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Evaluation of Water Quality During Herbicide Applications to Kerr Lake, OK[1]

KENNETH MORRIS

Limnologist

AND

RON JARMAN

Chief

Water Quality Division

Oklahoma Water Resources Board

Oklahoma City, Oklahoma 73152

ABSTRACT

In 1977 and 1978, Robert S. Kerr Reservoir, Oklahoma, was treated with a herbicide by the Corps of Engineers to control Eurasian watermilfoil. Before, during, and after treatment the Oklahoma Water Resources Board performed water quality monitoring to evaluate this herbicide treatment. The 1978 treatment and monitoring program was intensified compared to that in 1977. In 1978 BEE 2,4-D, was detected twice, and were within the water quality standard. The major results included significant increases in total phosphorus concentrations at three sites and a significant decrease in ammonia nitrogen at one site after treatment. 2,4-dichlorophenol was never detected which was of major concern in the study. In summary, Oklahoma's Water Quality Standards were not violated.

INTRODUCTION

In 1977, the U.S. Department of the Army, Corps of Engineers (COE), Tulsa District, requested the Oklahoma Water Resources Board (OWRB) to conduct a chemical monitoring program on Robert S. Kerr Reservoir in conjunction with their Aquatic Plant Control Program. The COE is concerned about the infestations of an aquatic plant, Eurasian watermilfoil (*Myriophyllum spicatum* L.), in the Reservoir due to the problems this plant causes for the Tennessee Valley Authority (5). The main purpose of OWRB's involvement in 1977 was to detect any violation of water quality standards from the herbicide butoxyethanol ester of 2,4-dichlorophenoxy acetic acid (BEE 2,4-D).

The OWRB's Water Quality Division performed the chemical monitoring in 1977 and submitted a report to the COE. In 1977 five sites were treated, approximately 158.1 ha, with BEE 2,4-D. At these sites temperature, dissolved oxygen, pH, conductivity, two forms of nitrogen and phosphorus, and BEE 2,4-D were monitored. From 39 water samples collected, the herbicide was detected only once in the Little Sans Bois Creek area (3).

The results of this preliminary investigation did not indicate that the treatment program affected the water quality of Robert S. Kerr Reservoir, although a significant nutrient increase occurred after treatment.

The 1978 program is an expanded version of the 1977 program and involves monitoring ten sites, two of which are controls. The objectives were to compare water quality data (mainly nutrients) collected from the treated areas with that of the controls, and the pretreatment data compared to post treatment data. Since this reservoir is shallow and is considered generally homothermic, the water quality of the coves and associated drainages were assumed to be closely related.

MATERIALS AND METHODS

The COE treated eight areas on Robert S. Kerr that contained Eurasian watermilfoil. Treatment began on June 5, 1978 and was completed on June 21, 1978, with approximately 463.3 ha treated with 4,218 kg of the granular BEE 2,4-D herbicide (Table 1). A second treatment was applied in the South Canadian River on August 22-24, 1978. Ap-

TABLE 1. SUMMARY OF HECTARES TREATED AND AMOUNT OF HERBICIDE APPLIED BY AREA ON ROBERT S. KERR DURING THE 1978 AQUATIC PLANT CONTROL PROGRAM.

Date	Location	Site Number	Ha Treated	Kg Applied
5 June	Illinois River	6	7.4	136
6 June	Sallisaw Creek	8	9.3	68
6 June	Applegate Cove	1	15.4	113
6 June	Cowlington Point	2	24.7	181
7 June	Cowlington Point	2	12.4	91
8 June	Little San Bois	3	86.5	635
12 June	Tamaha	4	55.6	408
13 June	Sandtown Bottom	7	29.7	544
14 June	Canadian River	5	12.4	227
19 June	Canadian River	5	105.0	907
21 June	Canadian River	5	105.0	907
			463.3	4218
(Second Treatment)				
22 August	Canadian River	5	61.8	1134
23 August	Canadian River	5	108.7	1996
24 August	Canadian River	5	37.1	703
			207.6	3833

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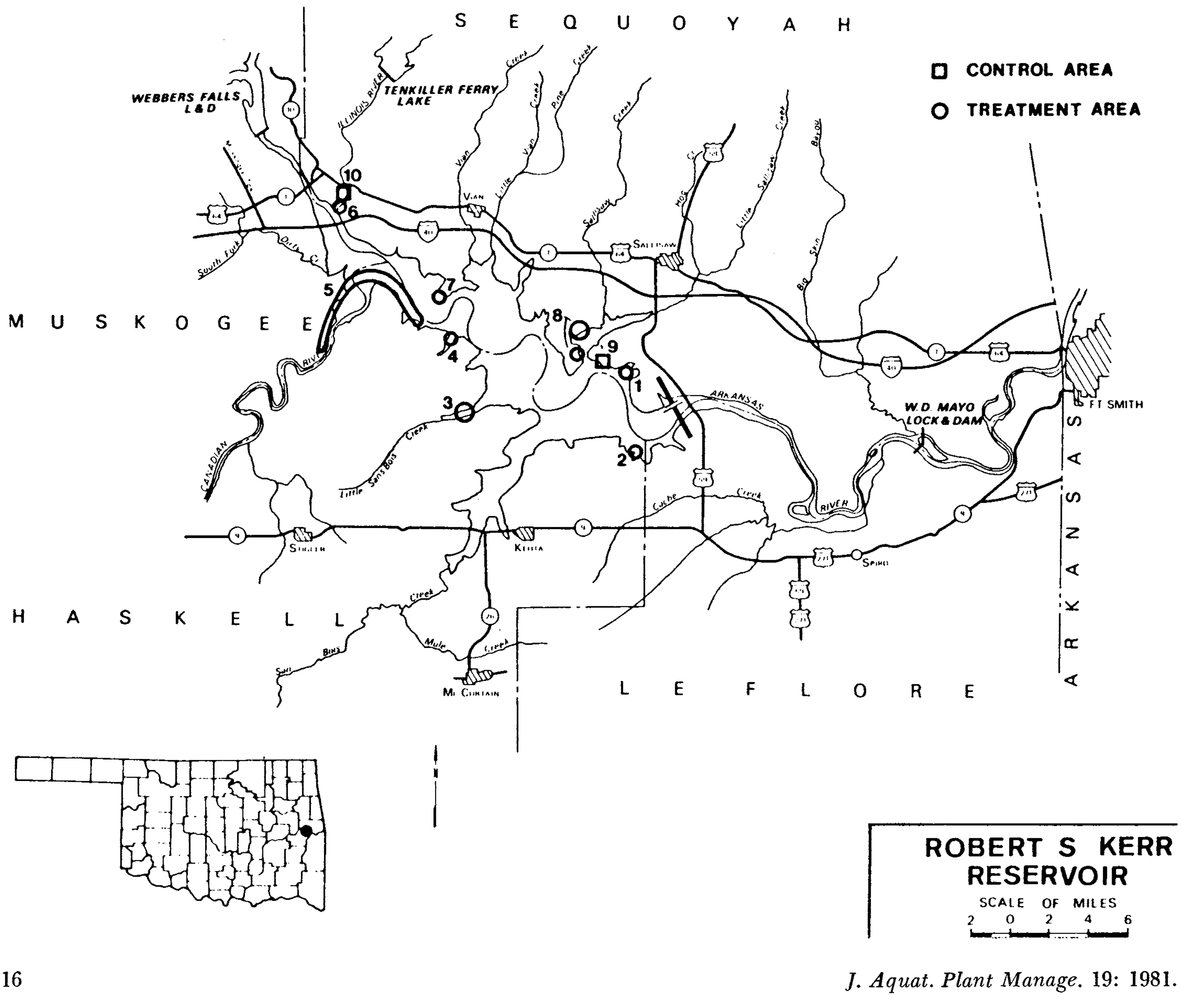
proximately 202.6 ha were treated with 3,833 kg of herbicide (Table 1). This herbicide was the same formulation (AQUAKLEEN) used in the 1977 program.

Water quality monitoring was initiated on May 31, 1978, at ten monitoring sites (Figure 1). Two of these sites monitored represented controls, one for the main reservoir and the other for the Illinois River. The eight other sites monitored represented a separate area that was treated with the herbicide. At each of the ten sites, three areas were selected for monitoring, total sample points equaled 30. Each sample point was marked with a brightly colored buoy so that monitoring was performed within the same general vicinity each time.

Prior to treatment an attempt was made to sample each site twice (one per day) but due to unforeseen circumstances, this was not possible in all cases. Post treatment was conducted generally on the same day and then seven more times (one per day) during the next three week period. Due to financial constraints and bad weather, all sites were not monitored under such a stringent schedule. Site 5 was only monitored three times after the August treatment, mainly for herbicide detection, but on September 7 and 24, for temperature, dissolved oxygen, conductivity, and pH.

Dissolved oxygen, pH, conductivity, and temperature were examined *in situ* with a hydrolab Model 6D Surveyor. Water samples were collected for laboratory analyses to determine the concentrations of total phosphorus, ammonia nitrogen, the herbicide, and one of its by-products, 2,4-dichlorophenol.

Water samples were taken by submerging one liter polyethylene containers below the lake's surface and allowing them to fill. Two bottles were filled at each site, one for herbicide and total phosphorus analyses and the other for the 2,4-dichlorophenol and ammonia analyses. Approximately 2 mls of sulfuric acid were added to the 2,4 dichlorophenol/ammonia sample and then both water samples placed on ice. Sulfuric acid was found to be an adequate preservative for phenolic compounds up to 3-4 weeks stored at 4 C (2). To ensure the safety regarding the suggested holding times at the end of each day's sampling, the iced samples were returned to Oklahoma City. Therefore, the samples were at the lab within 24 hours after collection.



The Oklahoma State Department of Health, Water Quality Laboratory, analyzed the samples according to the 14th Edition of Standard Methods (1).

The nutrient and pH data were analyzed by one-way analysis of variances according to Steel and Torrie, 1960 (6). Control data was compared to treatment data with pretreatment and posttreatment analyses performed separately. Once these statistical comparisons were made, each area's pretreatment data was compared with its immediate posttreatment data (i.e., generally six samples compared to about nine samples). These statistical analyses were facilitated by an IBM 5110 and IBM 370-158 system.

RESULTS AND DISCUSSION

A total of 809 water samples were analyzed; 240 for BEE 2,4-D analysis, 158 for the 2,4-dichlorophenol, 186 for ammonia nitrogen (NH_3) and 225 for total phosphorus (TOT-P) analysis. The herbicide was only detected once (3 μg/L) in Applegate Cove (Site 1) on June 6 within four hours after treatment. On one other occasion, a possible trace was detected in the Little Sans Bois Creek area on June 8. The herbicide by-product was never detected, probably due to rapid breakdown in the presence of fairly adequate pH values (i.e., pH was generally above 7). Therefore the state's standard for 2,4-D of 100 μg/L was not violated (4).

The conductivity gradually increased during the monitoring period. At Site 1A the conductivity was 610 μmho/cm on May 31 and increased to 1110 μmho/cm by June 22. A regression analysis on this data revealed a correlation coefficient of 0.9 with a slope of 0.035. In general the conductivity followed a similar trend at each area and then after June it seemed to decline. The pattern the conductivity followed did not appear associated with the herbicide treatment.

The dissolved oxygen (DO) experienced a fairly wide range of variation, naturally depending on the time of day and month sampled. During late June some concentrations in excess of 10 mg/L were obtained, nearly at all areas. At Sites 5 and 10 the DO monitored never exceeded 11 mg/L. The highest DO encountered was at Site 9 (the lake control). On June 27, Site 9A at 4:50 p.m. the DO was 20.0 mg/L and 18.2 mg/L at 9B, with 13.8 mg/L at 9C. Probably an algae bloom could explain such high dissolved oxygen concentrations. The lowest DO concentration monitored (4.2 mg/L) was at Site 4C prior to treatment on May 31. The DO usually was at least above 6 mg/L and not below 5 mg/L at all areas after treatment. In view of these factors, the herbicide treatment did not impair the dissolved oxygen.

The NH_3 posttreatment concentrations were lower at Site 5 than Site 9 and determined significantly different at the 0.025 probability level. The other NH_3 control to pretreatment comparisons were found not to be significantly different.

The ammonia data did not necessarily follow any specific trend. The reservoir control (Site 9B) NH_3 concentrations displayed a low correlation coefficient (.066). On June 6 at Site 6C the NH_3 concentration was 0.789 mg/L which is the largest concentration experienced. Although at the Illinois River Control (Site 10C) on June 7 a large NH_3 concentration was found (0.473 mg/L). Another high ammonia concentration (0.698 mg/L) was encountered at the control 9B on June 9. Basically from the 186 ammonia analyses only 20 were in excess of 0.2 mg/L.

The total phosphorus (TOT-P) samples analyzed did not exhibit a detectable trend for the reservoir control (9ABC). The correlation coefficients for the TOT-P data at each of these sites were; 0.008, 0.556, and 0.08, respectively. The pretreatment data for the reservoir sites were significantly different at the 0.05 level, but only posttreatment phosphorus concentrations for Sites 7 and 9 were considered different at the 0.001 level, therefore the TOT-P concentrations appear more stable after treatment.

Considering that Site 7 was near the main channel of the Arkansas River and not in a protected location such as Site 9, one would expect the phosphorus concentrations to be higher in the protected area. However, Site 9 phosphorus concentrations were generally smaller than Site 7's.

The largest phosphorus concentration (0.585 mg/L) was detected at Site 6B on June 13 in the Illinois River. The other high concentrations were encountered at Sites 3B and 4A, (i.e., 0.300 and 0.265 mg/L, respectively). Although a few high concentrations were obtained, there was no indication that these values were due to the herbicide application.

The pH did not fluctuate a great deal and seemed to be about the same at all 10 areas as the correlation coefficient for pH at Site 1A was 0.570 suggesting the absence of any linear trend. The lowest pH value (6.3) found was at Site 8A on May 31, but the pH was usually above 7 and below 9.2 at Site 8.

The pH prior to treatment was determined not to be significantly different at all sites. Although, after treatment, Sites 5 and 8, and Site 7 were determined significantly different at the 0.001 and 0.05 levels, respectively, from Site 9. As these pH differences found had means above 7.7 and since their variances did not create any drastic water quality problem the differences were considered not detrimental.

The main evidence which suggested the herbicide application had an indirect effect on Robert S. Kerr Reservoir water quality was related to the nutrient concentrations. In comparing pretreatment with posttreatment nutrient data statistically significant differences were found for TOT-P at Sites 3, 6, and 7 at the 0.001, 0.05 and 0.001 levels, respectively. The NH_3 as N for Site 7 was determined different at the 0.05 level.

Therefore, these differences indicate the herbicide treatment caused the TOT-P to increase at Sites 3, 6, and 7 and the NH_3 to decrease at Site 7. From these comparisons, three water quality groups were found on Robert S. Kerr: (1) Sites 1, 2, 3, 4, and 9—similar; (2) Site 6 and 10—similar; and (3) Sites 5, 7, and 8—dissimilar. Sites in group 1 were in protected coves, group 2 identifies the Illinois River and group 3 the sites were not protected as the others.

In summary, considering the data analyzed, the 1978 herbicide application did not degrade the water quality of Robert S. Kerr Reservoir. The possible effects of the herbicide included an increase in total phosphorus concentration at Sites 3, 6, and 7, and an ammonia nitrogen decrease at Site 7. These effects could have possibly been beneficial regarding primary productivity, but the nutrient changes could also cause high dissolved oxygen concentrations resulting from phytoplankton blooms. From these conclusions this water quality evaluation did not delineate any alarming water quality impacts.

As more efforts are directed towards plant control activities, two recommendations surface: (1) information regarding the reduction in numbers or biomass of the macroinvertebrate populations that inhabit watermilfoil that would perish from herbicide treatment would aid in evaluating herbicide impact; and (2) knowledge concerning the normal seasonal nutrient fluctuations in bodies of water and the benefits thereof should further assist evaluating potential impact from chemical control methods.

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