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Ouachita Baptist University

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DETERMINATION OF THE AMBIENT TOXICITY OF THE TAILWATER OF NIMROD LAKE

John T. Knight
Department of Biology
Ouachita Baptist University
Arkadelphia, AR 71923

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Arkansas Water Resources Research Center
University of Arkansas
Fayetteville, Arkansas 72701

Arkansas Water Resources Research Center

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Arkansas Water Resources Research Center
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113 Ozark Hall
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ABSTRACT

DETERMINATION OF THE AMBIENT TOXICITY
OF THE TAILWATER OF NIMROD LAKE

The objective of this research was to determine if ambient toxicity exists in the receiving stream below a reservoir in which water from the hypolimnion is released. The Ceriodaphnia 7-day test was utilized to determine if toxicity existed. This test is routinely used in the monitoring of municipal and industrial effluent. It has also been utilized in determining if ambient toxicity exists within receiving streams.

Nimrod Lake is a flood control impoundment on the Fourche LaFave River in west central Arkansas. The literature suggest that during stratification the hypolimnetic release contains high levels of iron, manganese, ammonia and sulfide during the period of stratification.

Patterns of decreased mean productivity and percent survival of Ceriodaphnia were found in the tailwater of the lake during the time the lake was stratified.

John T. Knight

Completion Report to the U.S. Department of the Interior, Geological Survey, Reston, VA, August 1991.

Keywords: Biomonitoring/Reservoir Management/Water Quality/Ceriodaphnia

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The support of the U.S. Department of the Interior, Geological Survey, who provided the funds, and Dr. Kenneth Steele, Director, Arkansas Water Resources Research Center, is greatly appreciated.

Finally, the students who participated in this research; Lesli Vickers, Kathy Simms, Wendy Moye and Jim Maxwell. Their help made this possible.

INTRODUCTION

Nimrod Lake is located in west central Arkansas in Yell and Perry Counties (Figure 1, Appendix B). Nimrod Lake is formed by a dam on the Fourche LaFave River and is maintained by the Corps of Engineers for flood control in the river drainage area. The Fourche LaFave river receives no permitted discharges (National Pollutant Discharge Elimination System), above Nimrod Lake, however, Nimrod Lake receives one direct municipal discharge from the City of Plainview, Arkansas.

The Fourche LaFave River below Nimrod Lake has been characterized as having higher turbidity and periodic low dissolved oxygen concentration (Nix, 1991; Arkansas, 1986). The section upstream from Nimrod Lake however, has been described as fairly high water quality (Arkansas, 1984). According to the Arkansas Water Quality Inventory Report (Arkansas, 1984), the designated uses for the entire river system are for propagation of fish, wildlife, and other aquatic and semi-aquatic life, raw water source for public water supplies, primary and secondary contact and recreation and other uses.

A. Purpose and Objectives.

The objective of this study was to determine if ambient toxicity exists in the tailwater below Nimrod Lake. The potential for ambient toxicity in the Fourche LaFave River below the dam is significant due to the fact that water quality degradation takes place in the hypolimnion of the lake and releases from Lake Nimrod are made from an elevation near the bottom of the reservoir. The release of hypolimnetic water during stratification of many lakes is known to have many effects on the physical and chemical characteristics of the receiving stream (Walburg et al, 1981). These properties include lowered temperature and dissolved oxygen, along with increased concentrations of iron, manganese, sulfide and ammonia (Walburg et al, 1981).

In addition, the ambient toxicity of samples obtained from varying elevations within the reservoir were also subjected to toxicity screening. Toxicity was evaluated using biological testing methods developed for use with wastewater discharges. The Ceriodaphnia dubia 7-day test (Mount and Norberg, 1984) , was utilized on samples collected from the tailwater and from the water column of the reservoir. The period of study was from April, 1990 through March, 1991.

B. Related Research.

As was mentioned earlier, hypolimnetic releases from

impoundments such as Lake Nimrod have the potential for impacting water quality in the receiving stream. In 1957, Ingols illustrated that the water quality of the Catawba River in South Carolina had been impacted by a hydroelectric dam. Ingols (1957), also pointed out that the deterioration of water quality below the reservoir did not imply that poor water quality is entering the lake.

Since that time, numerous studies have indicated that hypolimnetic releases may impact water quality in several ways. Studies of the effect on receiving streams from cold water release reservoirs have been numerous (Walburg et al., 1981). Most of these have focused on the effect of a decrease in temperature. A literature summary by Gordon (1983), however, indicates that the chemical aspects of lower level releases may also have an effect on the receiving stream. This summary also indicated that the occurrence of iron, manganese, and sulfur in reduced states is common in the hypolimnion of lakes and reservoirs.

Several investigators have indicated that the diversity of benthic macroinvertebrates decreases in the tailwaters of many reservoirs (Blanz et al, 1970; Hoffman and Kilambi, 1970; Isom, 1971; Abbott and Morgan, 1975; Jassby, 1976). The change in the population of fish in tailwaters has also been established (Ball and Petit,

1974; Edwards, 1978; Walburg, 1983). Brown (1967), found that coldwater releases have reduced the number of species found below the dams of three impoundments in Arkansas.

Grizzle (1982), found that many fish below Buford Dam, Georgia, were infected by parasites and exhibited lesions on the gills, liver, spleen and kidneys. The occurrence of lesions correlates with exposure to manganese and iron. The hypolimnetic release at Buford Dam was characterized by low pH, low dissolved oxygen, low oxidation-reduction potential and high metal concentrations.

Nix (1979), observed that Lake Greeson, Arkansas, becomes stratified and develops a seasonally anoxic hypolimnion. He also observed that anaerobic releases were observed during certain periods of the year. Even though the period of anoxic releases varied, it usually occurred in the late summer and early fall.

Nix (1986), also reported that the maximum concentration of manganese in the Lake Greeson tailwater during release periods was 1 mg/L. Both iron and manganese decreased downstream of the release. It was also observed that hydrogen sulfide was quickly lost from the stream. His data indicate that the manganese is deposited in the stream bed of the tailwater.

The criteria value (U.S. EPA, 1986), reported for

iron is 1.0 mg/L for freshwater aquatic life. The criteria for manganese and hydrogen sulfide are 100 ug/L and 2.0 mg/L respectively. The value for manganese represents that value for protection of consumers of marine molluscs, while the value for hydrogen sulfide reflects the protection of fish and other aquatic life in both fresh and marine water. The data collected by Nix (1986), for Lake Greeson, indicates that the concentrations of these elements occasionally rises above the established criteria in Lake Greeson.

Smith and Oseid (1972), indicate that low levels of hydrogen sulfide may be lethal or cause other chronic effects to trout and other pike fry fish. They also point out that low levels of oxygen may increase the toxicity of hydrogen sulfide. Ingols (1976), concluded that sulfides were the dominant lethal factor in fish kills at Greers Ferry National Fish hatchery, Arkansas.

Nix and Ingols (1981), observed a positive correlation between trout mortality and manganese concentration for certain periods of time during 1967. Their study was conducted utilizing aerated hypolimnetic water at Greers Ferry National Fish Hatchery. Their conclusions suggest that an oxidized form of manganese may be the cause of the observed mortality.

Nix (1991), observed that thermal stratification in Nimrod Lake began in mid May during 1988. He also

observed that anoxic conditions were established within the hypolimnion by mid July of 1988. The values reported by Nix (1991), for both total and dissolved iron, and total and dissolved manganese of the Nimrod tailwater were above the Quality Criteria for Water values (U.S. EPA, 1986). This study also established changes in the chemical nature of the Nimrod tailwater as a function of distance from the dam.

MATERIALS AND METHODS

Samples were obtained at approximately two week intervals for one year beginning in April, 1990. The sites selected (Figure 1), for sampling were chosen based on the ongoing research and historical data of Nix (1991). Station A was immediately below the dam, while station B was approximately one kilometer downstream. Station N-1 was located immediately above the dam within Lake Nimrod. During the months of April and May Stations A and B were sampled for routine chemical analysis and toxicity testing. Temperature and dissolved oxygen were measured *in situ* at one meter intervals at station N-1 throughout the study.

After the onset of stratification within the lake during June, 1990, samples were collected at four depths at station N-1 for both routine chemical analysis and

toxicity testing. These depths represented four regions within the water column: surface, thermocline, upper hypolimnion and lower hypolimnion. In this fashion, variances in water quality and toxicity ere observed throughout the period of stratification. This was continued throughout the remainder of the one year study period.

The routine chemical analysis of the samples taken included temperature, dissolved oxygen, pH, specific conductance (in situ), ammonia nitrogen, nitrate nitrogen, turbidity, alkalinity, hardness, total and dissolved iron, total and dissolved manganese, and sulfate. Temperature, dissolved oxygen, pH and specific conductance were determined in the field utilizing a Hydrolab water quality analyzer with calibration as described by the manufacturer.

Sampling protocol and analytical methods for the chemical parameters are described in Appendix A.

Ten liter grab samples were obtained for the toxicity tests. Samples were chilled upon collection and tests were initiated immediately upon arrival at the laboratory (within 5 hours).

Samples obtained from the hypolimnion contained little or no oxygen at the time of sampling. However, it was noted that manipulation of the sample (pouring, filtering, etc.), provided a means to aerate these

samples prior to initiation of the toxicity tests. This oxygenation of hypolimnetic samples simulated the conditions present in the oxygenated releases from Lake Nimrod.

The organisms utilized in the tests were obtained from third broods of mass cultured adult organisms. The diet chosen for the study consisted of a mixture of the green alga, Selenastrum capricornutum and an aqueous extract of Cerophyl. The algae consisted of a mixture of three and seven day old algal cells (Knight, 1989). Tests were initiated with less-than-12-hour-old neonates. The organisms were maintained and tested in a constant temperature environment of 25° C. The endpoints utilized for this study consist of survival and productivity of the organisms.

The randomized block design was utilized to remove variation between broods. This design provides for the removal of a block or blocks of organisms if the performance of the organisms warrants or if males are present. A set of ten organisms were also initiated with each tests as a performance control. These organisms were maintained in reconstituted hard water.

Endpoints of the toxicity tests were survival and productivity. Survival is presented here as percent survival, meaning the percentage of organisms that survive the test. Productivity refers to the mean number

of young per female produced during the seven day time period. Determination of differences in productivity were based on a posteriori comparisons using Tukey's test. This test was utilized if the analysis of variance suggested that there were differences in mean productivity. Homogeneity of variances was determined using Bartlett's test and the Hartley test for homogeneity. If the variances were homogeneous, analysis of variance was utilized ($p < 0.05$). If variances were heterogeneous, the nonparametric Kruskal-Wallis test was used to determine a posteriori differences (Gulley et al., 1988).

RESULTS AND DISCUSSION

Tables 1 through 4 (Appendix B), contain the productivity and survival data for the toxicity tests performed during April and May, 1990. The combined productivity for the performance controls for the tests presented in these tables was 24.4 young per female. Percent survival of the performance controls was 100 percent.

The temperature and dissolved oxygen profile of the lake indicated that the lake was in a fully mixed condition at the beginning of May. The dissolved oxygen profile of the lake on May 31, indicated that

stratification was established. The dissolved oxygen profiles are presented in Figures 2 and 3 (Appendix B).

It is interesting to note that productivity at both stations A and B were statistically significantly lower than the productivity of the control at the end of May. The variances for the test in Table 4 were heterogeneous, therefore the Kruskal-Wallis test was used to determine statistical differences.

Tables 5 through 11 (Appendix B), contain the productivity and survival data for the time period in which the lake was stratified. The analysis of variance and multiple comparison procedure for the data in each of these tables indicated that there were statistical differences between mean productivity for the test results detailed in Tables 11, 14, and 15. A closer look at the data in Table 11 indicates that there is a statistically significant difference between the productivity of the organisms in surface water and Station B when compared to the other samples.

The data in Table 14 show that the organisms in Station A, Station B and the 6 meter station exhibited higher productivity. However, the usefulness of the data in this test may be limited due to the questionable health of the organisms. It should be pointed out that the mean productivity for the control organisms was 17.6 young per female. This suggest that the health of the

organisms utilized may have influenced the results of this test.

The same argument applies to the data in Table 15. The control organisms mean productivity was 17.8 young per female. The data indicate that the productivity of the organisms in water collected from three meters was statistically different from the organisms in Station B.

Due to the high variances associated with the data for productivity, the analysis of variance procedure provided little information beyond the fact that **statistically significant** differences were not indicated by the data when analyzed from a given sampling time. The ambient toxicity data obtained over several months does, however, permit the establishment of temporal patterns of toxicity which correlate with selected water quality parameters.

The data collected in this study illustrates a pattern of reduced productivity and survival of the subject organisms during the time the lake is stratified. Table 26 shows the mean productivity and percent survival for the seven tests conducted during June, July, August and the first test of September. For reference, the mean productivity of the performance controls was 23.6 young per female. The percent survival for the performance controls during this time frame was 92.8 percent.

When compared to the mean productivity and percent survival of the organisms tested during the time the lake was mixing, a distinct pattern was developed. Both mean productivity and percent survival increased approximately 50 percent during the time the lake was full mixed. The mean productivity and percent survival of the performance controls during this time period were 25.2 and 99.3 respectively.

Figure 4 illustrates the pattern observed for the concentrations of iron and manganese at Station A. Additionally, the pattern observed for percent survival and mean productivity are also shown. The concentrations of iron and manganese were observed to be higher than the criteria values throughout the time period that the lake was stratified. These data suggest that there is a decrease in both percent survival and productivity during this same time period. At this time, further statistical analysis is warranted to reveal the significance of the patterns illustrated here. The results of these analyses will be presented in a comprehensive report of this research (in preparation).

The research described here attempts to bring together a historical problem associated with hypolimnetic releases from reservoirs with the decrease in water quality of the receiving stream. Obviously, the use of diversity indices from within the river would help

determine the impact this type of release has on the biota of the receiving stream. However, the unique characteristics associated with a hypolimnetic release (temperature), prevent the expected warm water communities from being established regardless of the release of toxic substances.

The use of laboratory toxicity tests has, in recent years, been used as a surrogate to field evaluations (Waller et al., 1990). The primary advantage of this type of testing is an increased sensitivity in the ability to detect differences between samples. In addition, toxicity screening is less expensive and removes the variance associated with in field evaluations. The protocol described here removes the effect of water temperature, discharge and varying water levels which may impact the biota of the receiving stream (reservoir tailwater).

The ability to reduce the variance associated with field evaluations, such that the data will be homogeneous, was not always reached in this study. However, the experimental design of this study presented both the potential for determining statistical differences between samples as well as long term testing to provide an adequate data base to reveal patterns that might develop through the course of a given year.

As mentioned earlier, the literature illustrates

several instances in which the criteria for iron and manganese are exceeded in the tailwater of a hypolimnetic release. The data collected in this study support those findings. Except for the months of April, 1990, December and January, 1991, the criteria for manganese was exceeded at Station A and B and within the hypolimnion. The criteria for iron was exceeded at all stations except the surface station during stratification.

CONCLUSION

The data presented here confirms earlier observations of high iron and manganese concentrations within the hypolimnion of Lake Nimrod. The release of water from the hypolimnion of Nimrod Lake results in high concentrations of iron and manganese in the tailwater. The data clearly illustrates that the national criteria for both iron and manganese are frequently exceeded during any given year.

Additionally, the Ceriodaphnia toxicity tests performed on the samples collected within the lake and the tailwater also indicate chronic toxicity during the time the lake is stratified. The observed pattern of toxicity is strongly suggestive that toxic conditions exist in the tailwater during periods of releases from an anoxic hypolimnion. The dynamic nature of the reduced chemical species which are introduced into the tailwater

of Lake Nimrod complicate the assessment of factors which are associated with the observed toxicity.

The data presented here indicate a need to evaluate the management practices of reservoirs with hypolimnetic releases.

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APPENDIX A

Sampling Protocol and Analytical Methods

Sampling Protocol:

Samples from streams are obtained near mid stream and mid depth from bridges or from boats. In cases where streams are small, a grab sample is obtained from the bank. If the size of the stream permits, a van Dorn type is used.

Samples from lakes are obtained from a boat or a designated location using a van Dorn type sampler. For some parameters (chlorophyll) a 2.0 meter integrated sample is obtained by lowering a 4 cm diameter PVC pipe to the desired depth, capping the top of the pipe then retrieving the tube. The contents of the tube are then emptied into a polyethylene container, mixed, then subjected to the required sample preservation.

As soon as practical following sampling, the sample is fractionated and specific aliquot are treated with appropriatae preservative. Logistics on sample handling varies from project to project. Samples are then transported to the OBU laboratory. A log book of samples are transferred to another laboratory, a chain of custody form is completed for each set of samples. A copy of a chain of custody form is attached. Holding times recommended by EPA are not exceeded except in special cases.

Although the fractionation and preservation of samples may vary depending on the nature of a specific project, the general scheme for fraction and preservation of samples is given below:

Aliquot A - 1 liter polyethylene bottle, held at 4°C

Aliquot B - 250 ml polyethylene bottle, acidified with sulfuric acid to pH 2 and held at 4°C

Aliquot C - 50 ml polyethylene bottle acidified with nitric acid to pH 2

Aliquot D - 200 ml polyethylene bottle filtered through a 0.45 micron filter and held at 4°C

Aliquot E - 50 ml bottle filtered through a 0.45 micron filter and acidified with nitric acid to pH 2

Aliquot F - 50 ml amber glass bottle, acidified with

sulfuric acid to pH 2

Aliquot G - 200 ml sterile container held at 4°C

Aliquot H - 2.0 L glass bottle with teflon lined lid held at 4°C

Analytical Methods:

The analytical methods used are those recommended by EPA (1) or in Standard Methods (2). The specific method used for each parameter along with the Aliquot (see above) used in the analysis are given below:

Parameter	Aliquot	Method and Reference
pH (field and lab)	in situ and A	electrometric (2)
alkalinity	A	electrometric titration EPA 310.1 (3)
iron	C (total)	
	E (filtered)	flame AA, EPA 236.1(3)
manganese	C (total)	
	E (filtered)	flame AA, EPA 236.1(3)
sulfate	D	ion chromatography (4)
nitrate-nitrogen	D	ion chromatography (4)
ammonia-nitrogen	B	specific ion electrode EPA 350.3 (3)
turbidity	A	nephelometric (2)

References:

(1) U.S. EPA, Handbook for Analytical Quality Control in Water and Wastewater Laboratories, EPA-600.4/-79-019, Cincinnati, Ohio (1979).

(2) American Public Health Association, AWWA, and WPCF, Standard Methods for the Examination of Water and Wastewater, Seventeenth Edition, Washington, D.C. (1989).

(3) U.S. EPA, Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, Cincinnati, Ohio (1970).

(4) Waters (Division of Millipore Corp.), "The IC-Pak Column and Column Gard Column and Care and Use Manual, Waters Publication, Millford, Mass. (1985).

APPENDIX B

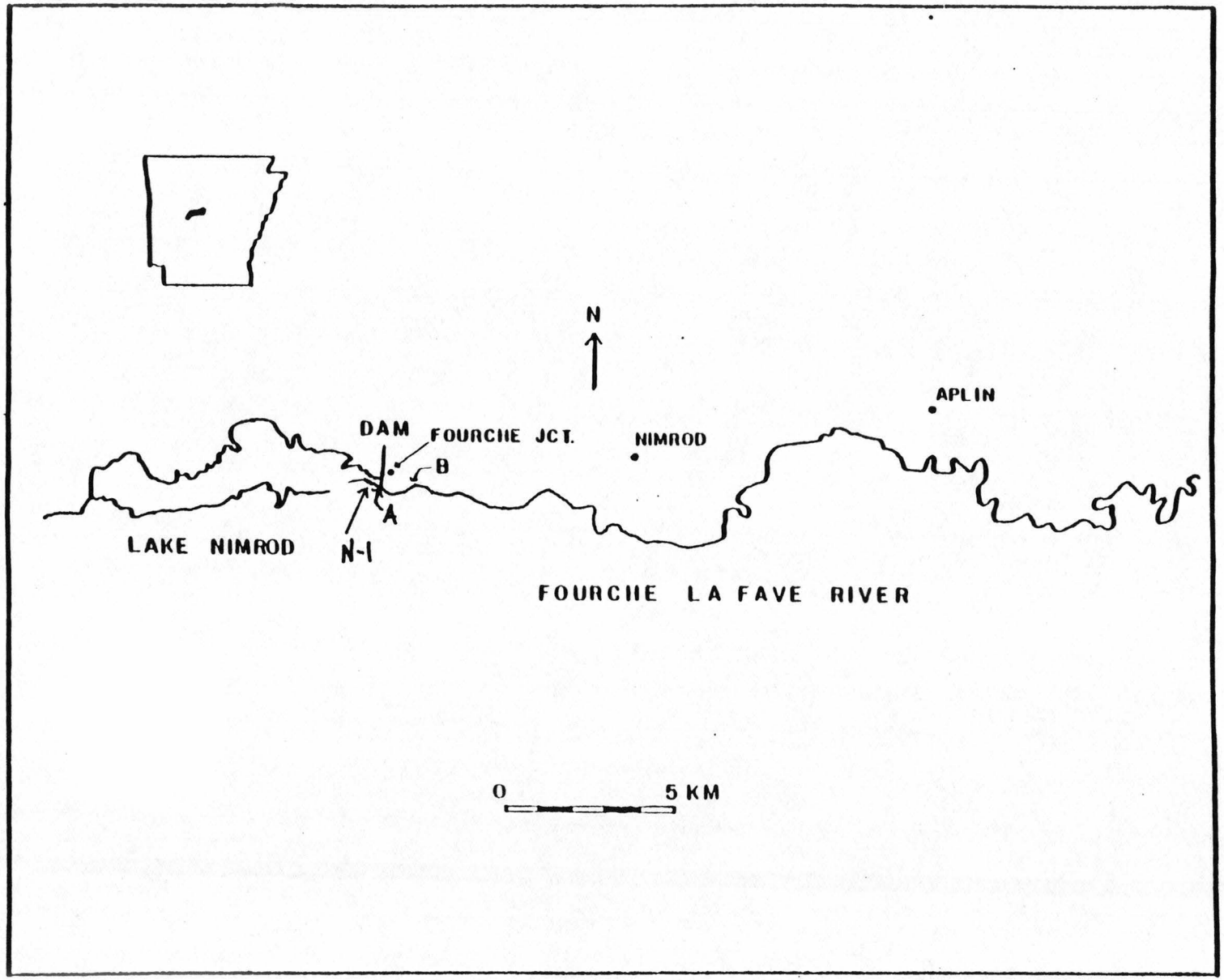
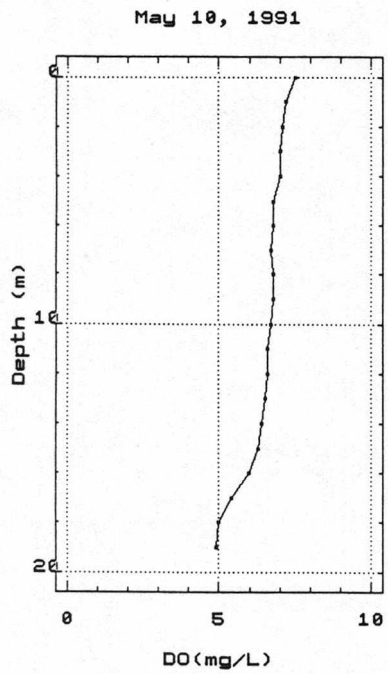
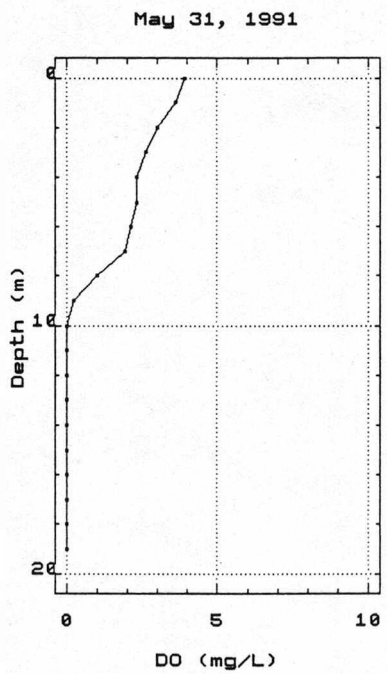

N
APLIN
DAM
FOURCHE JCT.
NIMROD
B
A
LAKE NIMROD
N-1
FOURCHE LA FAVE RIVER
0
5 KM

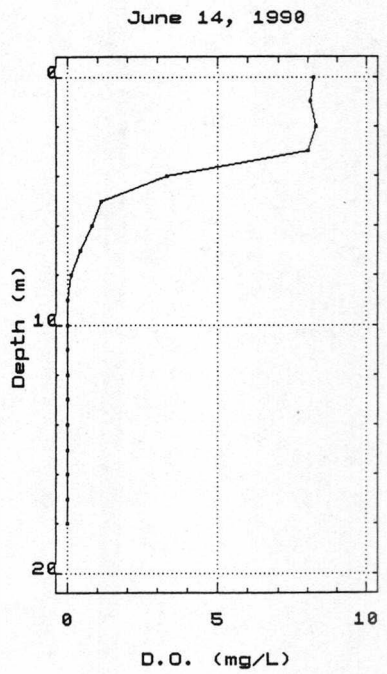
FIGURE 1

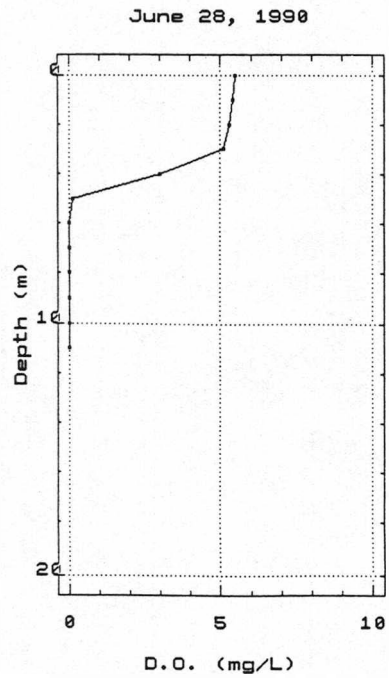
FIGURE 2

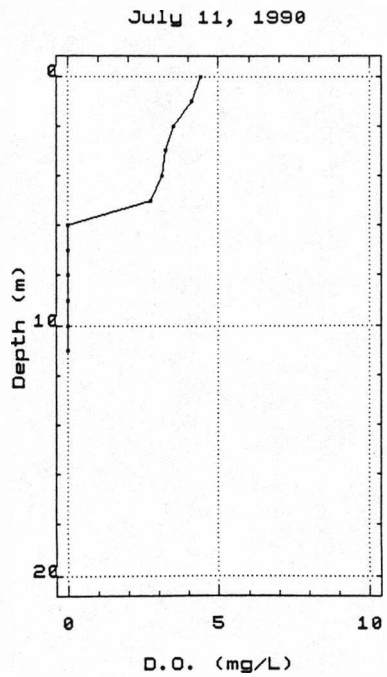
STATION N-1











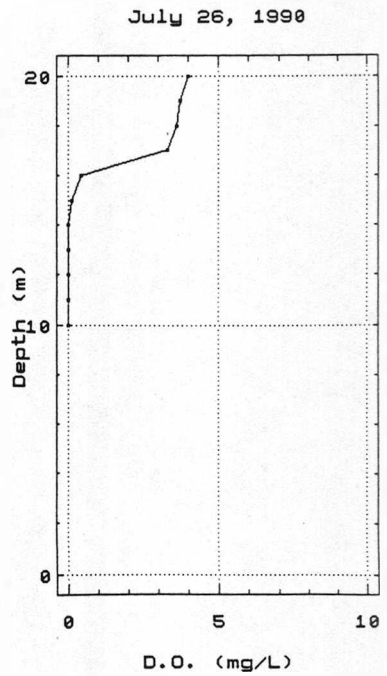


FIGURE 3

STATION N-1

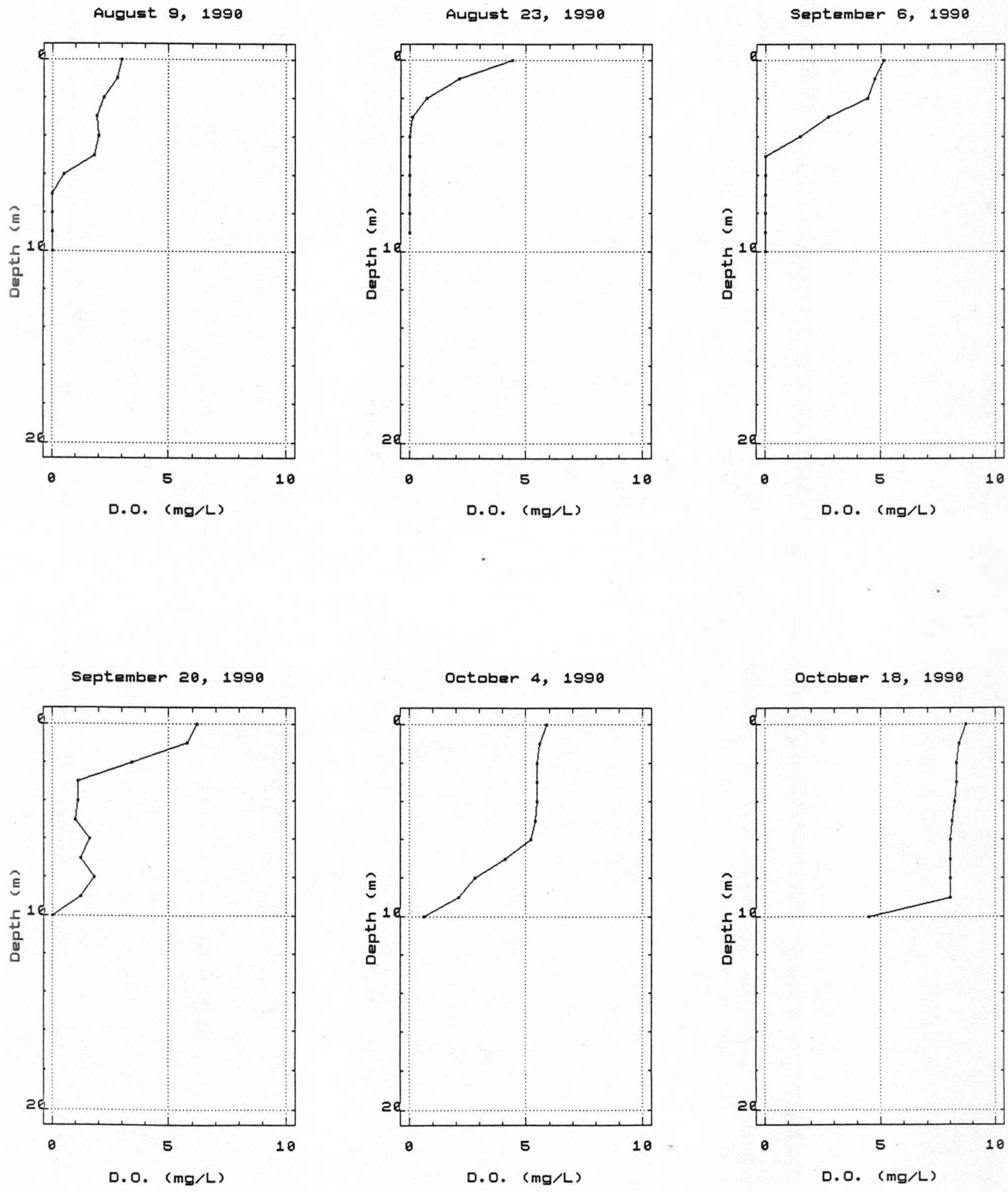
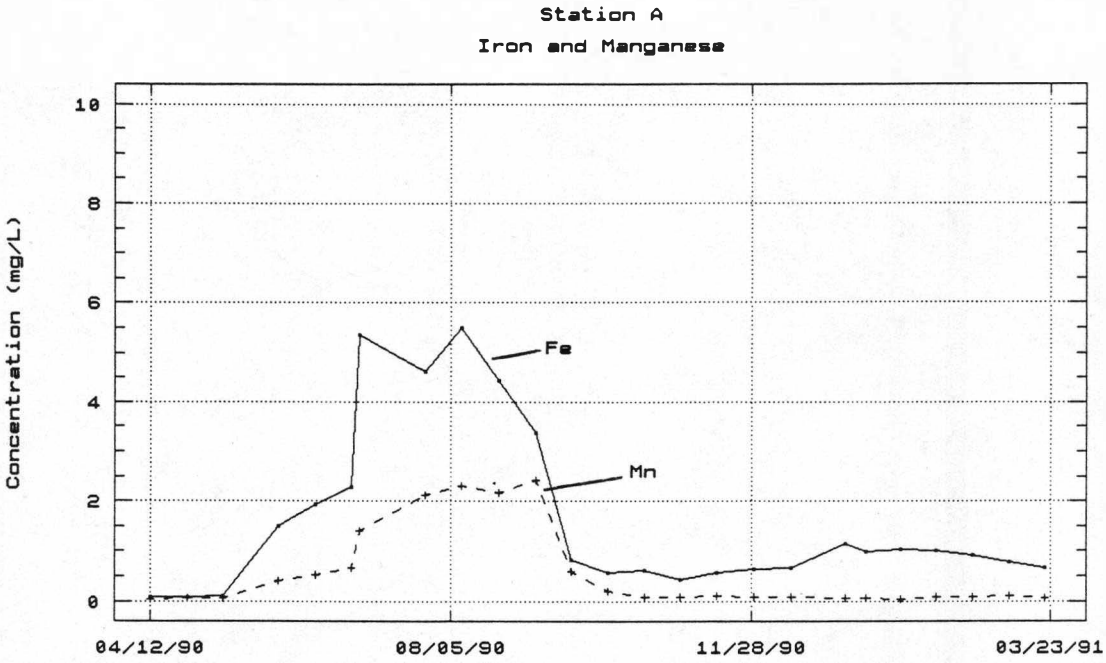


FIGURE 4


Station A
Iron and Manganese
Concentration (mg/L)
10
8
6
4
2
0
Fe
Mn
04/12/90
08/05/90
11/28/90
03/23/91

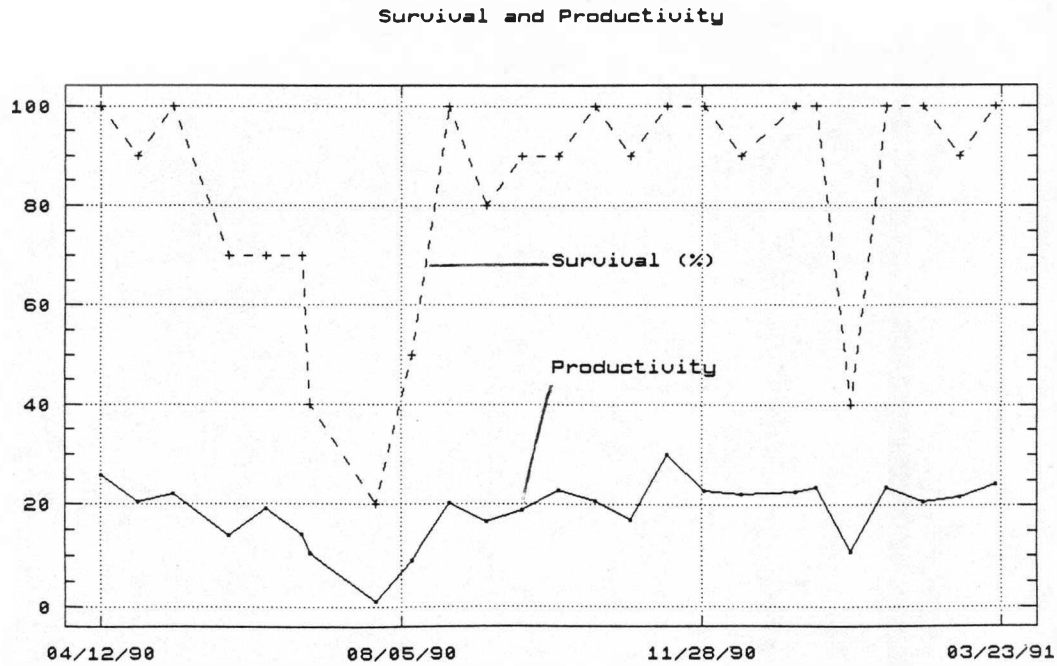

Survival and Productivity
100
80
60
40
20
0
Survival (%)
Productivity
04/12/90
08/05/90
11/28/90
03/23/91

Table 1
April 12, 1990

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	25.9	2.47	100
Station B	10	18.4	12.87	70

Table 2
April 26, 1990

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	20.6	8.24	90
Station B	10	21.8	1.81	100

Table 3
May 5, 1990

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	22.2	3.88	100
Station B	10	20.4	7.91	90

Table 4
May 31, 1990

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	13.7	9.78	70
Station B	10	11.3	7.44	90

Table 5
June 14, 1990 *

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	19.0 @	12.57	70
Station B	10	24.4	13.16	80
Station 2	10	12.4	11.14	50
Station 4	10	10.9	10.01	40
Station 12	10	12.1	14.33	40
Station 17	10	19.6	13.02	60

Table 6
June 28, 1990 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	14.0 @	8.93	70
Station B	10	15.6	9.24	70
Station 2	10	11.5	11.02	50
Station 4	10	12.8	9.67	60
Station 9	10	9.5	9.05	40
Station 13	10	14.8	8.39	70

Table 7
July 11, 1990

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	10.6 @	12.83	40
Station B	10	9.5	12.42	40
Station 2	10	5.5	8.87	20
Station 5	10	2.5	4.60	0
Station 7	10	4.2	8.97	20
Station 10	10	5.8	9.76	20

* Variances were heterogeneous.
** Variances were homogeneous.
@ No statistically significant differences were found.

Table 8
July 26, 1990 *

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	1.1 @	2.60	20
Station B	10	1.4	3.27	0
Station 2	10	2.0	5.66	0
Station 4	10	3.9	6.33	30
Station 7	10	2.2	4.02	20
Station 9	10	2.4	6.92	0

Table 9
August 9, 1990 *

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	9.1 @	8.77	50
Station B	10	12.1	10.69	60
Station 2	10	2.7	5.7	0
Station 6	10	2.6	3.63	20
Station 8	10	0.0	0.0	0
Station 10	10	3.0	4.16	0

Table 10
August 23, 1990 *

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	20.3 @	2.5	100
Station B	10	18.7	7.77	90
Station 0	10	19.7	10.67	80
Station 1	10	18.1	10.23	80
Station 5	10	18.6	7.4	90
Station 9	10	11.2	9.89	60

* Variances were heterogeneous.
@ No statistically significant differences were found.

Table 11
September 6, 1990 *

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	16.6ab	8.03	80
Station B	10	23.5a	8.16	90
Station 0	10	17.0a	9.58	80
Station 3	10	5.2b	8.79	20
Station 6	10	16.4ab	11.88	70
Station 9	10	12.2ab	7.57	80

Table 12
September 20, 1990 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	18.9 @	7.46	90
Station B	10	23.3	6.70	80
Station 0	10	23.9	8.23	90
Station 3	10	27.0	3.86	100
Station 5	10	24.9	6.47	80
Station 9	10	23.4	4.53	90

Table 13
October 4, 1990 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	22.8 @	4.83	90
Station B	10	21.8	3.08	100
Station 0	10	19.8	4.44	100
Station 4	10	19.9	3.04	100
Station 7	10	22.1	2.77	100
Station 9	10	21.4	2.12	100

* Variances were heterogeneous.
** Variances were homogeneous.
@ No statistically significant differences were found.
a Denotes statistical significance.

Table 14
October 18, 1990 *

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	20.8a	3.36	100
Station B	10	13.6ab	8.92	70
Station 0	10	0.00b	0.00	0
Station 3	10	0.00b	0.00	0
Station 6	10	11.2ab	9.45	60
Station 9	10	0.00b	0.00	0

Table 15
November 1, 1990 *

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	17.0ab	5.12	90
Station B	10	16.4b	3.66	100
Station 0	10	17.3ab	6.27	100
Station 3	10	21.1a	2.96	100
Station 6	10	18.0ab	6.62	90
Station 9	10	18.3ab	5.91	100

Table 16
November 15, 1990 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	29.9 @	5.02	100
Station B	10	25.9	10.44	90
Station 0	10	27.3	9.87	90
Station 3	10	27.5	6.08	100
Station 6	10	25.4	6.0	100
Station 9	10	26.4	9.56	90

* Variances were heterogeneous.
** Variances were homogeneous.
@ No statistically significant differences were found.
a Denotes statistical significance.

Table 17
November 29, 1990 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	22.9 @	5.07	100
Station B	10	19.3	8.62	90
Station 0	10	18.7	8.1	90
Station 3	10	21.5	7.4	100
Station 6	10	16.4	10.23	80
Station 9	10	22.9	9.93	90

Table 18
December 13, 1990 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	22.0 @	11.43	90
Station B	10	21.4	12.9	80
Station 0	10	28.7	4.37	100
Station 3	10	30.9	4.33	100
Station 6	10	29.5	4.40	100
Station 9	10	30.4	6.84	100

Table 19
January 3, 1991 *

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	22.7 @	4.52	100
Station B	10	20.9	8.47	90
Station 0	10	21.9	8.31	100
Station 3	10	23.0	2.94	100
Station 6	10	22.2	8.65	90
Station 9	10	19.3	7.27	90

* Variances were heterogeneous.
** Variances were homogeneous.
@ No statistically significant differences were found.

Table 20
January 11, 1991 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	23.6 @	5.89	100
Station B	10	23.3	6.77	100
Station 0	10	22.4	3.47	100
Station 3	10	20.9	2.33	100
Station 6	10	23.5	6.69	100
Station 9	10	22.6	2.46	100

Table 21
January 24, 1991 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	10.8 @	12.03	40
Station B	10	10.7	9.58	50
Station 0	10	11.5	12.39	50
Station 3	10	13.6	11.85	60
Station 6	10	4.3	8.33	20
Station 9	10	13.5	11.84	60

Table 22
February 7, 1991 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	23.6 @	3.98	100
Station B	10	21.7	8.47	90
Station 0	10	19.5	6.57	90
Station 3	10	21.9	3.81	100
Station 6	10	21.3	3.37	100

* Variances were heterogeneous.
** Variances were homogeneous.
@ No statistically significant differences were found.

Table 23
February 21, 1991 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	20.8 @	7.53	100
Station B	10	19.6	8.75	80
Station 0	10	24.1	8.88	90
Station 3	10	21.3	9.57	80
Station 6	10	22.4	6.74	90
Station 9	10	24.3	8.51	100

Table 24
March 7, 1991 **

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	21.6 @	8.86	90
Station B	10	15.7	7.41	90
Station 0	10	23.2	7.6	90
Station 3	10	17.0	7.44	80
Station 6	10	17.5	9.80	80
Station 9	10	20.3	7.95	90

Table 25
March 21, 1991 *

Identification	N	Mean Productivity	Standard Deviation	Percent Survival
Station A	10	24.2 @	2.25	100
Station B	10	22.8	1.87	100
Station 0	10	25.6	4.38	100
Station 3	10	26.0	3.91	100
Station 6	10	21.5	3.50	100
Station 9	10	20.2	8.28	90

* Variances were heterogeneous.
** Variances were homogeneous.
@ No statistically significant differences were found.

Table 26

Mean Productivity and Percent Survival

June through Mid-September 1990 (Stratification)

Identification	Mean Productivity	Percent Survival
Station A	12.3	54.3
Station B	15.0	61.4
Station 0	10.1	40.0
Station 3	8.0	35.7
Station 6	9.0	40.0
Station 9	9.9	41.4

Mid-September 1990 through March 1991 (Mixing)

Identification	Mean Productivity	Percent Survival
Station A	21.5	92.1
Station B	19.7	86.4
Station 0	20.3	85.0
Station 3	20.8	87.1
Station 6	20.1	83.6
Station 9	20.3	85.7