placed in the Chippewa River at a location approximately one-half mile upstream from the river's confluence with the outlet stream from

Amacoy Lake. The other was deployed in the major inlet creek to Amacoy Lake approximately 100 meters downstream from the Highway 40 stream crossing. The monitoring units were programmed to continuously log water quality readings once an hour from April 19 to June 1, 1994. Water quality variables measured were as follows: temperature (C), pH, specific conductivity, and DO [both percent saturation and milligrams per liter (mg/L)].

Results

Chippewa River Continuous Monitoring

Figures 11 through 14 show water temperature (C) and DO concentration (mg/L) at the Chippewa River monitoring site from April 20 to May 30, 1994. Regular oscillations in temperature indicate daily warming and nighttime cooling periods, with a late-April period of temperature decline due to a combination of cooler weather with overcast skies. Overall, the graphs show a gradual rise in temperature, with stronger diel fluctuations mirrored by corresponding fluctuations in DO after May 19 with the onset of the major portion of the phytoplankton growth season. Throughout the period of record, DO was between 6 and 10 mg/L, which exceeds the minimum State of Wisconsin standard of 5 mg/L for surface water. Low periods of 6 mg/L were generally limited to nights after May 19, when algal respiration contributed to brief periods of depletion just prior to sunrise.

The fall period of record, from September 9 through October 24, is shown in Figures 15 through 19. Again, the graphs show a classic response of a large, surface-water river to gradual cooling and senescence of in-stream photosynthesis. Daily cycles in temperature and DO mute rapidly after September 13. DO moves relatively rapidly to a static, background level of between 7 and 8 mg/L. Of significance is the lack of oxygen depletion due to algal senescence.

In general, both spring and fall graphs show the classic response of a relatively large surface-water river to the onset of seasonal temperature and growth regimes and are not, in themselves, symptomatic of poor water quality.

Inlet Continuous Monitoring

In contrast to those from the Chippewa River, data from the inlet stream (Figures 20 through 23) show much greater variation, both daily and seasonally. This behavior is typical of small streams and points out their greater sensitivity to climatological trends, and more rapid response and wider range of flows due to watershed scale effects. In this regard, monitoring of small, running-water bodies presents some tactical difficulties that are illustrated in the record. A drop in stage on May 26 exposed both temperature and DO probes, resulting in air-temperature readings and super-saturation and off-scale readings on the part of the oxygen probe. Normal readings were restored on May 29, when the instrument was re-wetted by a rise in stage.

Inspection of the spring inlet monitoring record shows that the minimum state water quality standard of 5 mg/L DO was violated for a number of days after May 10. On two separate occasions, periods of low DO exceeded 48 consecutive hours. The overall trend shows a rapid decline after May 10 and may have been due to an extended dry spell that reduced the wetted area of the stream, resulting in localized oxygen depletion. Whether oxygen depletion would occur under a more normal seasonal flow regime is a question that cannot be fully answered with the available data. Based on the results of the water chemistry investigation detailed below, eutrophication within this stream channel by itself does not appear to be significant enough to contribute to violation of water quality standards, except under the flow regime encountered in the year of record. Due to an equipment failure, no fall period of record, which might have assisted the analysis, was recovered.

Comparative Water Chemistry

Levels of total phosphorous from the four sites sampled in 1994 are presented in Table 4.

TABLE 4
1994 Comparative Total Phosphorous (mg/L)
Amacoy Lake

Date	Chippewa River (5 miles downstream)*	Chippewa River (Amacoy Lake)	Amacoy Lake (A1-T)*	Main Inlet (INL-1)
April 26	0.070			
April 27		0.075		0.039
May 2			0.036	
June 20			0.022	
July 25			0.029	
August 17	0.029			
September 7			0.049	
September 18		0.051		0.028
November 21	0.040			
Average	0.050	0.063	0.034	0.034

* *Sampled by Craig Roesler, WDNR.*

Total phosphorous ranged from 0.022 to 0.075 mg/L over the course of the sampling period and represent values normally associated with moderately eutrophic conditions. On average, Chippewa River phosphorous levels are nearly twice those of the lake and main inlet. Average river levels, however, are skewed by higher spring and fall values perhaps more representative of runoff concentrations. The August phosphorous level in the Chippewa River (0.029 mg/L) is identical to the July Amacoy Lake value and also agrees with the values of 0.020 to 0.035 mg/L recorded by Brakke in 1991 and 1992. In contrast to the Chippewa River, the main inlet (site INL-1) did not show higher values during spring and fall. Phosphorous concentrations from this source were nearly identical to those in the lake during the summer period.

Discussion

Although concentrations of total phosphorous in the Chippewa River exceed those in Amacoy Lake, analysis of the potential impact of the restoration of flushing flows must take into account the dynamics of the system involved. Thus, the situation prior to the 1970 construction of the flood-control structure must first be examined.

Based on observations of long-term residents and anglers, the historical data indicate a steady deterioration of both water quality and the fishery after construction of the flood-control structure—facts confirmed by this series of lake planning grants. During the 1960s and into the 1970s, there were several lakeshore resorts that had septic systems with direct overflow to the lake during summer periods of high use. Septic systems along the shore would also leach nutrients during high-water events, which typically occurred every year. Yet, even under these high-loading conditions, the waters of the lake remained clear and supported an abundant and diverse fishery. Observant residents attributed this situation to the connection with the Chippewa River and the periodic dilution of lake water by floods. Since construction of the flood-control structure, nutrient sources from septic systems have decreased with the upgrading of some systems and the breakup of resorts, fracturing of use patterns, and general decline in the intensity of use of other septic systems. Water quality, however, has continued to degrade despite control of these nutrient sources.

This historical situation calls to question the comparative water quality status of the Chippewa River during that period. If the reestablishment of flushing flows can be viewed as a negative impact to the lake in light of the current phosphorous data set, it follows logically that prior to flood control, the water quality of the Chippewa River was either considerably better than that of the lake or that some mechanism of nutrient export was occurring—a mechanism that is no longer working. If nutrient levels were significantly higher in the river in comparison to the lake prior to 1970, the lake would have acted as a nutrient reservoir, with corresponding effects on water quality.

The flushing effect observed by residents can be estimated through examination of flow records for the Chippewa River. Analysis of existing gage data from the Bruce station and comparison of lake and river elevations indicate that flushing flows would have occurred above a discharge of 6,900 cubic feet per second (cfs), with a rise in stage of 3 feet over the mean discharge of 4,500 cfs. The 2-year discharge of the Chippewa River at Bruce is approximately 9,000 cfs. Examination of 74 years of record prior to 1992 shows 69 years having floods in excess of this discharge, with some years showing two or more flooding periods including summer floods. Flood communication was apparently quite regular, with some floods exceeding 10 days duration.

The effect of flushing flows could have been twofold. First, the dilution and transport of dissolved and colloidal phosphorous out of the lake to the river may have occurred. This would have required relatively clean river water (unlikely during flood events) and high background levels in lake water. Second, the flood events could have functioned as a recruitment vector for a wide range of lake- and riverine-adapted biota which, after maturing in the relatively nutrient- and habitat-rich environment of the lake, could either emigrate through the unobstructed river channel—taking out nutrients in the form of phosphorous bound within living tissue—or function to sequester phosphorous through trophic cascade effects (Carpenter and Kitchell, 1993). In the absence of the road fill and structure, no significant barriers to fish immigration or phosphorous export in the form of detritus and living tissue would exist.

These phosphorous vectors would have been continuous and across the board of aquatic phyla, and would have included autochthonous material from near-shore lake and stream channel habitats. Recruitment of fish populations through immigration from the river would have served to support what was essentially a large backwater breeding pond, reinforcing the Chippewa River fishery while absorbing and translocating the majority of the continuing phosphorous load to the lake. Phosphorous would move rapidly from phytoplankton to zooplankton, then through planktonic grazers (perch) and piscivorous game fish. After fixation in animal or planktonic proteins, the phosphorous could move out of the system due to a combination of hydraulic and density-dependent behavior effects. This scenario assumes a net export of biomass much higher than under existing conditions but is plausible under the previously existing fishery and habitat scenario sustained by flushing flows and wave scour effects. It also assumes that the existing biotic assemblage in the lake is incapable of exporting comparable quantities of biomass, and that the existing structure forms a barrier to significant export of biomass, probably through a combination of the inhibition effects of the tubes, elimination of floods, and localized destruction of stream channel habitat. Under existing conditions, nutrient export would be limited primarily to the dissolved and colloidal fractions of the phosphorous cycle which comprise, on average, only 10 percent of the internal phosphorous load of a lake (Wetzel, 1975). An advantage to phosphorous removal by these biotic vectors is the potential for continuous movement of phosphorous out of the system, a feature lacking in the flood-dilution theory.

Under the alternate scenario where eutrophic levels of phosphorous where diluted by pristine river waters, historical evidence to this effect would certainly be available. While empirical data is extremely limited in the historical record, a general assessment of the likelihood of degrading water quality can be made by questioning local officials of long experience with the region, particularly if they are involved with control of point and non-point discharges associated with human land uses. The upstream drainage of the Chippewa River at Amacoy Lake includes the southwestern third of Ashland County, most of Sawyer County, and the upper third of Rusk County. Of these areas, a majority of the drainage in Ashland and Sawyer counties is forested, with agricultural land uses becoming more common in Rusk County. Sawyer County, on the other hand, probably contributes more urban runoff from a number of towns along STH 70. In discussions with local land conservation offices, the consensus is that water quality and nutrient levels in the Chippewa River have probably decreased somewhat over the past 25 years, due to control of point sources, cleanup of municipal wastes, and decline in non-point runoff due to farm closures and consolidation.

Conclusions and Recommendations

In the introduction to this report, two future potential management alternatives were offered:

- Modification or elimination of existing flood-control structures.
- Potential in-lake management strategies, which might include either overall enhancement of spawning habitat or certain changes in angler harvest options.

In the framework of a true lake restoration project, the data support modifying the structures. Management strategies, while effective under certain circumstances, are little more than reactionary "band-aid" approaches to a larger, systemic dysfunction. The combination of historical and parametric data clearly indicates that the biotic system of Amacoy Lake and unrestricted flow communication with the Chippewa River functioned to sequester and transport large amounts of excess nutrients without affecting water quality. Efforts to duplicate this function through intensive, in-lake management and habitat alterations are unlikely to prove cost-effective and may further complicate matters unless the hydraulic component is also addressed.

As a lake system departs from its historical structure and function (e.g., by adding artificial spawning shoals made from trucked-in cobble/gravel), it becomes increasingly difficult to understand with any degree of certainty the actual effects of such departures. That is to say, understanding of overall lake health and function depends largely on whether or not one can clearly see cause and effect relationships. As one adds more artificial "causes" to the system, it becomes less clear what the true effects are. Such an approach usually results in a system with many structural or regulatory "band-aids," none of which may address the real roots of a problem, because they are not solutions sustained by ecological relationships that function in the absence of human interference.

It is clear that Amacoy Lake no longer supports the overall quality fishery that historical information shows is possible. A positive step toward reestablishing a functional and diverse fishery in Amacoy Lake would be to consider truly restoring the lake to its historic function—that of a fully operating flowage system in complete communication with the Chippewa River. If the above is carried out, the fishery in Amacoy Lake will most likely eventually revert to its full potential without the aid of artificial spawning habitat or other similar measures. In addition, restoration of historical flushing flows could also significantly affect trophic dynamics within the lake, which could result in the overall enhancement of the system's water quality.

The results of these planning grants have clearly illustrated that the ecological solution to the problems of Amacoy Lake must involve elimination or major modification of the flood-control structure under River Road. To this end, Mead & Hunt recommends the following:

- Complete detailed floodway/flood fringe surveys of the stream channel between the Chippewa River and Amacoy Lake.

- Perform a hydrologic study to determine exact magnitudes, durations, return intervals, and lake-river stage relationships. A major objective should be to identify the maximum allowable rise in lake stage consistent with protection of private property along the lakeshore. The impact of the complete elimination of the roadfill and structure should also be assessed.

- Perform a feasibility study for structural alternatives to the existing tube and gate devices. The structure should have the maximum possible breadth of channel consistent with stability and a bottom of natural materials.

- Collaborate with local government officials on funding and additional features of the project, which could offer other recreational or ecological benefits. Alternatives could include transportation enhancement using federal or state highway funds, e.g., an ISTEA (Internodal Surface Transportation Efficiency Act) project, to construct a boat landing or handicapped fishing access in the area as part of the road\structure reconstruction.

- Initiate a periodic, long-term fisheries and water quality monitoring program to track changes after reconstruction or elimination of the flood-control device. The potential for research applications and the participation of the WDNR Bureau of Research, the University of Wisconsin, or other parties should be investigated.

Amacoy Lake offers a superb opportunity for cost-effective lake restoration in an environment ripe for further scientific investigation on trophic cascade effects and nutrient allocation. To our knowledge, no previous investigations have been undertaken in this regard on an open system like Amacoy Lake. Under the current water quality and fishery scenario, there is little to be risked by restoring flows and nothing to be gained through a more conservative approach. Instead, reconstruction of the flood-control structure to allow control over the range of flood flows will provide an element of supervision unattainable in the majority of comparable restoration efforts. With a coordinated and concerted effort on the part of lakeshore residents, public officials, resource managers, and scientific advisors, Amacoy Lake promises to be a unique and perhaps exemplary ecological restoration.

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Carpenter, Stephen R. and Kitchell, James F., 1993. The Trophic Cascade in Lakes, Cambridge University Press, Cambridge, Great Britain.

Wetzel, Robert G., 1975. Limnology, W.B. Saunders Company, Philadelphia, Pennsylvania.

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Figures

WALLEYE

Length-Frequency

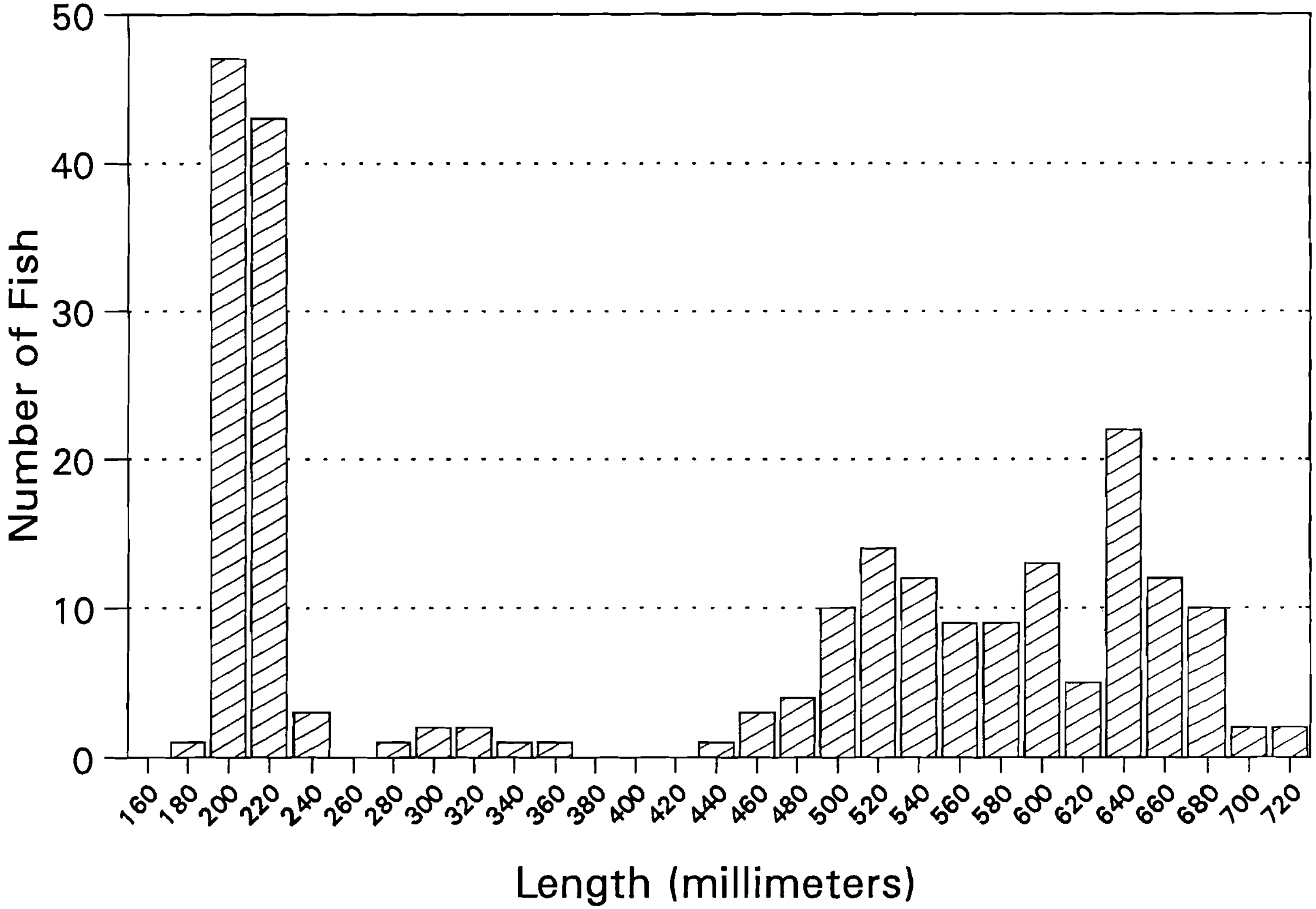

FIGURE 1

Muskellunge

Length-Frequency

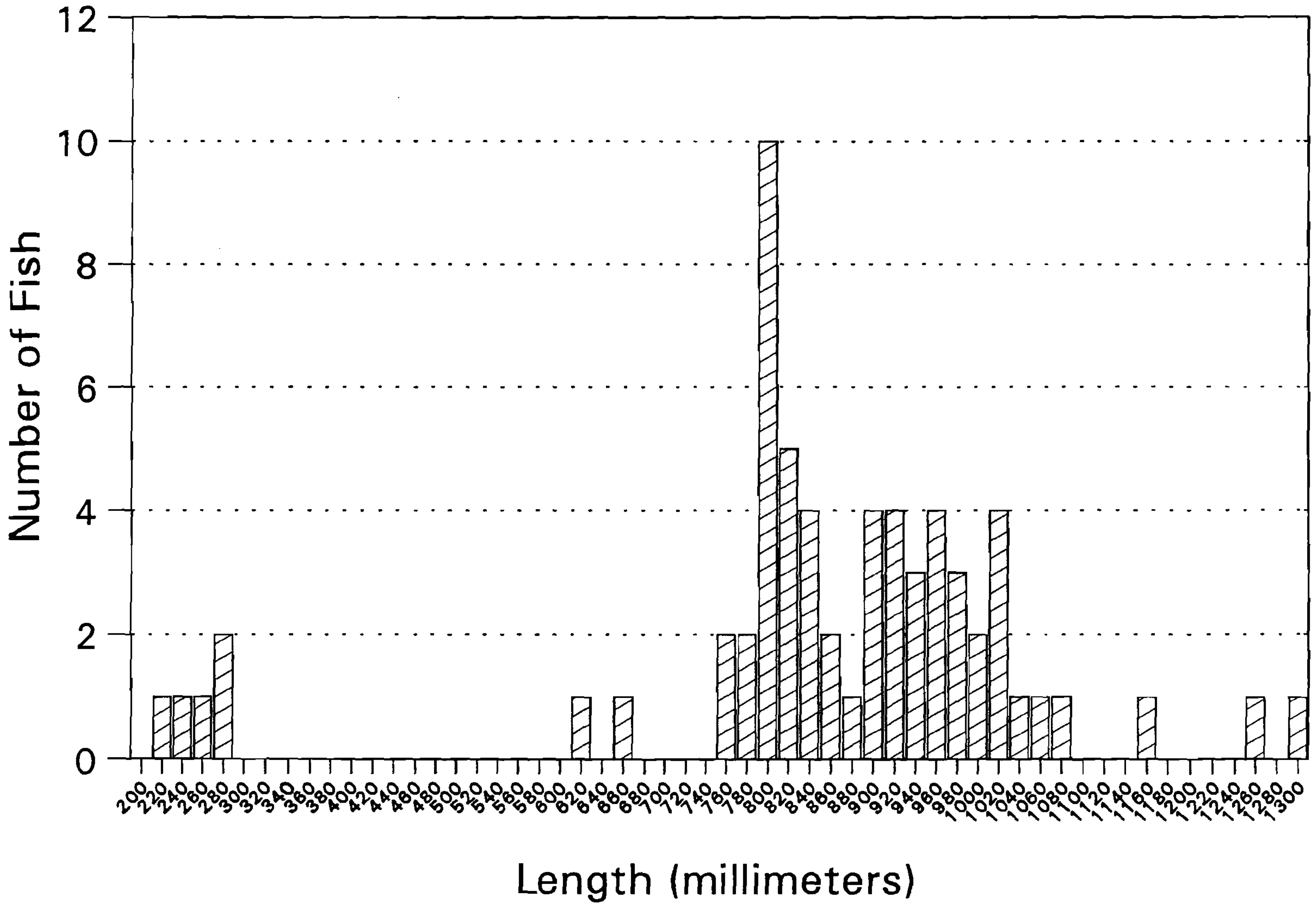

FIGURE 2

Northern Pike

Length-Frequency

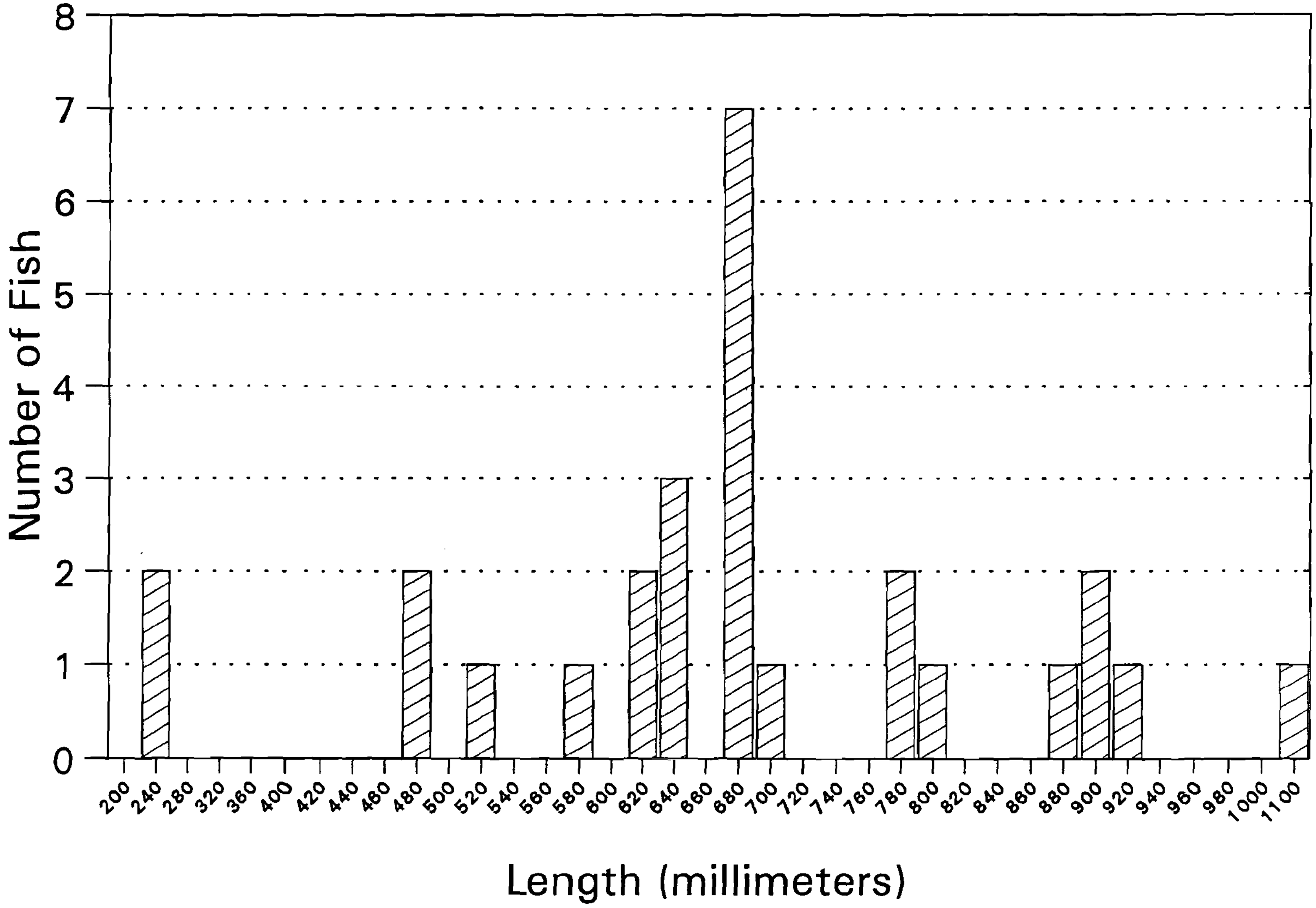

FIGURE 3

Bluegill

Length-Frequency

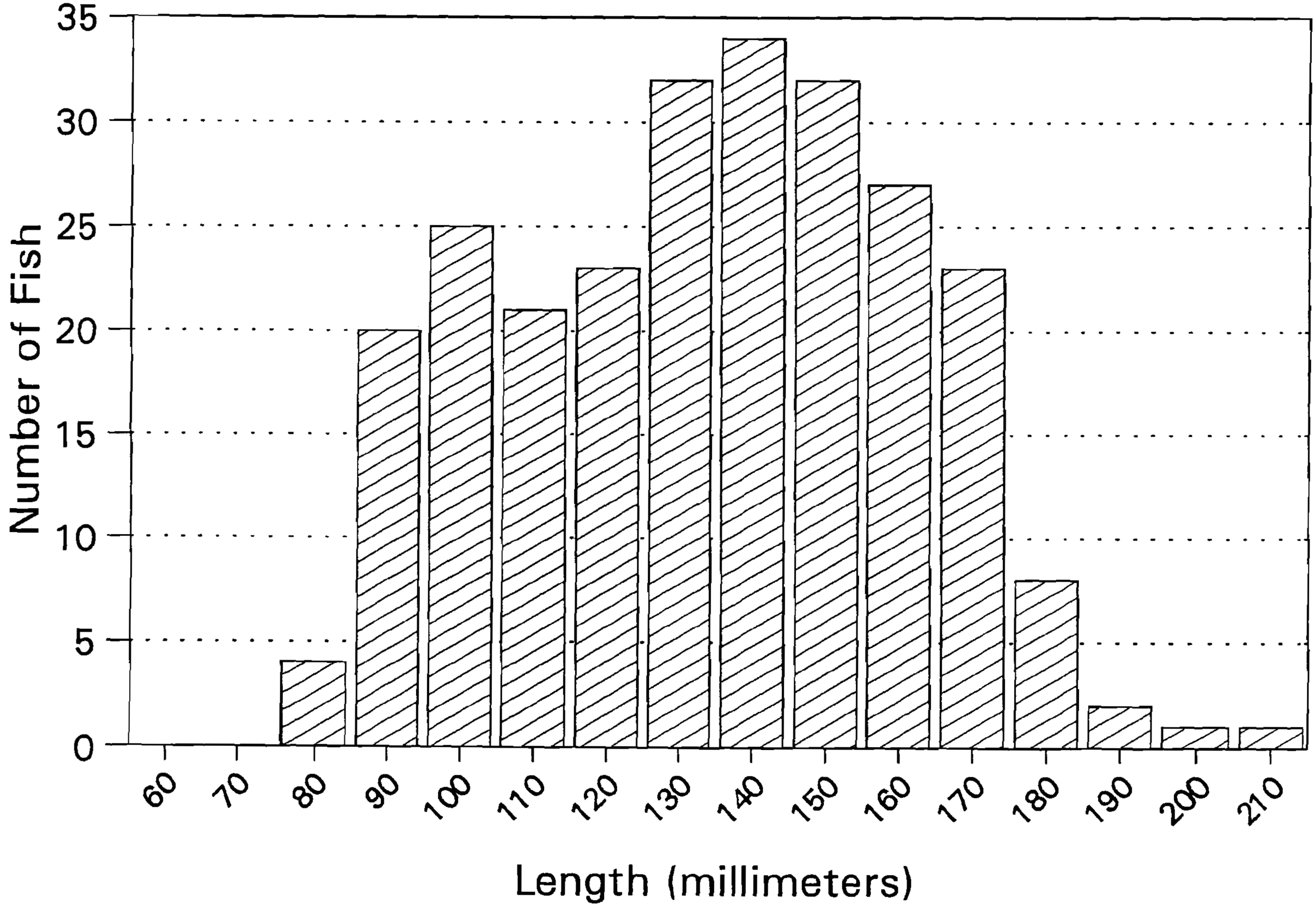

FIGURE 4

Yellow Perch

Length-Frequency

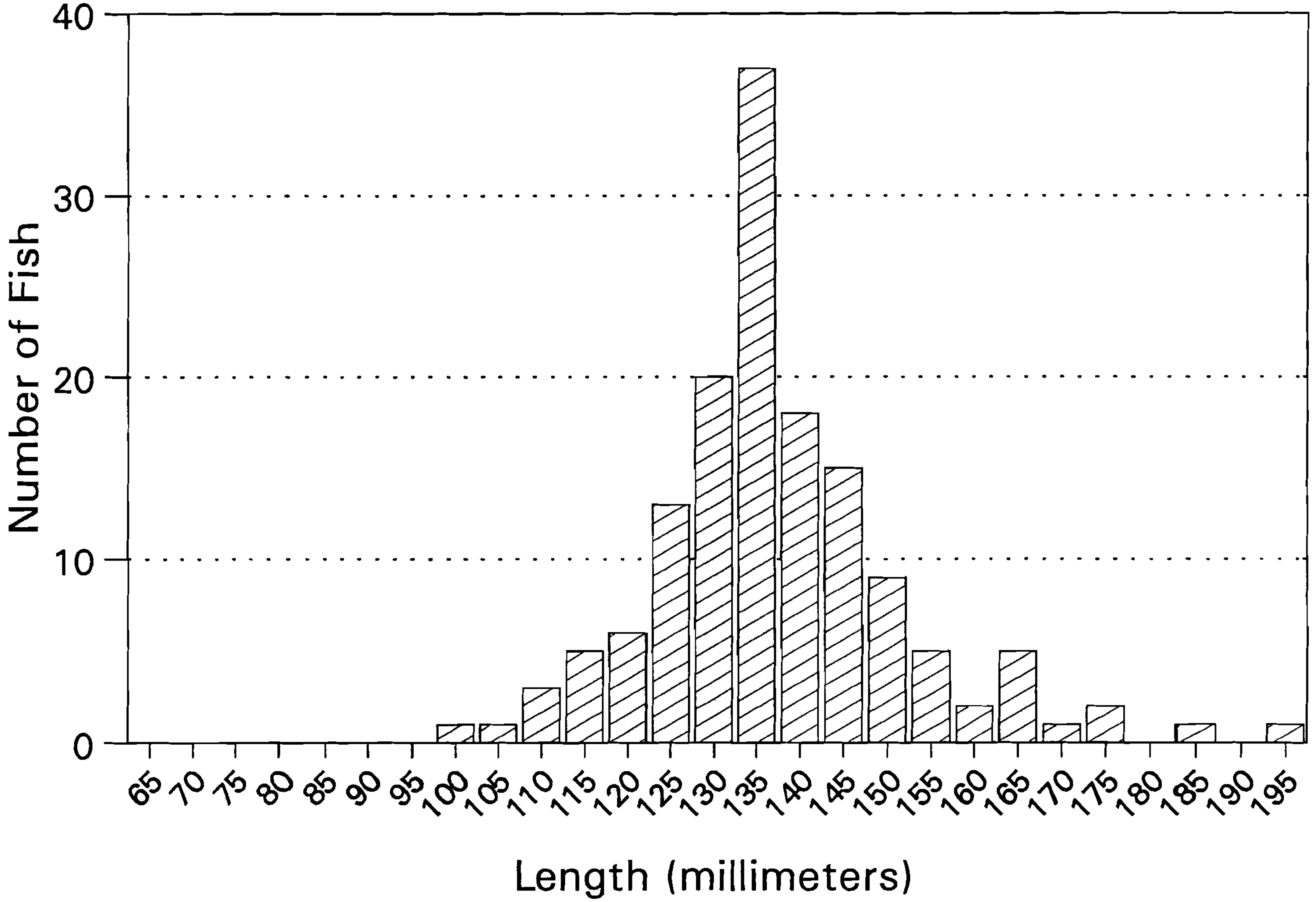

FIGURE 5

Pumpkinseed

Length-Frequency

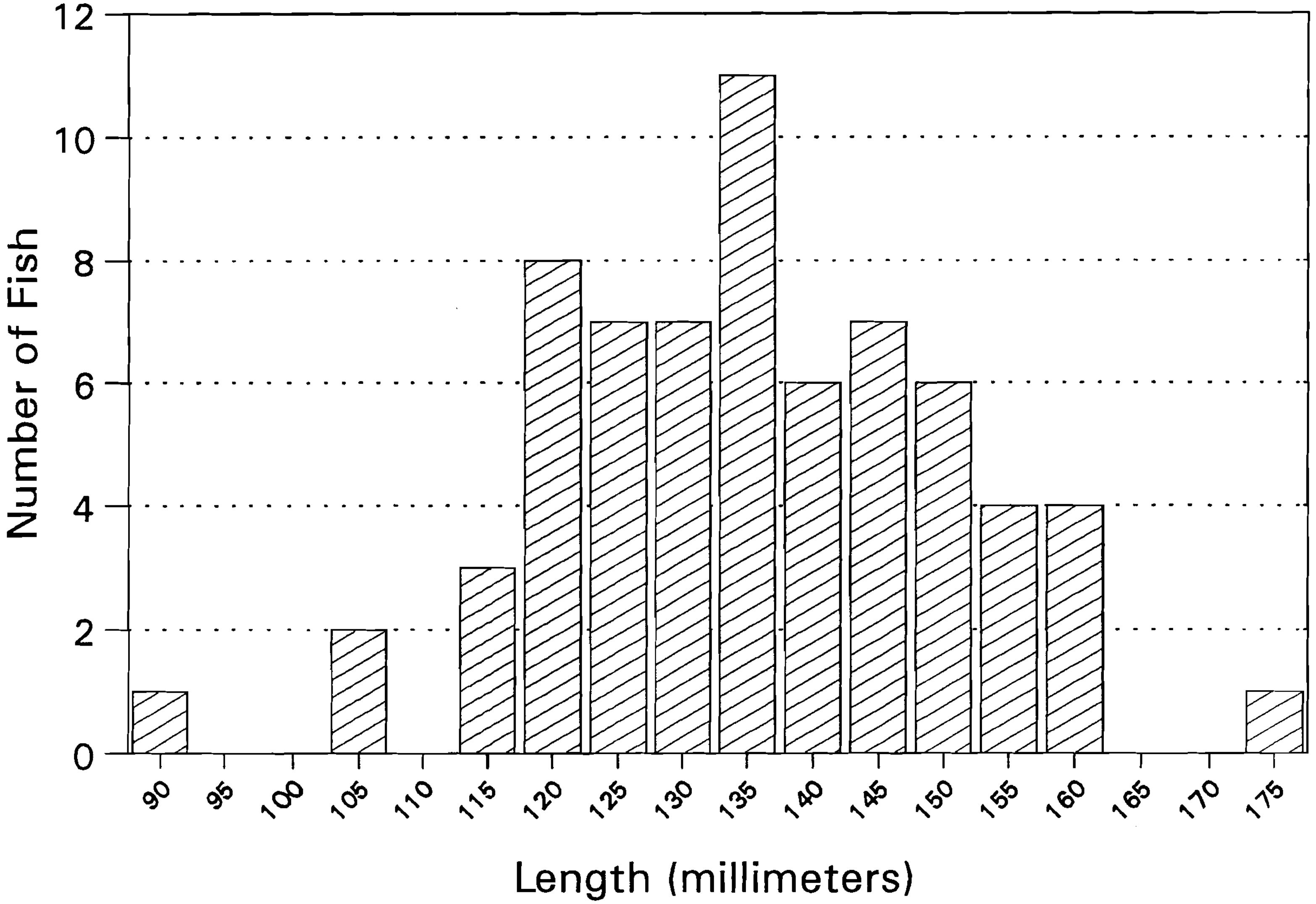

FIGURE 6

Black Crappie

Length-Frequency

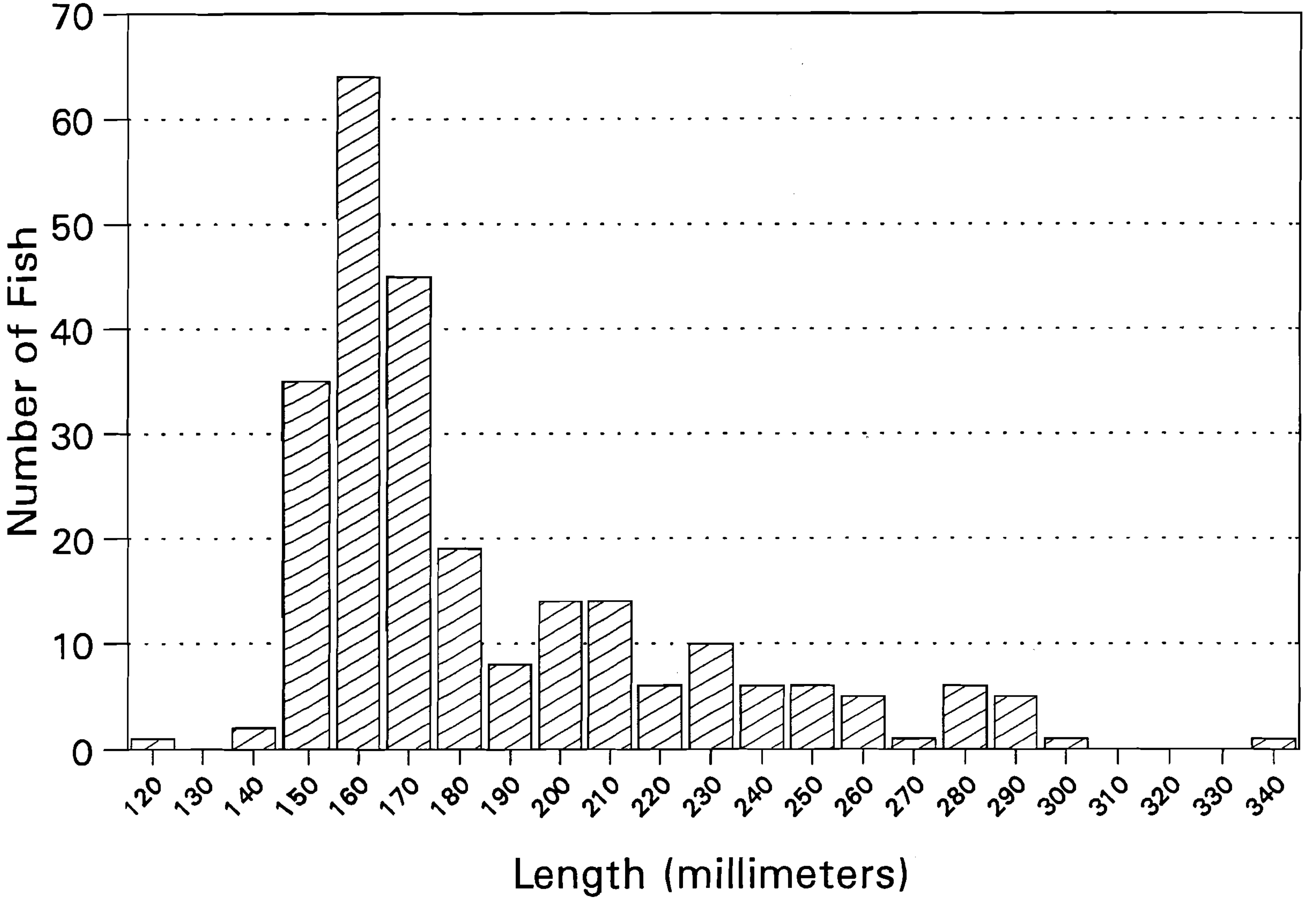

FIGURE 7

Largemouth Bass

Length-Frequency

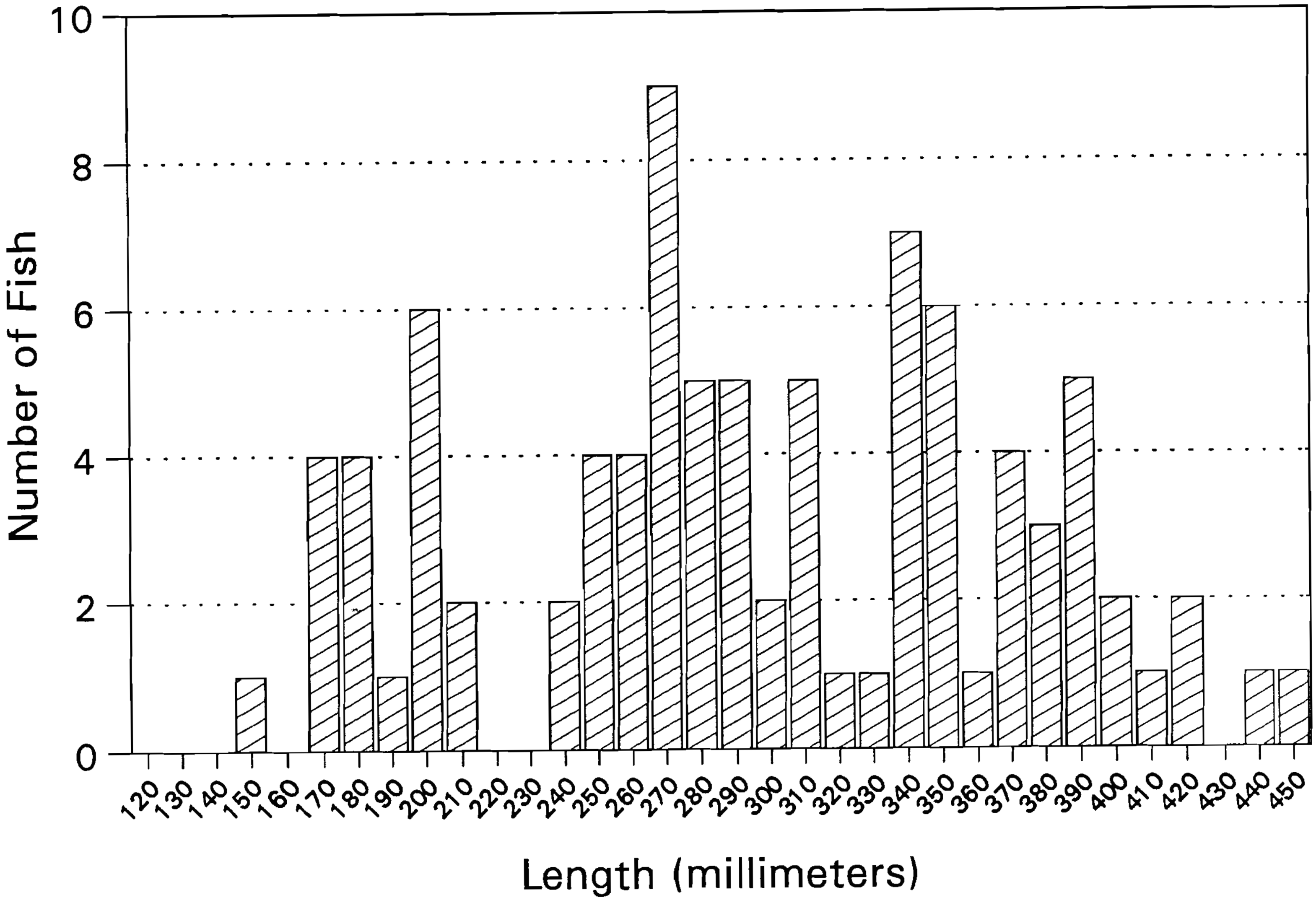

FIGURE 8

Golden Shiner

Length-Frequency

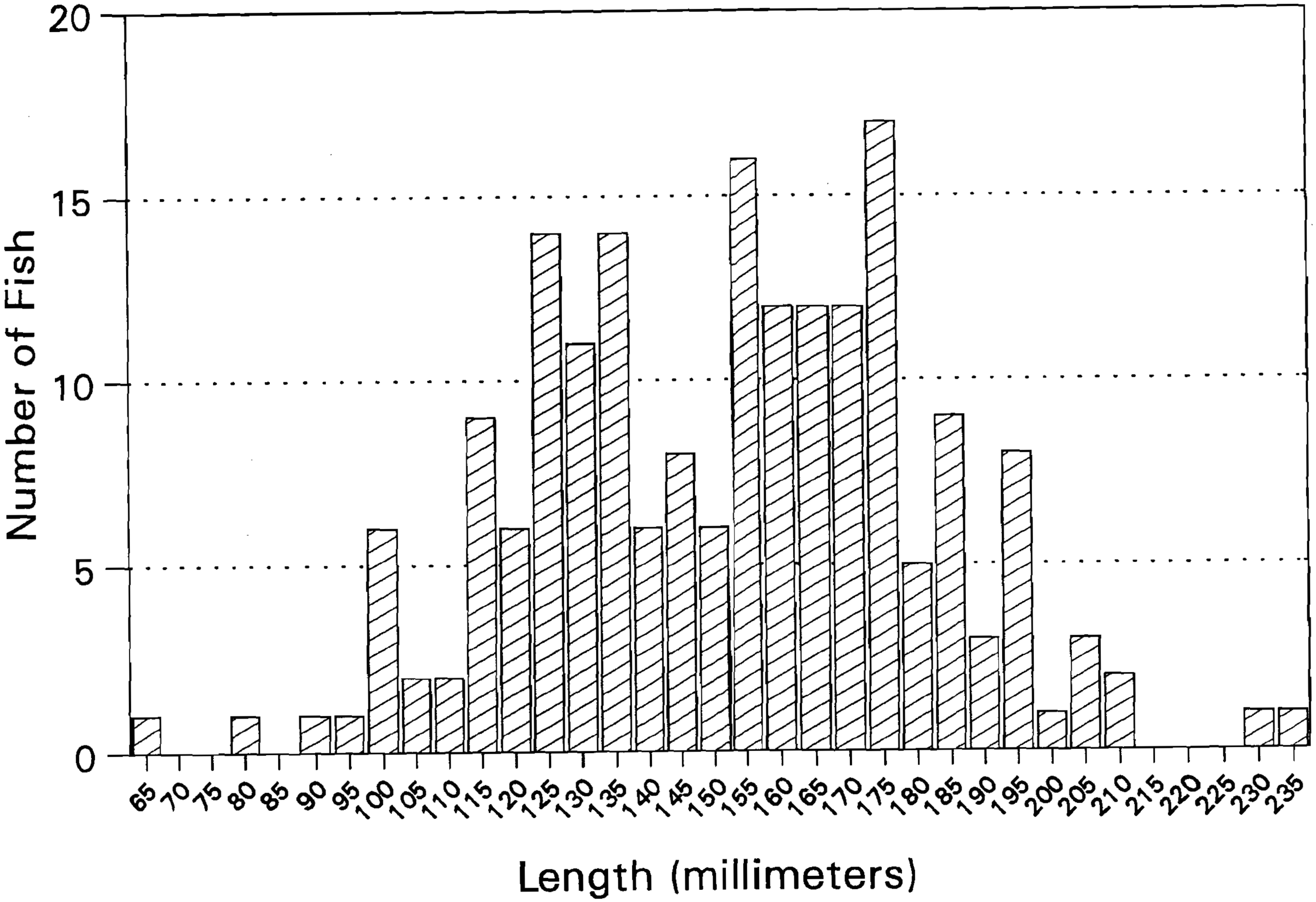

FIGURE 9

White Sucker

Length-Frequency

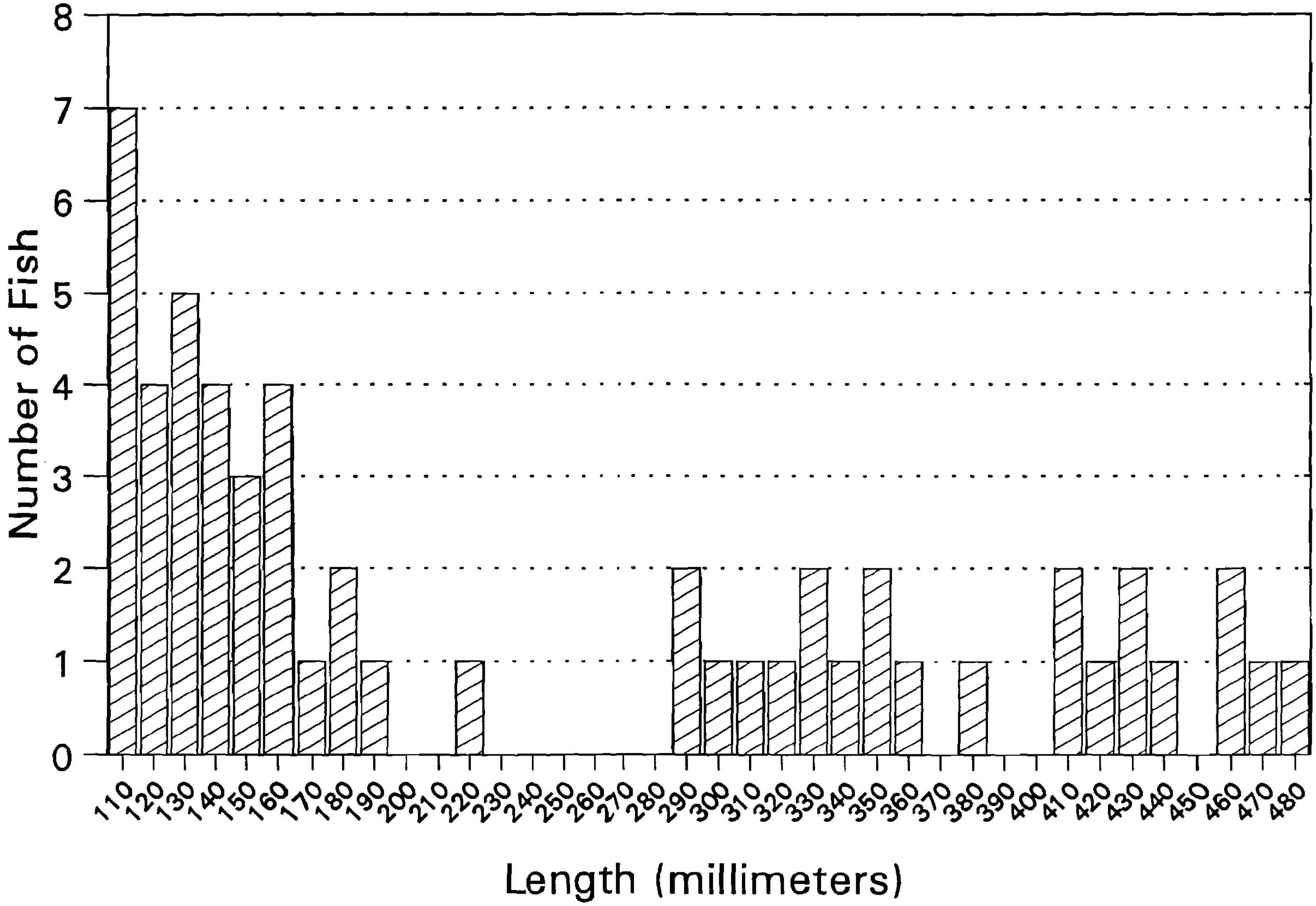

FIGURE 10

River Site - Spring 1994

Temperature and Dissolved Oxygen

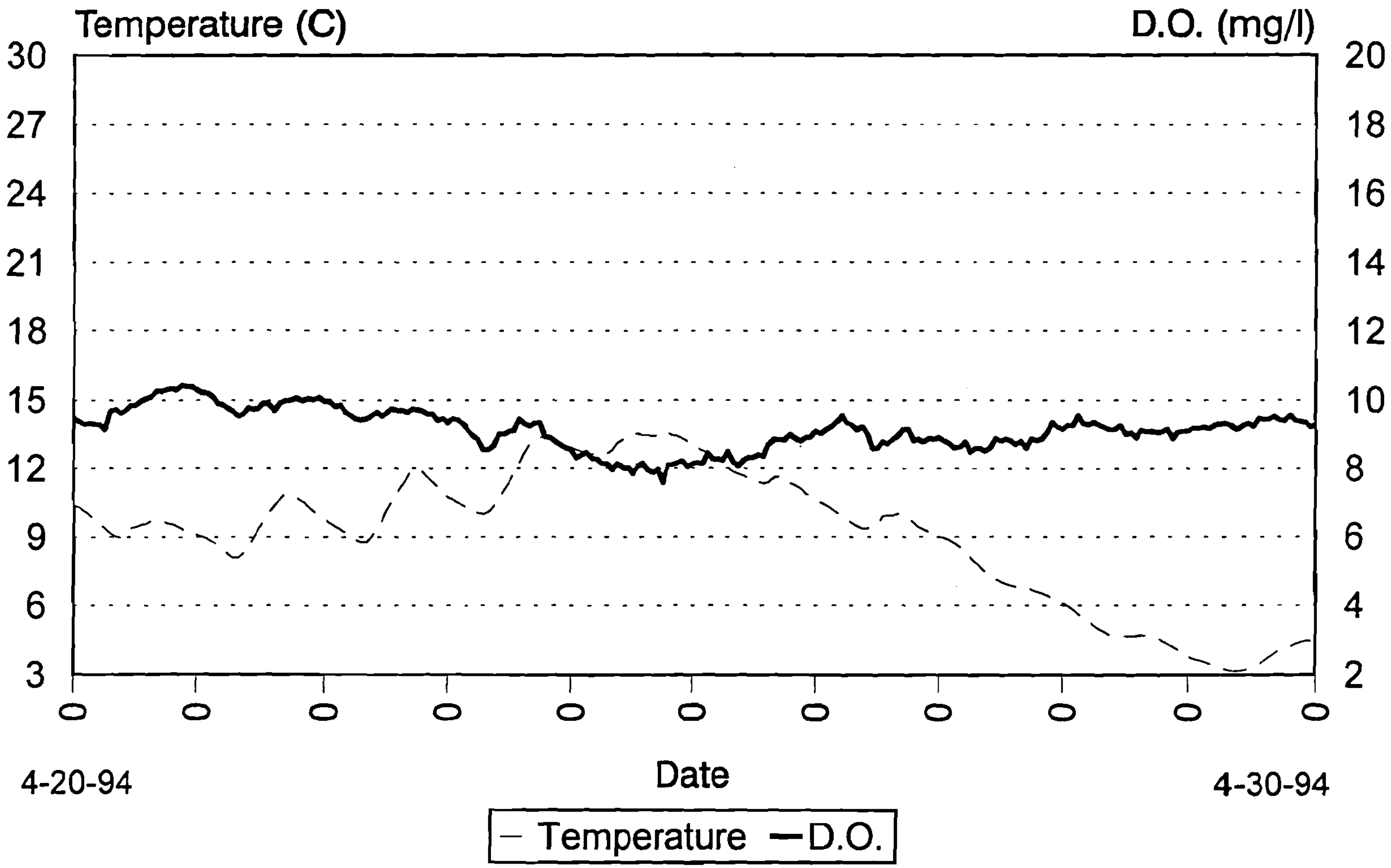

FIGURE 11

River Site - Spring 1994

Temperature and Dissolved Oxygen

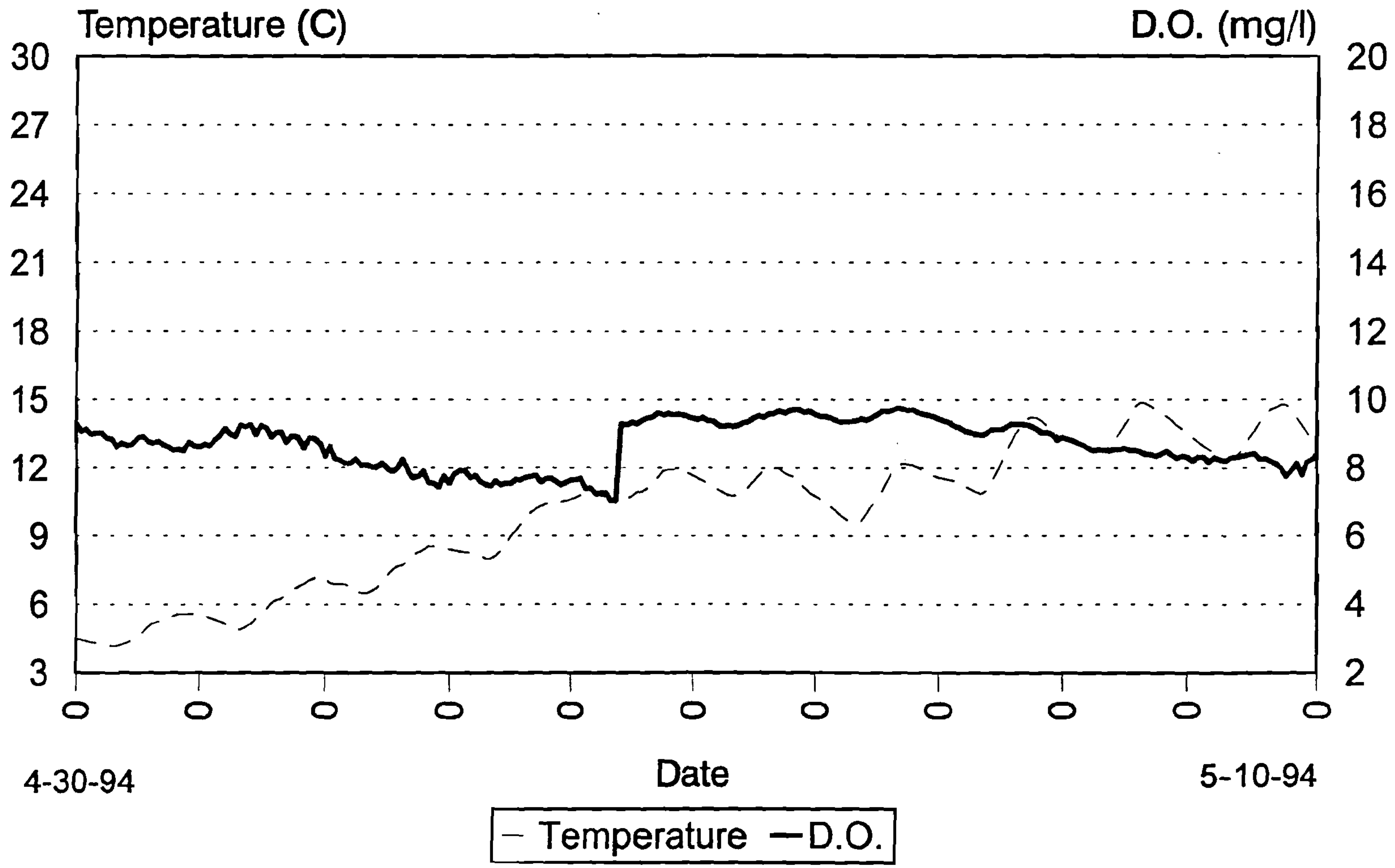

FIGURE 12

River Site - Spring 1994

Temperature and Dissolved Oxygen

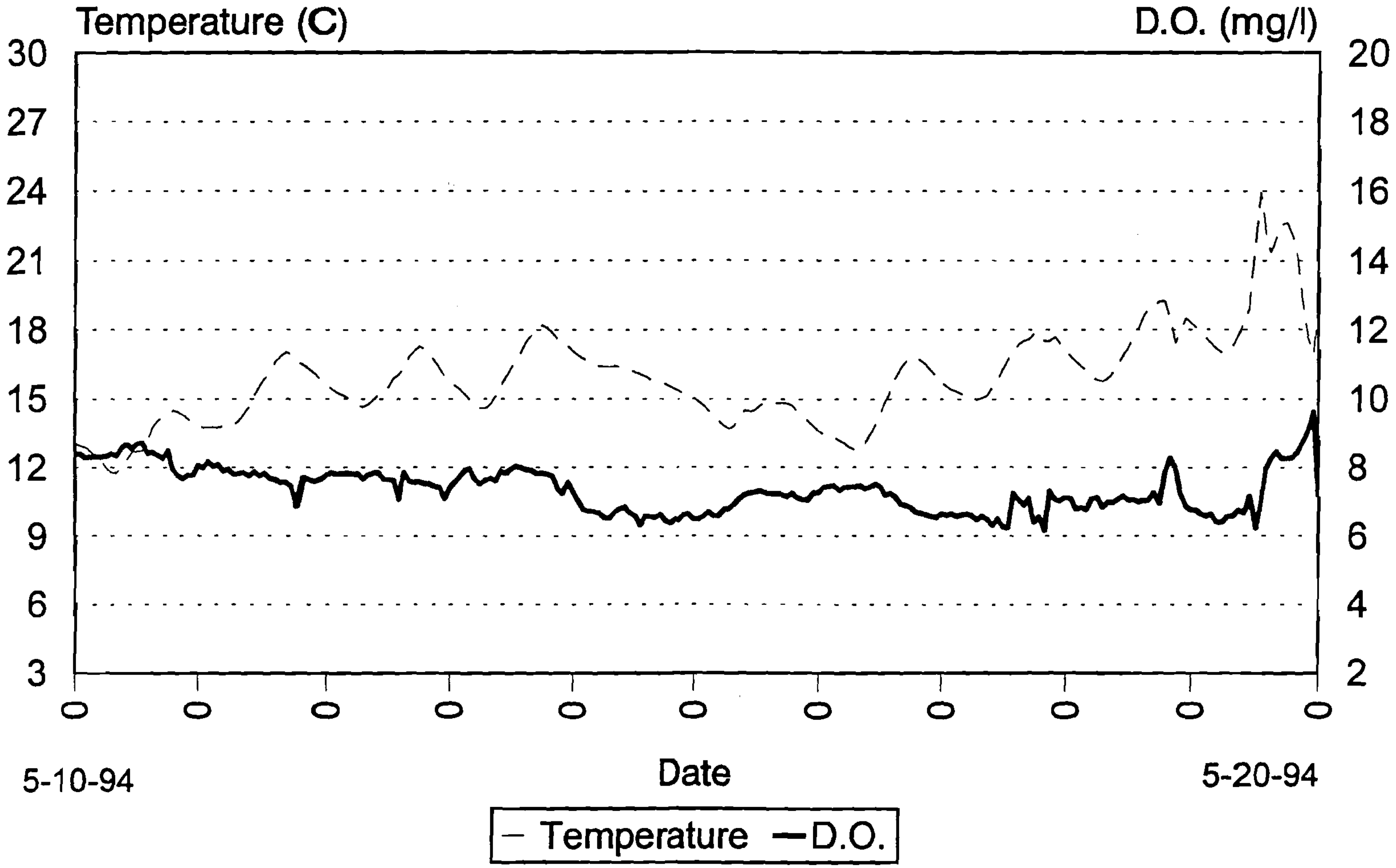

FIGURE 13

River Site - Spring 1994

Temperature and Dissolved Oxygen

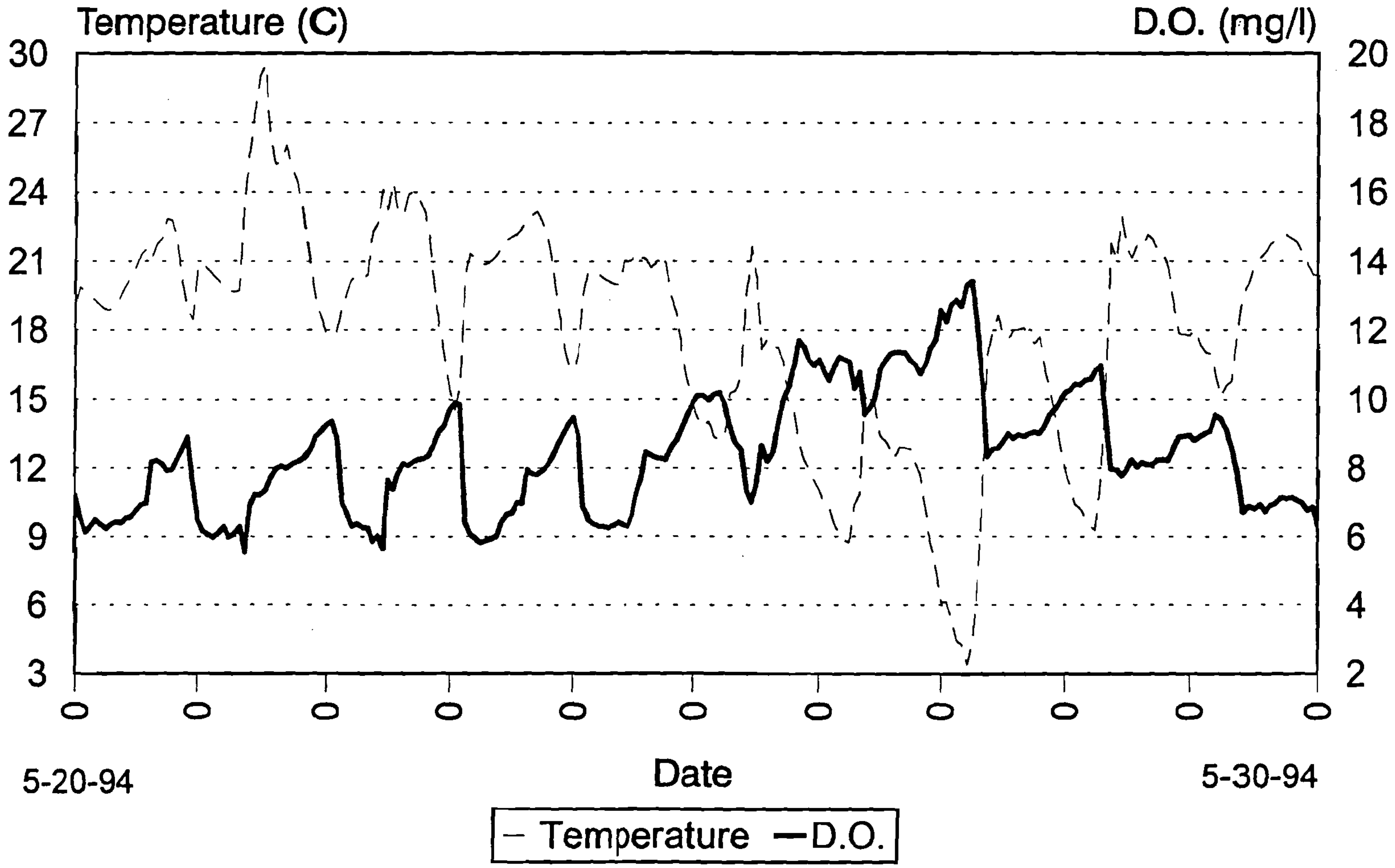

FIGURE 14

River Site - Fall 1994

Temperature and Dissolved Oxygen

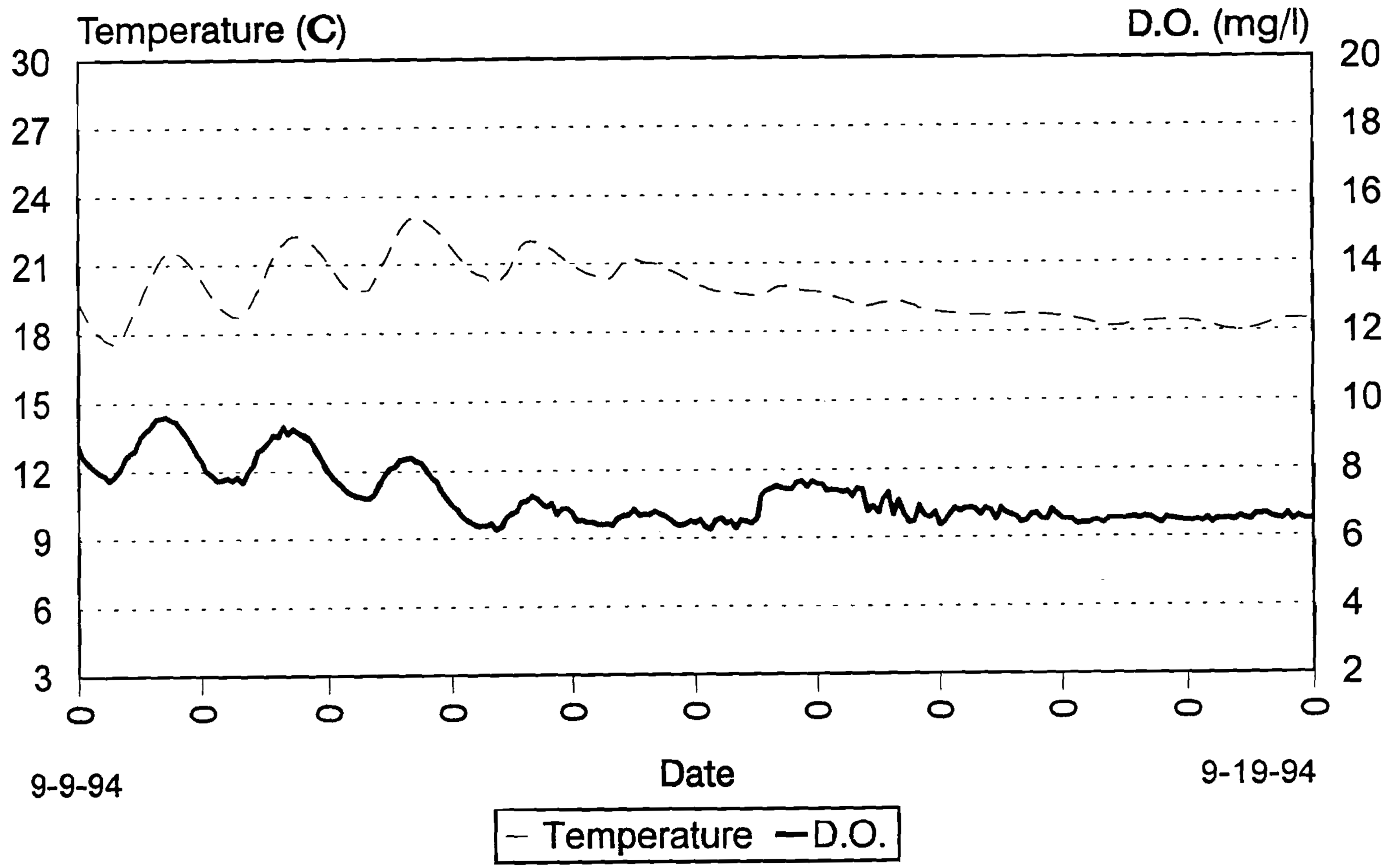

FIGURE 15

River Site - Fall 1994

Temperature and Dissolved Oxygen

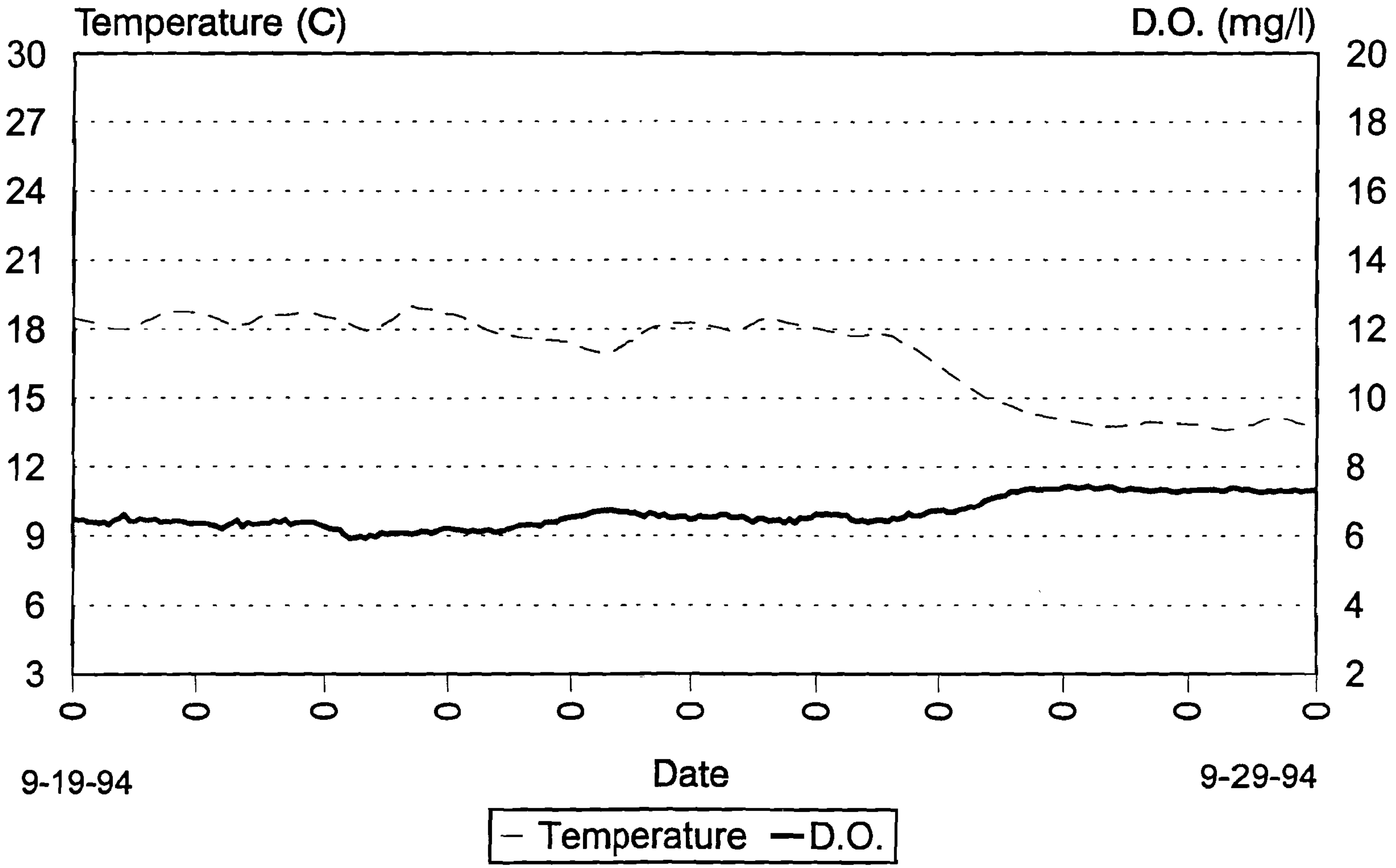

FIGURE 16

River Site - Fall 1994

Temperature and Dissolved Oxygen

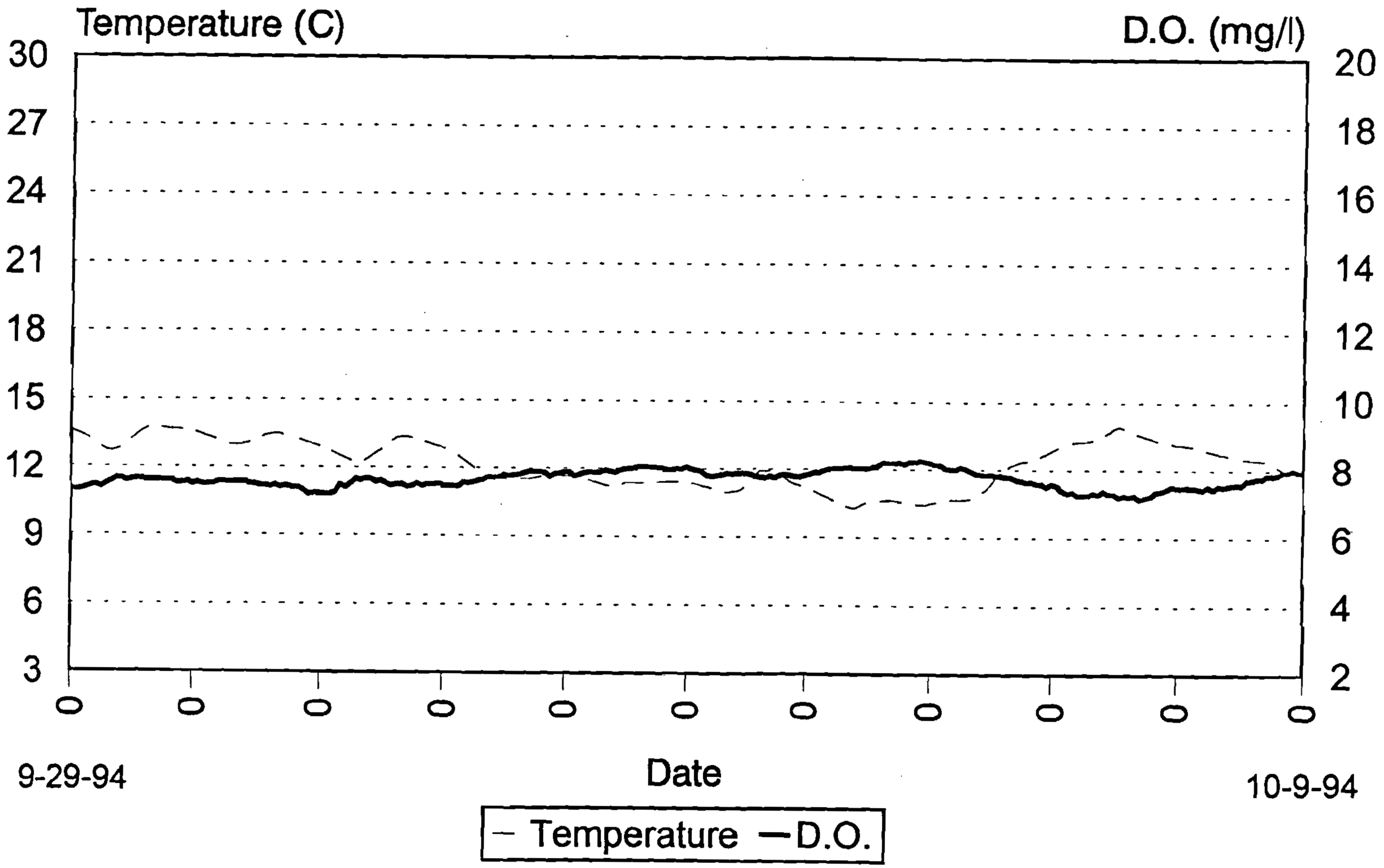

FIGURE 17

River Site - Fall 1994

Temperature and Dissolved Oxygen

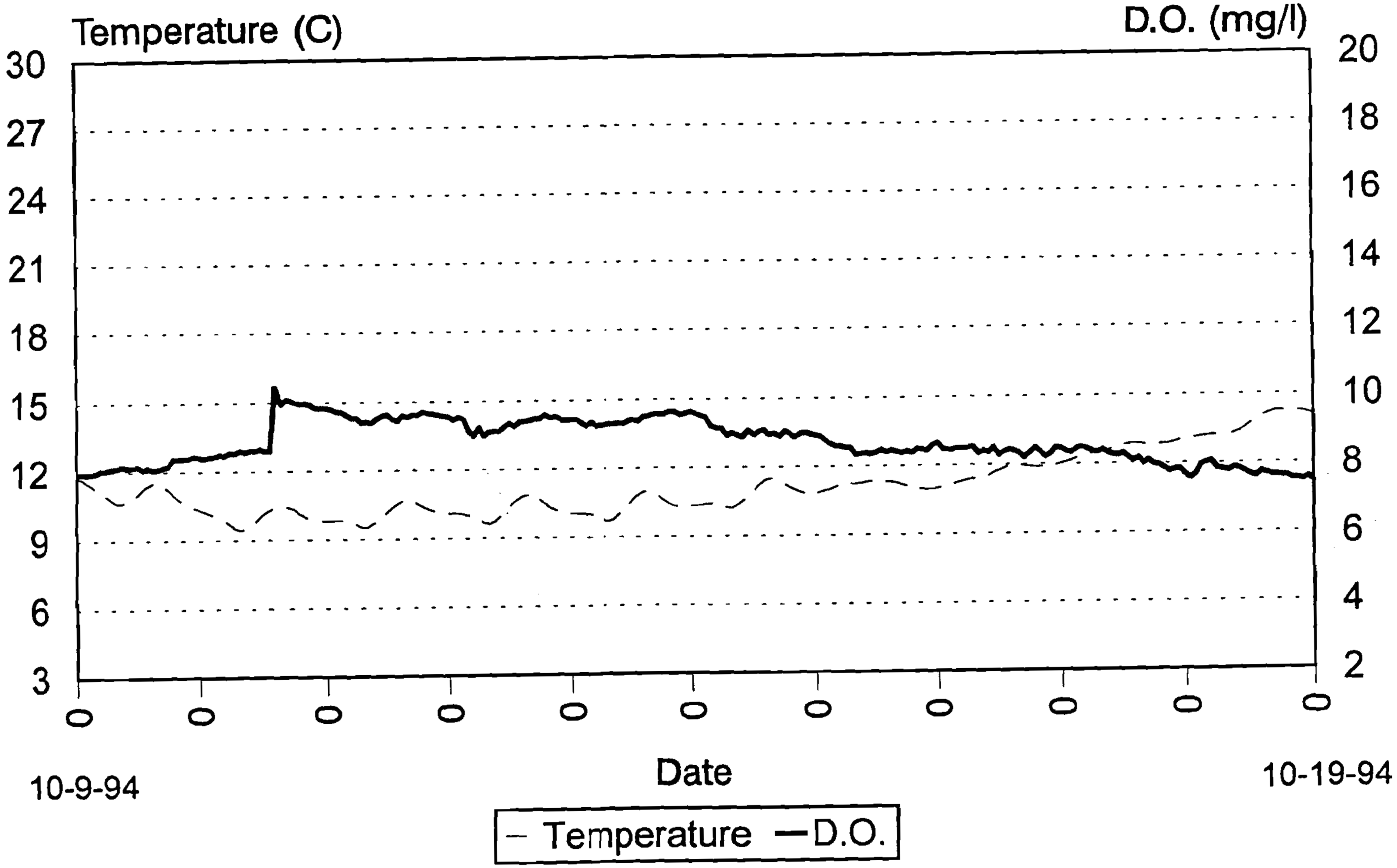

FIGURE 18

River Site - Fall 1994

Temperature and Dissolved Oxygen

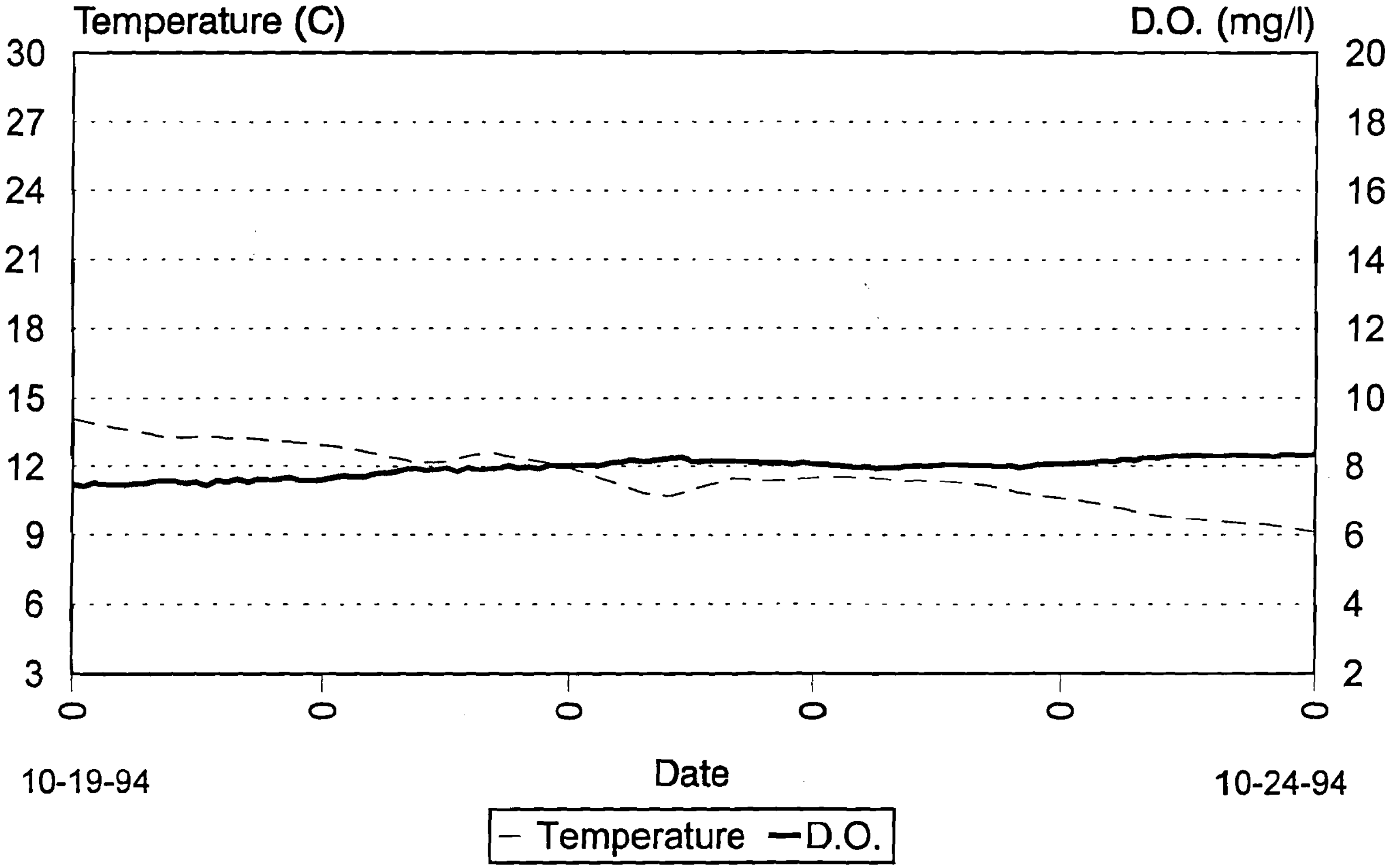

FIGURE 19

Inlet Site - Spring 1994

Temperature and Dissolved Oxygen

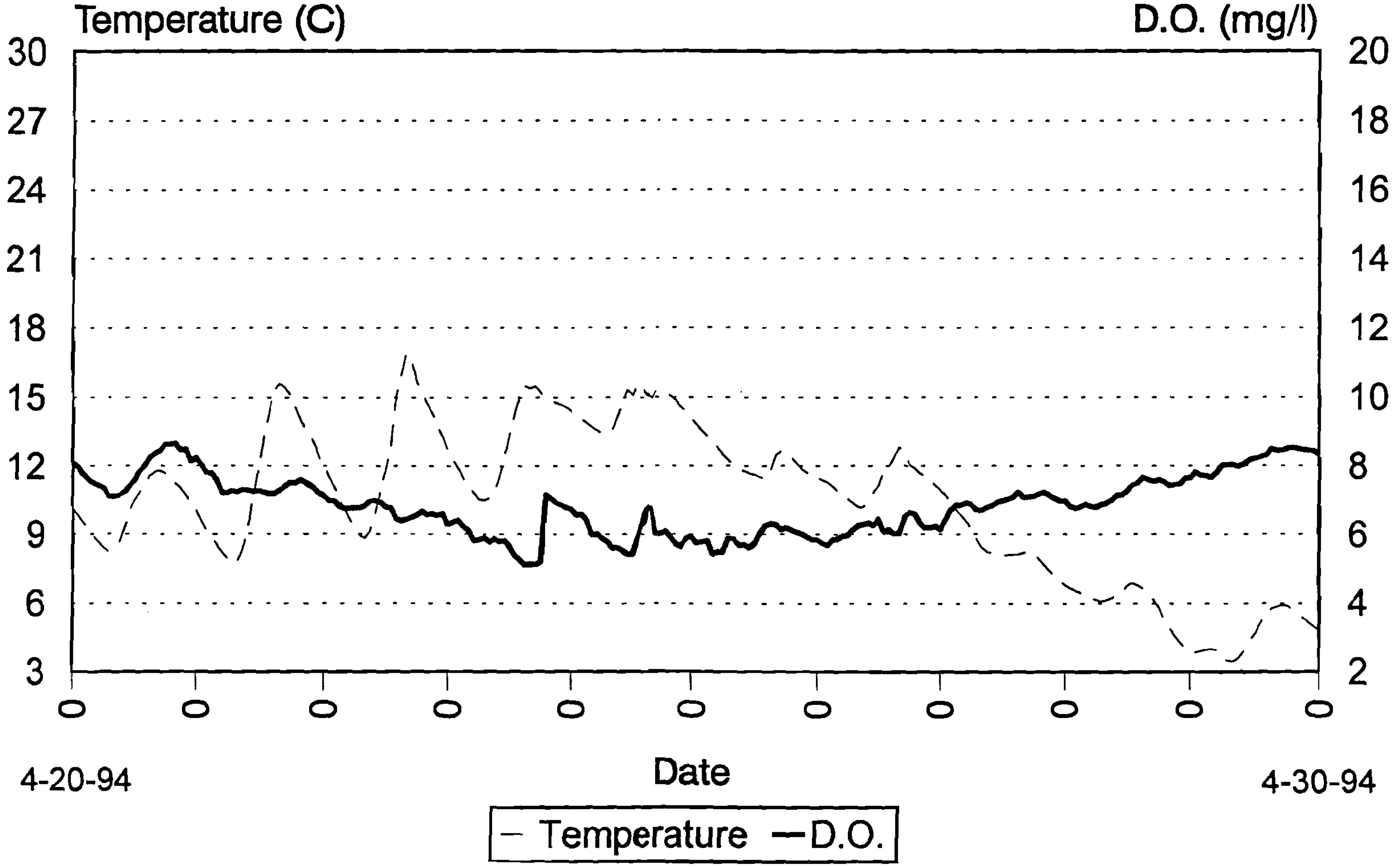

FIGURE 20

Inlet Site - Spring 1994

Temperature and Dissolved Oxygen

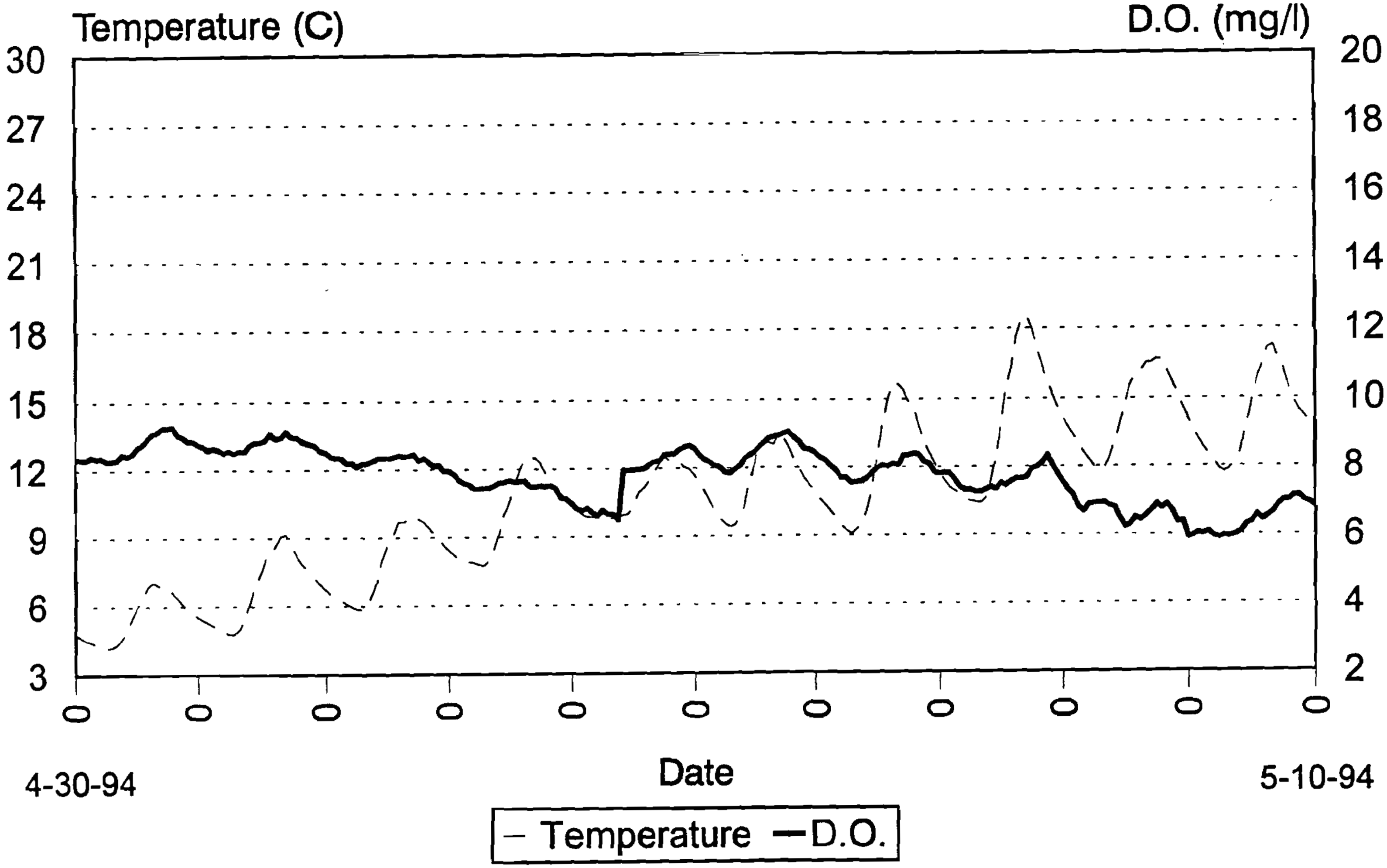

FIGURE 21

Inlet Site - Spring 1994

Temperature and Dissolved Oxygen

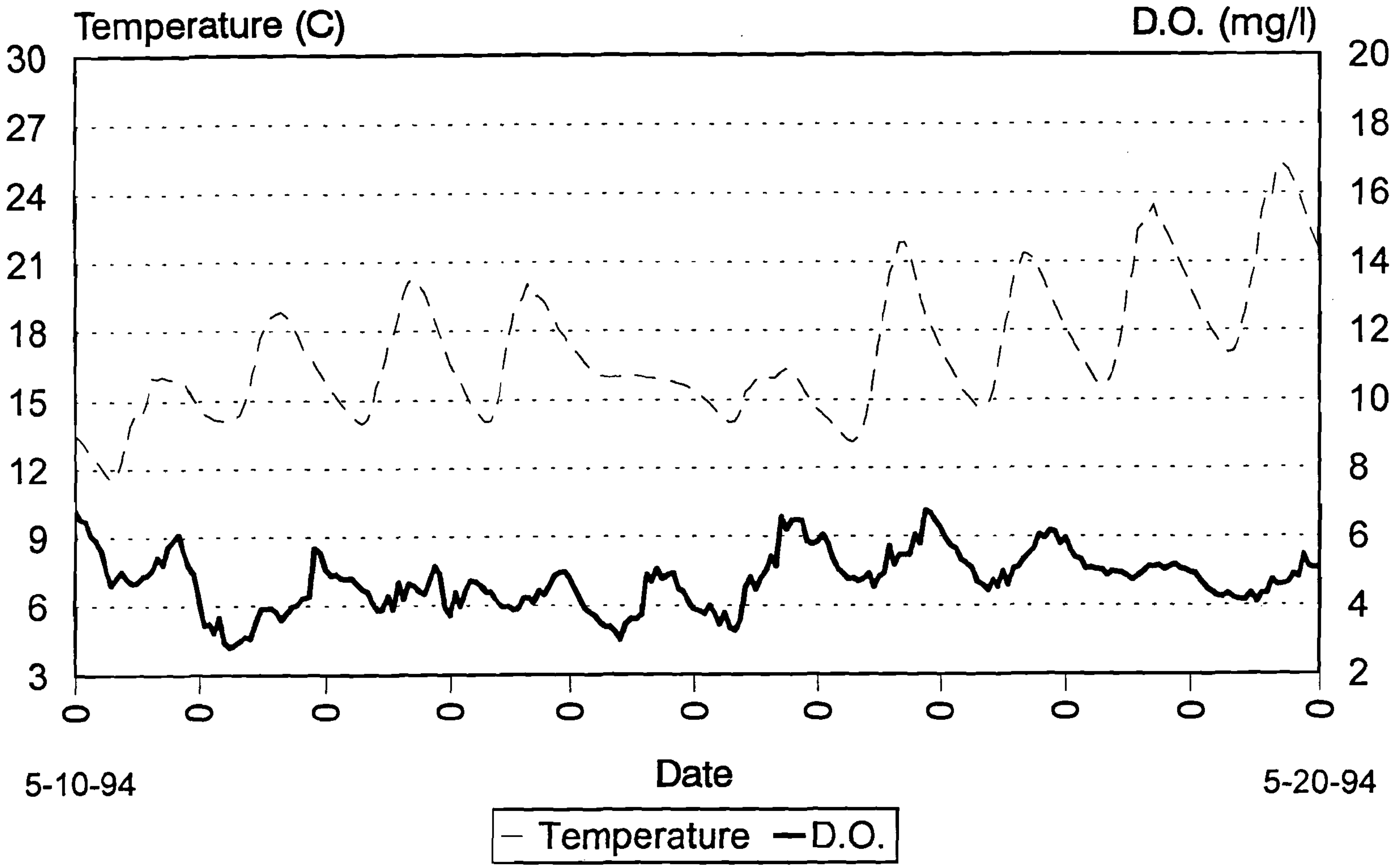

FIGURE 22

Inlet Site - Spring 1994

Temperature and Dissolved Oxygen

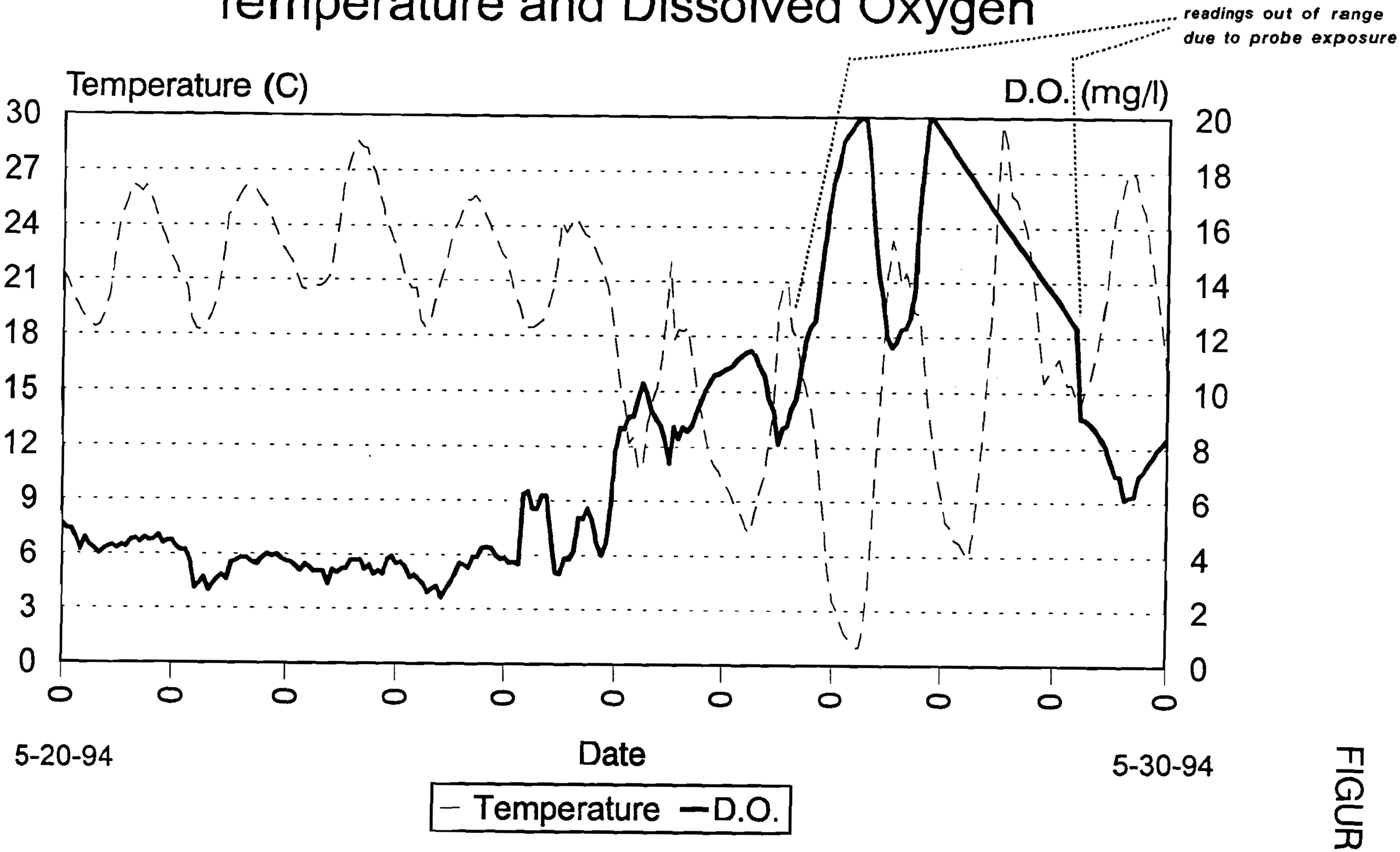

FIGURE 23