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Effects of Original Vegetation on Reservoir Water Quality

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EFFECTS OF ORIGINAL VEGETATION ON RESERVOIR WATER QUALITY

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ABSTRACT

The purpose of this study was to undertake an initial step that would lead to a better understanding of the effects of nutrients released from vegetation inundated by water at newly constructed reservoirs. Specifically, a series of leaching studies were conducted on representative grasses, herbage and trees to determine the relative nutrient release rates of nitrogen and phosphorous. In addition, a limited field study was conducted as well as a vegetation inventory of a proposed Bureau of Reclamation reservoir near Edna, Texas.

The results of the leaching study were presented as percent nutrients released from the various types of vegetation as a function of time. The total quantity and rate of nutrient release varied greatly depending upon the type of vegetation. As an example, nutrients released from grasses and herbage proved to be released at a greater rate, contain a greater quantity of nutrients per unit weight of vegetation and generally be more available in greater quantities based on weight per unit area than for trees. This indicated that although trees are often the only vegetation removed from a reservior site, the amount of nutrients available for release by the herbage and grasses will probably have a much more significant impact on reservoir water quality and should be considered in the reservoir clearing policy.

Several recommendations were made based on study results including a methodology for predicting the effects of original vegetation on reservoir water quality for any specific project.

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CHAPTER I

INTRODUCTION

Clearing policy is a controversial subject among those concerned with the construction of new reservoirs. Should all vegetation be removed? Should grass and brush remain, but all trees be removed from new reservoirs? These questions plague reservoir designers because of the differences in philosophy between the groups having an interest in the reservoir. For example, groups promoting fresh water fisheries would be interested in providing natural habitats for fish species and would favor little or no clearing of original vegetation. On the other hand, those concerned with a new reservoir as a potential domestic water supply would prefer to have as much original vegetation removed as is economically feasible. Flood control interests may favor an even different clearing policy. These differences in philosophy, when viewed in light of the scarcity of technical information on clearing and the high cost of clearing, have prompted the need for this investigation.

The objective of this study was to determine the effects of terrestrial vegetation, inundated by a reservoir, on the water quality in reservoirs. More specifically, this study attempted to quantify the role of original vegetation as a nutrient source and thus as a factor in eutrophication. The study was divided into five parts as follows:

1) A literature review to evaluate the past accomplishments in determining the effect of original vegetation on water quality,
2) Leaching and decomposition studies to determine relative rates of nutrient release for representative types of vegetation commonly found at Texas reservoir sites,

3) Field studies conducted at three selected test reservoirs (Appendix A),
4) A vegetation inventory of the proposed Bureau of Reclamation Reservoir site near Edna, Texas (Appendix B), and
5) Preliminary recommendations on clearing policy based on the conclusions from this study.

CHAPTER II

LITERATURE REVIEW

Current Reservoir Clearing Policies

The Bureau of Reclamation constructs a number of reservoirs in Texas and throughout the west. The Bureau has developed guidelines for reservoir clearing which are intended to be flexible so that the requirements of all interests will be served (1). The Bureau understands the need to preserve fish and wildlife habitats as well as promote the use of the shoreline for fishing, boating, and other recreational benefits. Reservoir clearing policy, as explained by the Bureau, is based on cooperation with interested government, state and private agencies who are asked to act in an advisory capacity.

Primary considerations are given to the prevention of clogging of control works at spillways and outlets and to provide safe and efficient reservoir operation. The Bureau's position is that clearing should be adequate for public safety and health requirements, particularly when the reservoir is used as a municipal water supply. Fish and wildlife needs, boating, fishing, and other recreational uses and general appearance of the reservoir are considered as "secondary considerations."

Different clearing criteria are set for each zone of the reservoir. The bottom zone (Zone 1) is that portion of the lake that will be five feet below the minimum operating level as shown in Figure 1. Except for several periods of short duration, this zone will be underwater at all times. A five foot clearance is provided for boating operations. Clearing includes the removal of saleable timber and other material and the removal of hazardous trees or of material located adjacent to the

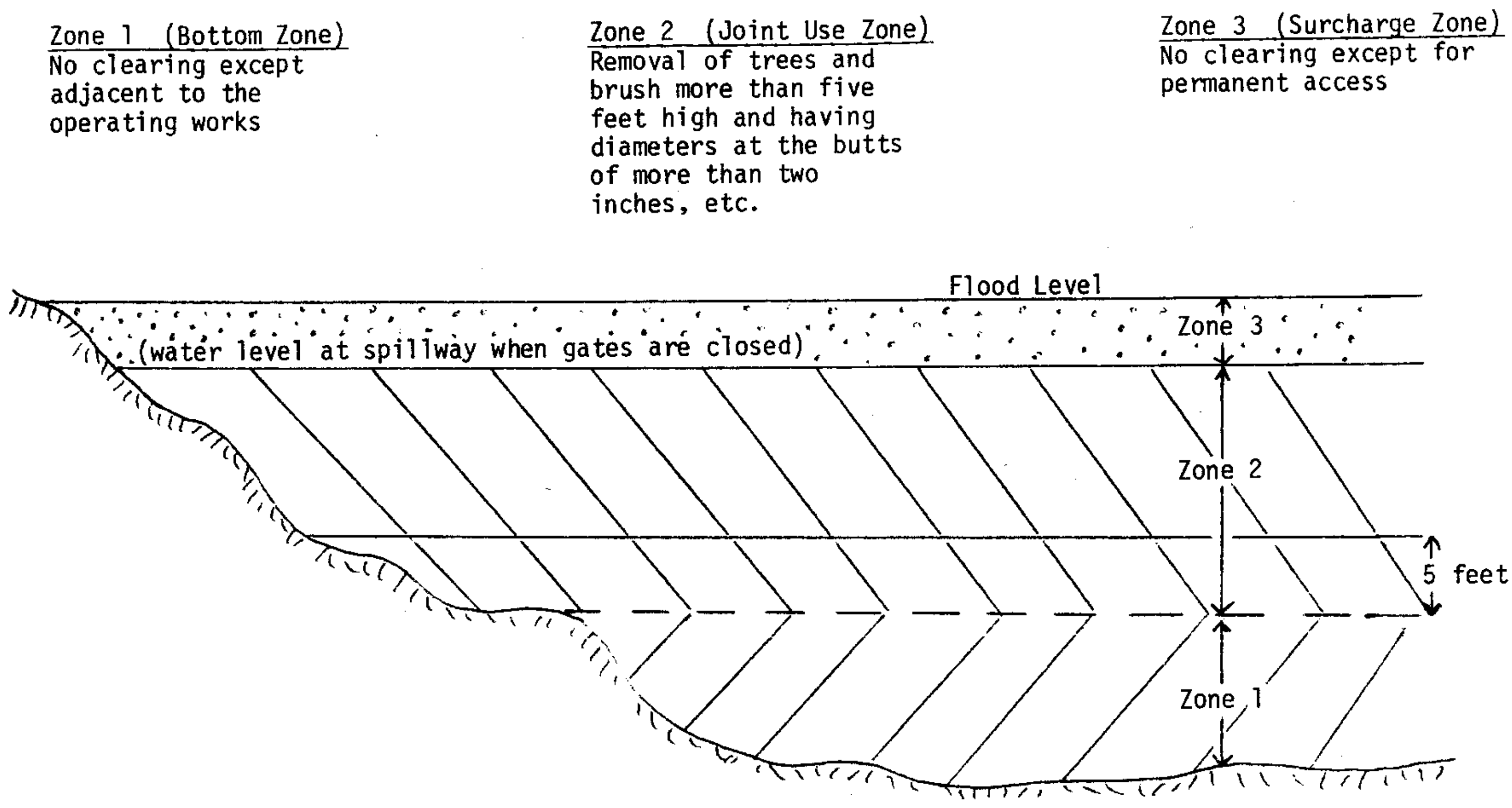


Figure 1: Bureau of Reclamation Clearing Policy

operating works of the dam. The joint use zone (Zone 2) begins at the top of Zone 1 and extends to the spillway gates when closed. In this zone, clearing includes the removal of trees and brush more than five feet high and having diameters at the butts of more than two inches. Trees and stumps are either uprooted or cut off at ground level with a maximum stump height of six inches. Cut timber, dead timber, branches and other floatable and combustible material larger than four inches in diameter, and all materials longer than five feet are burned and buried with a minimum of two foot cover.

The surcharge zone (Zone 3), or that area that extends from the joint use zone and above, will in general be underwater for only short periods of time. No clearing is done in Zone 3 except for that which is required for permanent access.

The Army Corps of Engineers has a clearing policy similar to the one developed by the Bureau of Reclamation (2). Like the Bureau's policy the objective of the Corps is to remove only that material required to reduce construction costs, clear areas that would create hazards, and to consider maximizing the practical benefits to fish and wildlife. An additional objective is to "eliminate pollution." This objective is expanded to include those projects where a water supply is involved. If a total clearing procedure is cheaper than affecting the "counteracting water treatment required," the reservoir will be cleared. However, the Corps estimates that water quality problems associated with original vegetation are negligible after a period of ten years.

Previous Vegetation and Water Quality Studies

Although evidence of cause and effect relation of original vegetation on water quality are relatively scarce, a few studies have been reported that related directly to this question. Two investigations were conducted by Ewer and Biswas on Lake Volta in Africa (3,4). During the construction of Lake Volta, no clearing or other site preparation was undertaken because of a lack of roads into the work area, a lack of manpower, and a shortage of funds. Vegetation was not burned because it was thought that this would cause excessive release of nutrients to the water after filling. The field sampling indicated that in the finished reservoir there was essentially no dissolved oxygen (DO) below 10 meters and very little below five meters the first two years. In some areas where weeds covered the surface, the DO was zero from the base of the weeds downward. Average surface values were recorded between 30 and 50% of saturation. Secchi disk readings were about one meter. The authors concluded that the cause for the lack of DO in the lake was from the heavy vegetation left behind during construction (3).

Leentvaar reported on a study of Lake Brokopondo waters in Surinan (5). Within 3 to 4 weeks after filling, there was zero DO below 3 to 4 meters and a serious hydrogen sulfide problem in the deeper parts of the lake. It was stated that the low pH and anaerobic conditions probably prevented the decay of submerged trees. It was concluded that the submerged trees had a two way detrimental effect on the lake by 1) reducing water circulation and hence, lowering the DO, and 2) providing sites for attached algal mats which became breeding areas for mosquitoes (5).

Mitchell conducted a study on Lake Kariba between Zambia and Rhodesia in Africa (6). The lake became eutrophic during filling producing almost continuous blooms of blue-green algae and leaving the hypolimnion completely deoxygenated. Over the years, the lake has slowly become mesotrophic. Blooms are now rare and of short duration with deoxygenation of the hypolimnion limited to the submerged river beds. During the early years of the lake, there was a greater discharge of nutrients than influent of nutrients. Mitchell concluded that the eutrophic problems were caused by the immense quantity of inundated organic matter which released considerable amounts of nutrients (6).

In the United States, Sylvestor and Seabloom completed one of the most valuable studies relating site preparation to reservoir water quality (7). This study was performed at the 775 acre Howard A. Hanson Reservoir on the Green River in Washington. The objectives of the study were to compare the effect of various soils and vegetation on water quality. The clearing policy consisted of stripping the reservoir site of all vegetation, debris, and logs greater than 4 inches in diameter or 4 feet in length. The exceptions to the plan was an 80-acre swamp in the lower portion of the impoundment which was cleared of standing timber only. The possible effects of the swamp on water quality were of concern but the cost to cover the swamp or remove the vegetation was estimated at about one million dollars. It was decided not to clear the swamp but to establish a surveillance program to monitor effects of the swamp on water quality. Prior to being placed in service, the reservoir was flushed two times and refilled.

Sylvestor and Seabloom initiated a sampling program in which a number of parameters were measured at different stations throughout the lake over soils of different organic content. Samples were taken within a foot of the bottom at each station and indicated that little difference in water quality could be detected between stations although somewhat higher values for color and tannin and lignins were reported over the submerged swamp area.

One of the purposes of the Sylvestor and Seabloom study was to determine the BOD for various soils and types of vegetation. Each sample was weighed and placed in bottles of seeded dilution water. Samples were incubated at 20°C on a shaker device in the absence of light. Table 1 presents the laboratory results for the BOD of soil and wood samples. From this table the following conclusions were made: 1) BOD was a function of organic content, stage of decomposition, degradability of the organic function and surface area exposed, and 2) grass, leaves, and weeds exerted a greater BOD than logs and standing timber.

Table 2 presents the water quality after submergence of vegetation in 3.5 liters of Green River water. Results indicated that charring appeared to exert less oxygen demand, but tended to raise the alkalinity of the water significantly. Odor appeared to be a function of vegetation type. Bark showed a greater effect on water quality than wood. Rotting wood had a greater effect than fresh wood. It was apparent that leaching from wood and bark required large quantities of DO and had a significant effect on adding nutrients and color to the water.

Sylvestor and Seabloom concluded the study by making the following recommendations for clearing policies:

1) All standing timber, brush, stumps, etc., should be removed from reservoirs.
2) Grass and other forms of herbage should be mowed and removed immediately before inundation.
3) Impoundment areas should be flushed several times before

TABLE 1

BOD OF SOIL AND WOOD SAMPLES

(Sylvester and Seabloom)

Sample Description*	Organic Matter by Dry Weight percent	Concn. of sample g/l	3-day BOD mg/l/g	7-day BOD mg/l/g	15-day BOD mg/l/g
Organic muck soil (1)	30	1	1.5	2.3	3.7
Swamp organics (peaty)(2,7,9)	73	1	3.8		
Silt loam sediments (3)	9	5	0.16	0.22	0.40
Gravel loam with wood fragments (4,6)	17	5	0.24	0.42	0.60
Swamp litter (7)	80	0.5	3.0	4.6	8.2
New sediment (Silt loam)(8)	14	5	0.34		
Pasture loam with dead grass (10)	20	0.5	10.0	15.8	
Fir wood shavings (fresh from dried lumber)		1	5.5		
Fir wood (rotting)		1	0.9	0.9	1.7
Cedar wood fragments		1	2.4		
Hemlock wood fragments		1	2.6		
Forest litter: ferns and maple leaves		1	7.9		
Fir bark: fragments		1	1.0		
Cedar bark: fragments		1	2.4		
Hemlock bark: fragments		1	3.8		
Alder bark: fragments		1	2.4		

*Station number, if any, in parentheses.

TABLE 2

WATER QUALITY AFTER 2 WEEKS SUBMERGENCE IN 3.5 LITERS OF GREEN RIVER WATER *

Sample Description	Sample Volume ml	pH	DO ppm	Total Alkalinity $CaCO_3$ ppm	Conditions at 25°C µmhos	Color Units	Ammonia Content as N ppm	Organic Content as N ppm	Nitrate Content as N ppm	Potassium Content as N ppm	Odor
Control		7.3	8.6	21	44	6	0.02	0.07	0.03	0.7	0
Fir wood	130	5.6	0	7	26	32	0.08	0.21	0.21	2.7	0
Fir wood (rotting)	185	4.6	0	0	35	90	0.20	0.26	0.09	2.3	H_2S
Fir wood (charred)	100	6.4	2.8	19	48	20	0.26	0.16	0.24	2.8	0
Fir bark	220	4.6	0	0	64	200	0.14	0.51	1.96	9.9	0
Hemlock wood	210	5.9	1.5	10	38	50	0.10	0.24	0.32	5.7	woody
Hemlock wood (rotting)	235	4.8	0	2	67	170	0.03	0.66	0.68	16.3	sweetish
Hemlock wood (charred)	195	6.8	3.1	26	60	10	0.25	0.14	0.14	5.2	sour
Hemlock bark	175	5.0	0	3	48	130	0.08	0.30	0.27	11.2	sweetish
Hemlock bark (charred)	185	7.0	3.8	48	101	22	0.09	0.16	0.15	10.1	chemical
Cedar wood	100	6.0	0	5	25	65	0.14	0.36		1.1	soapy
Cedar wood (charred)	120	7.1	5.2	22 q	43	7	0.03	0.07	0.04	0.8	faint
Cedar bark	145	6.3	0	13	44	90	0.02	0.11	0.30	6.2	H_2S
Cedar bark (charred)	125	6.5	0	58	115	90	0.19	0.29		7.1	sweetish

* From Sylvester and Seabloom

permanent filling.

Allen studied taste and odor problems at a new reservoir in a wooded area (8). He found that phenols leached from trees surrounding the lake and from trees inundated by the water caused taste and odor problems. He also concluded that decomposition in creek beds caused significant taste and odor problems. Allen recommended that reservoir sites should be cleared completely of vegetation not only within the area to be inundated but also along the shoreline.

Leaching studies were performed by Wetzel and Manning on dry hickory and maple leaves (9). Leaves were placed in a nylon mesh bag in a recirculating stream. The water was analyzed at intervals for particulate organic carbon (POC), total dissolved organic carbon (TDOC), labile dissolved organic nitrogen (LDON), and refractory dissolved organic nitrogen (RDON).

Bacteria counts were taken in order to demonstrate the rate of utilization of the leached nutrients. Figure 2 presents the results of this leaching study which indicate that total dissolved and particulate organic carbon levels increased rapidly within a 30 hour period and then decreased to near background levels after 10 days. Refractory dissolved organic nitrogen levels increased rapidly within the initial 12 hours of the leaching run and then increased very slowly during the remainder of the 25 day run. Labile dissolved organic nitrogen, on the other hand,increased slowly within thirty hours and then decreased slowly over the remainder of the leaching period. Bacteria counts, as might be expected, corresponded very well with dissolved organic carbon concentrations. Results indicate a one day lag time between maximum total dissolved organic carbon concentrations and maximum bacteria counts. The

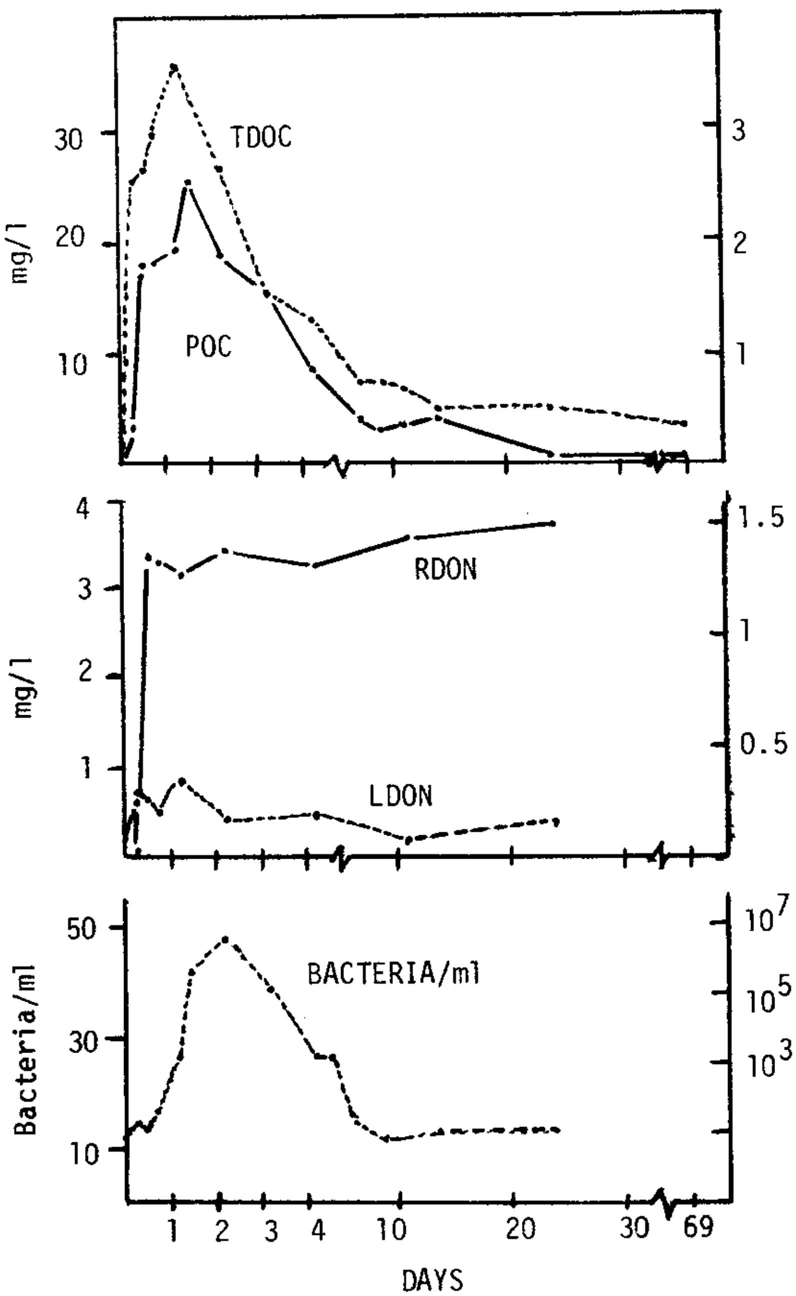


Figure 2: Nutrient and Bacterial Concentrations with Time after Wetzel and Manning's Study on Leaves

results from this study showed that organic compounds are leached rapidly from hardwood leaves, but that rapidly increasing bacterial populations quickly reduced concentrations of labile components to near ambient stream levels.

A similar leaching study was performed by Lee and Cowen at the University of Wisconsin in which the leaching rates of soluble phosphorous were measured for oak and poplar leaves (10). Table 3 shows the results of this study which indicated that the two types of leaves released different percentages of phosphorous to the water, but that in each case, leaching of phosphorous was significant. Lee and Cowen also found that when leaves were cut in small pieces, the leaves released almost three times as much soluble phosphorous as whole leaves.

A study by Burkholder and Bornside was directed towards determining the rate of decomposition of marsh grass in sea water (11). Field measurements, shown in Figure 3, indicated that within one year the marsh grass was almost completely decomposed. The results from this study were similar to other studies which indicated that leafy vegetation inundated by a reservoir or by tidal or flooding action was decomposed relatively rapidly compared to woody vegetation.

Summary

While the Bureau of Reclamation and the Army Corps of Engineers recognize that clearing policy is important with regard to recreation and water supply needs, the scope of this recognition is more restricted to physical effects because of limited information on cause and effect relationships of original vegetation on water quality. Also, physical effects of not clearing, such as clogging of outlet works, can produce

TABLE 3

SOLUBLE P LEACHED FROM OAK AND POPLAR LEAVES

Leaves	Soluble P Leached ug/g of Leaves Reactive	Unreactive	Total	Soluble Total-P Leached % Total-P in Leaves
Oak[a]	44	10	54	5.4
Poplar[b]	120	20	140	21

[a]7.86 g, air-dry wt.; leachate vol. 960 ml; total-P in leaves 1,000 ug/g

[b]9.32 g, air-dry wt.; leachate vol. 950 ml; total-P in leaves 675 ug/g

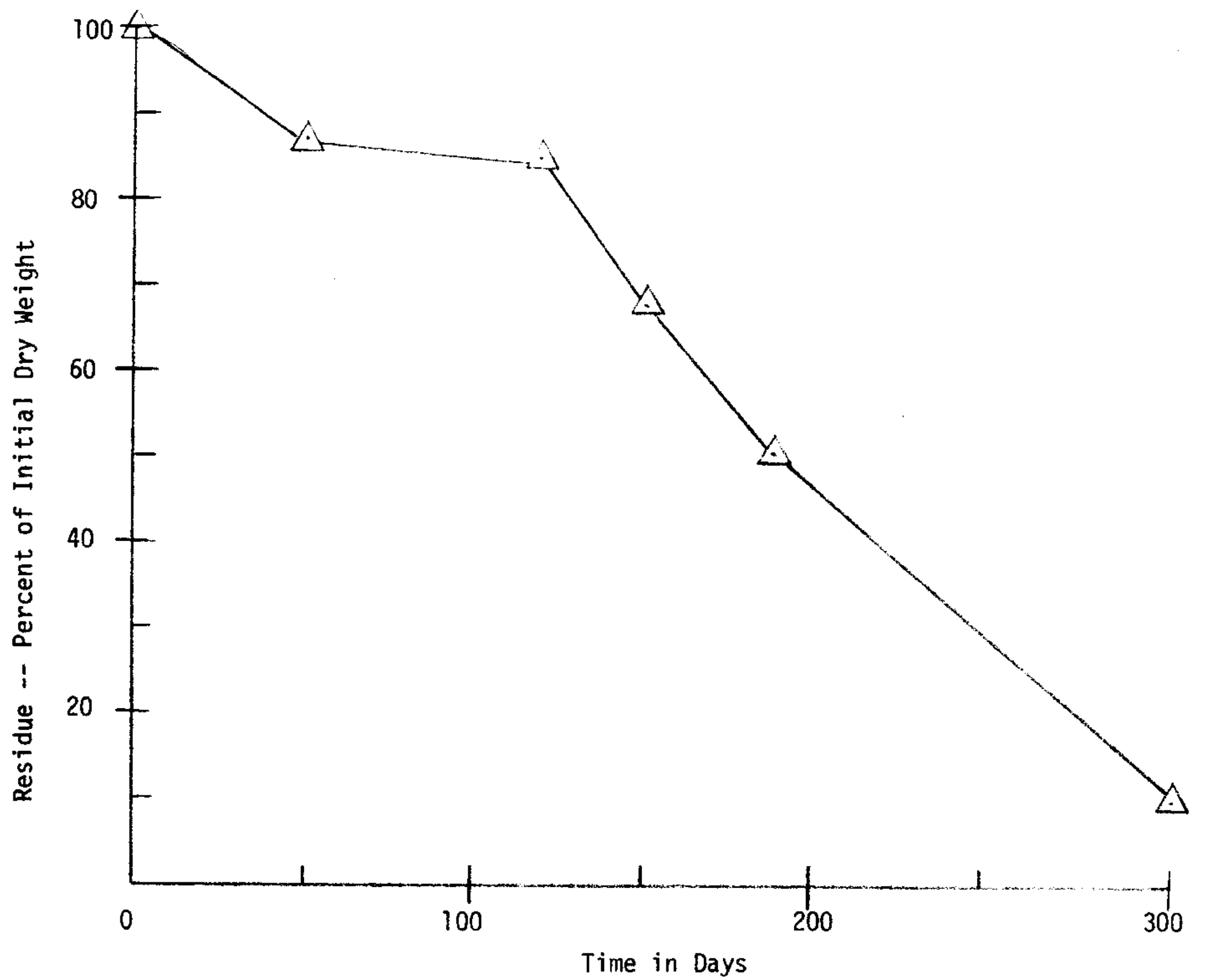


Figure 3: Decomposition Rate for Marsh Grass in Seawater by Burkholder and Bornside

direct consequences while chemical and biological effects from vegetation are more subtle. These reasons combined with economic considerations have placed effects of vegetation on water quality lower on the list of clearing priorities.

While information concerning the effects of inundated terrestrial vegetation upon water quality is sparse, several tentative conclusions can be drawn from previous work as follows:

1) Large quantities of inundated vegetation as found in jungle areas of the world may have a rapid and profound effect upon water quality in a new reservoir. Low dissolved oxygen concentrations near the surface and extensive blue green algae blooms in several new reservoirs have been attributed to decomposition of inundated original vegetation.

2) Effects of inundated terrestrial vegetation upon water quality are not necessarily permanent and can be partially or completely reversed over long periods of time. The rate of reversal will probably depend on flushing rates, initial vegetation loading, land use surrounding the reservoir, temperature, basin morphometry, etc.

3) Decomposition rate of vegetation is largely a function of tissue type. Leaves decompose and release nutrients at a more rapid rate than bark and wood.

4) Inundated terrestrial vegetation may cause severe taste and odor problems in reservoirs. Odor and taste produced are largely a function of vegetation type.

5) Phosphorous is leached at a rapid rate from dead hardwood leaves and particularly from leaves that have been cut or in

some way damaged.

6) Grasses may be almost completely decomposed within one year of inundation.

The above conclusions are based on a limited amount of technical data from various parts of the world. The purpose of this report is to build upon the previous work so that the results from this study are more applicable to the effects of original vegetation on water quality in Texas reservoirs.

CHAPTER III

MATERIALS AND METHODS

Five separate laboratory test series were conducted during the study. With the exception of the first of two preliminary leaching runs, all of the tests utilized the same apparatus, environmental conditions, and experimental methods. The objectives of the initial two tests were to provide basic information for the selection of apparatus and methods used for the remainder of the study.

Apparatus. Ten gallon rectangular glass aquariums were used as leaching vessels in all but the initial two test runs which employed one-gallon wide-mouthed jars. Aeration, when used, was provided by portable air compressors and supplied through plastic tubing and 3/4" diffusion stones. Hose clamps were used to control air flow to each stone to ensure equal air flow to each tank. Mechanical stirring was provided by small paddles which allowed equal mixing between tanks with little surface turbulence. Gro-lux flourescent tubes were used as a light source to encourage photosynthesis in the leaching vessels.

Experimental Conditions. Leaching was performed in an environmentally controlled chamber with temperature maintained at 20°C and humidity at 70%. Lighting was provided evenly to each leaching vessel for alternating periods of 12 hours. Lights were placed to provide an intensity suitable for algal growth. Aeration, when used, was adjusted so that the dissolved oxygen concentration at the beginning of each leaching study was near saturation.

Collection and Preparation of Vegetation

Live vegetation was collected from healthy plants which had not been recently fertilized or treated with insecticides or herbicides. Dead vegetation was collected from the same plants to ensure genetic environmental homogeneity. With grasses, each species (alive or dead) was collected from the same patch by cutting the stem. Leaves were collected intact at ground level.

After collection, all vegetation was rinsed in distilled water to remove foreign substances. This was accomplished without soaking to minimize premature leaching of nutrients. After washing, vegetation was dried at room temperature and weighed. Portions were set aside for leaching and for dry weight determinations. All vegetation was left intact except where cutting was necessary to provide the proper weight for leaching. An attempt was made to select bark and twig samples that were relatively the same size. Portions of each type of vegetation were dried at 80°C until a constant dry weight was determined.

Collection and Use of Water for Leaching

With the exception of the first preliminary study which employed three types of water, all water for leaching studies was collected from Big Creek Marina at the north bank of Lake Somerville, Texas. The first preliminary study used distilled water, Lake Somerville water, and water collected from Yegua Creek at the US 21 highway bridge near Lincoln, Texas. Water was collected in 55 gallon plastic containers, and transported to the laboratory. Leaching water was placed into the leaching vessels 12 hours before vegetation was added to allow acclimation to temperature and humidity conditions. Aeration, when used, was started 12 hours prior to the application of vegetation. Excess water was stored in the leaching room for use as replacement for losses from evaporation and sampling.

Each leaching vessel contained twenty-five liters of leaching water with the exception of the one gallon jars used in the preliminary study which contained 3 liters of water each. All volumes were maintained throughout each leaching run.

Sampling Procedure. After vegetation had been added to each leaching vessel, 300 ml samples were collected at intervals over the test period. Water in each vessel was stirred thoroughly before samples were removed. Samples were collected with a 100 ml pipette and care taken not to remove any vegetation with the sample. Samples were placed in 1000 ml cubitainers and stored at 4° C until analysis was preformed. In addition, dissolved oxygen concentrations were measured prior to each sample collection. A YSI unit was used for this determination.

Analytical Procedures. The following analytical methods were used for all analysis throughout the study:

Test	Method
Alkalinity	Sulfuric acid titration (12)
BOD_5	DO meter and probe; incubation at 20° C (13)
Color	APHA Platinum Cobalt Standards for water (12)
Dissolved Oxygen	YSI model 51A oxygen meter (13)
Hardness	EDTA Volumetric method (12)
Ammonia-Nitrogen	Distillation plus nesslerization (12)
Nitrate-Nitrogen	Brucine Method (12)
Nitrite-Nitrogen	Hach Ferrous Sulfate Method (14)
Total Nitrogen	Kjeldahl Method plus Nesslerization

Total Phosphorous	Persulfate Digestion and Ascorbic Acid Method (12)
pH	pH meter (12)

CHAPTER IV

RESULTS AND DISCUSSION

Preliminary Studies

Two preliminary leaching and decomposition series were performed to test some of the methods and equipment that would be used throughout the remainder of the study. The first series utilized nine test jars and was conducted over an eleven day period beginning April 15, 1974. Specifically, the run was designed to test the effects of water composition and aeration on nutrient release rates for coastal Bermuda Grass. Bermuda Grass was selected as the test vegetation in both preliminary series because of availability and an expected rapid rate of nutrient release. The three types of water used as leaching solutions were obtained from Lake Somerville, Yegua Creek above Lake Somerville, and from the laboratory distilled water supply. Three one-gallon jars containing each water type were used in the first series to determine the effects of the following solution regimes:

1) Artificial aeration by compressed air and diffusers,
2) Replacement of the leaching water at 24 hour intervals, and
3) No aeration or replacement.

The relationships between nitrogen release with time as measured by total Kjeldahl nitrogen is presented in Figures 4-6 for the eleven day period. Figures 7-9 show dissolved oxygen profiles for each tank under the three regimes. The pH was monitored, but no significant variation between tanks was observed. The data indicates that, at identical vegetation loadings, samples in Yegua Creek water not aerated or changed released nitrogen at a faster rate than samples in distilled water or Lake

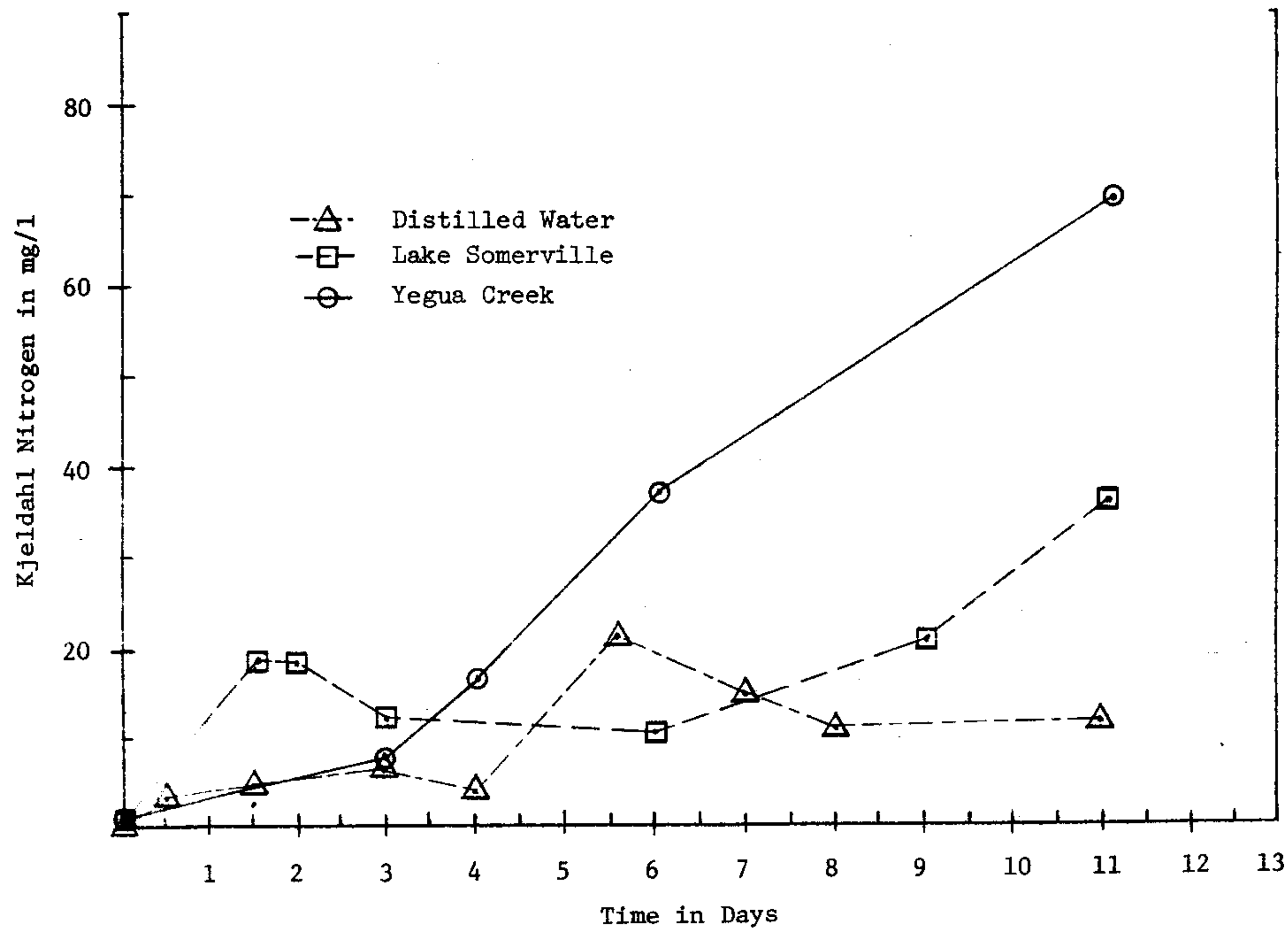


Figure 4: Kjeldahl Nitrogen Release with Time for Coastal Bermuda Grass Using Three Different Unaerated Leaching and Unchanged Solutions (Test Series 1)

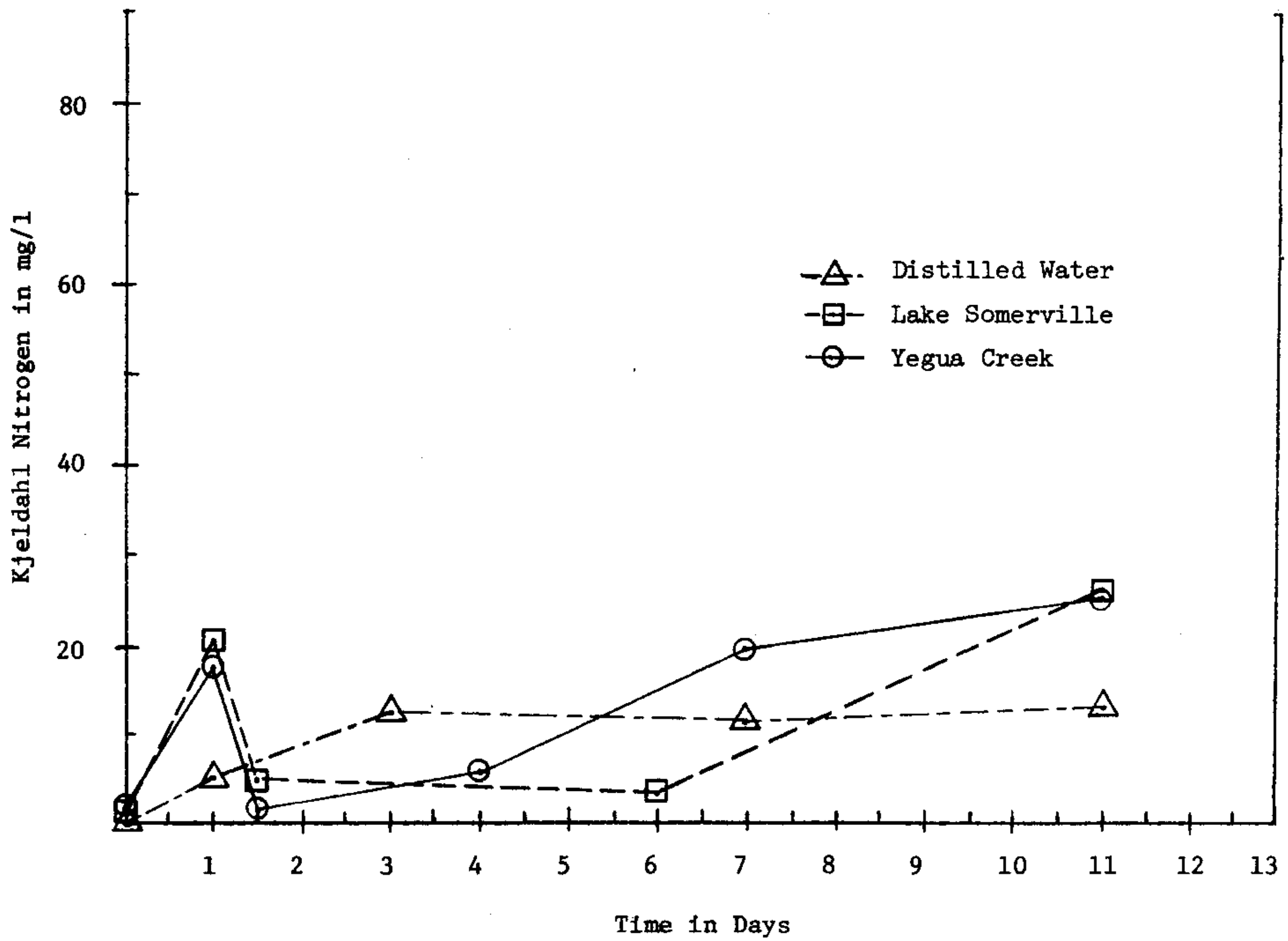


Figure 5: Kjeldahl Nitrogen Release with Time for Coastal Bermuda Grass Using Three Different Leaching Solutions that were Changed Each 24 Hours (Test Series 1)

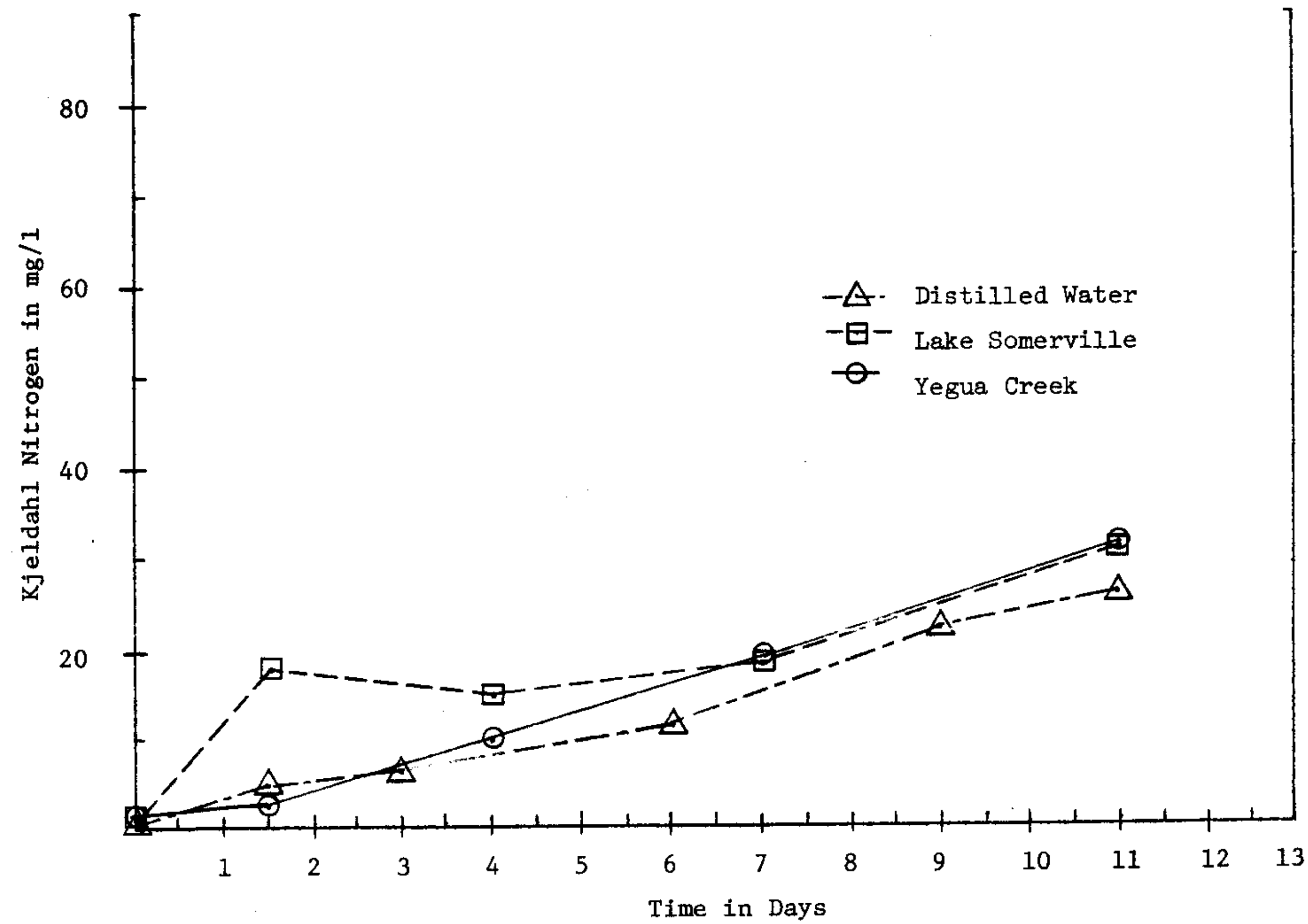


Figure 6: Kjeldahl Nitrogen Release with Time for Coastal Bermuda Grass Using Three Different Leaching Solutions Under Aeration (Test Series 1)

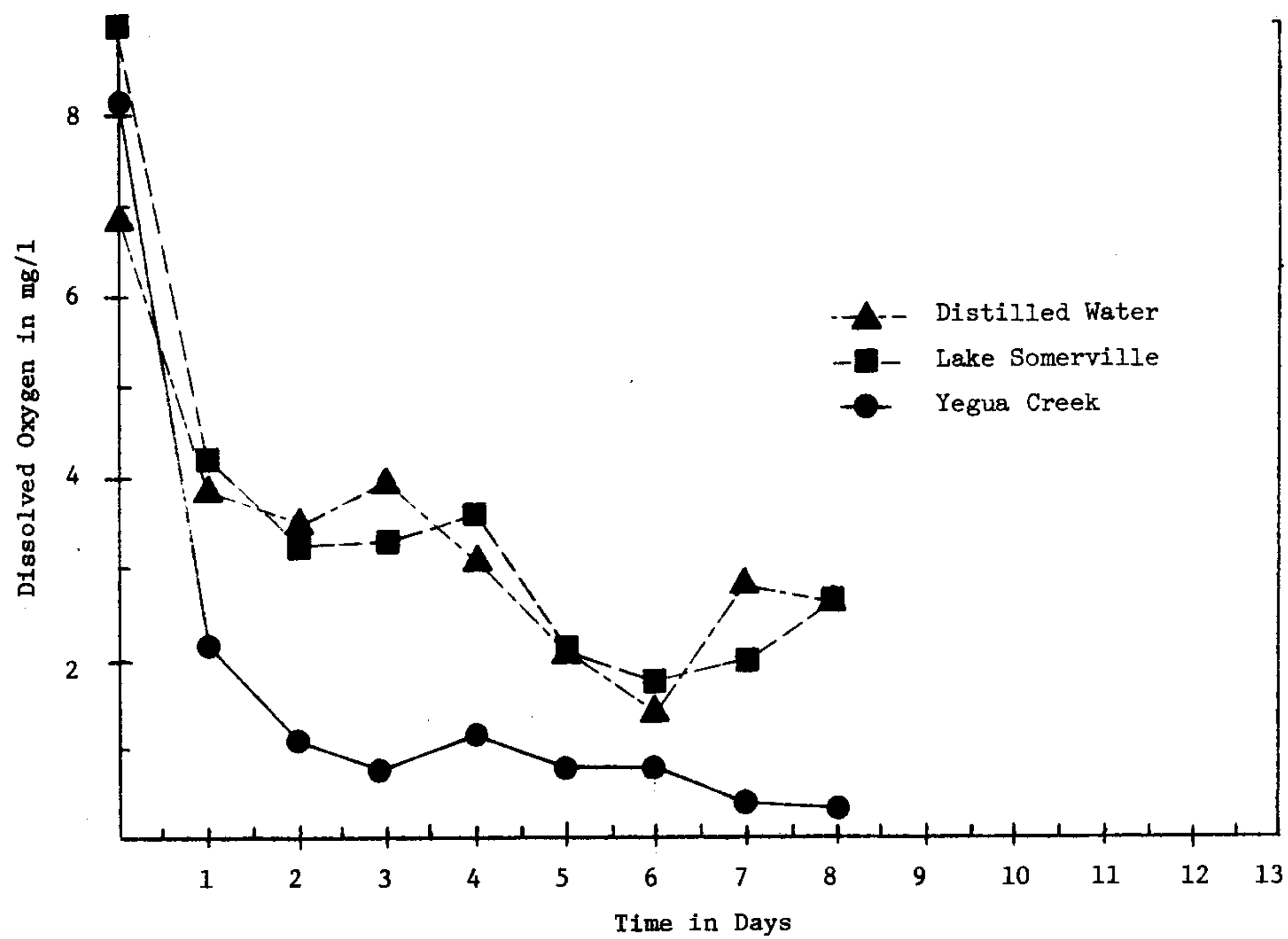


Figure 7: Dissolved Oxygen Concentration with Time for Coastal Bermuda Grass Using Three Different Unaerated and Unchanged Leaching Solutions (Test Series 1)

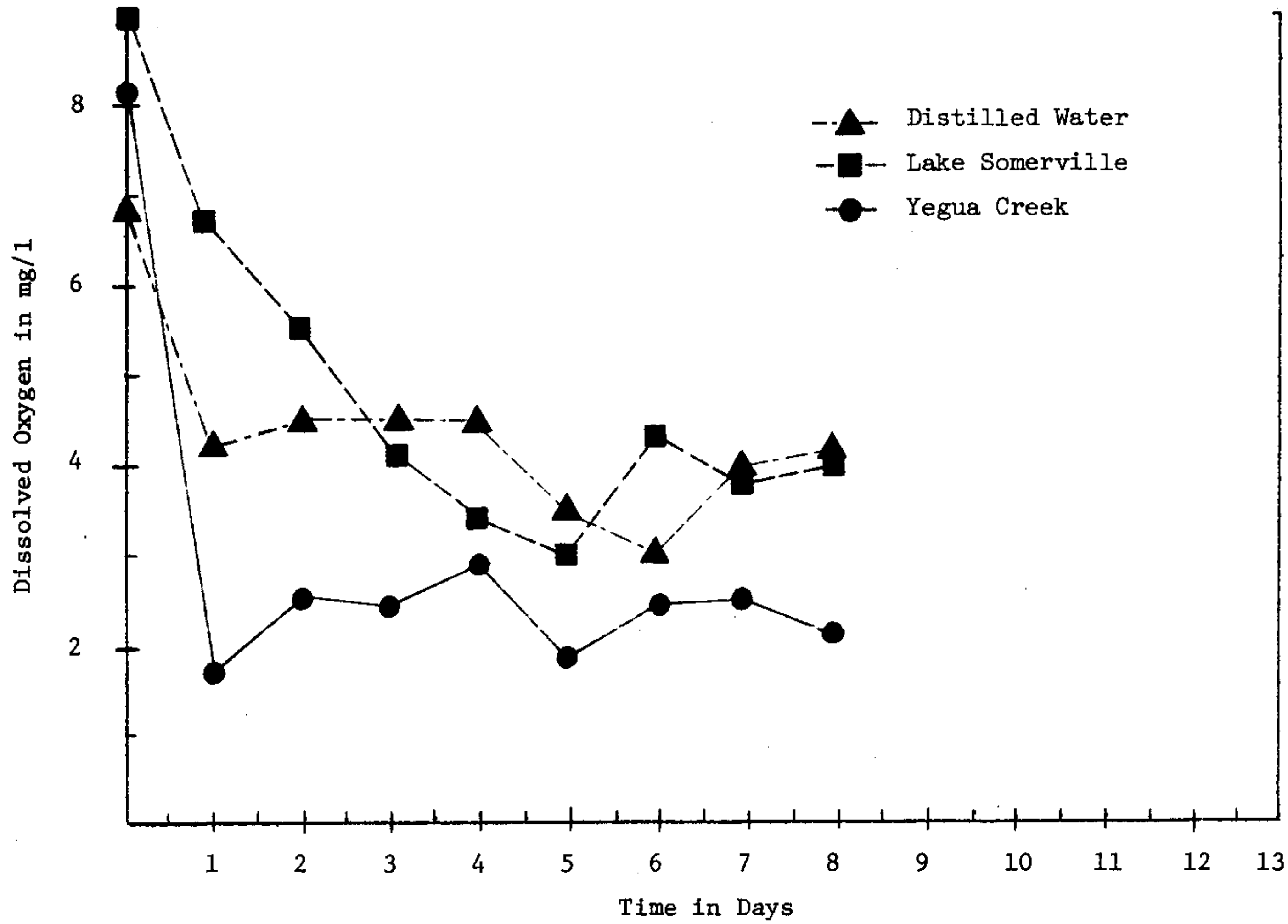


Figure 8: Dissolved Oxygen Concentration Release with Time for Coastal Bermuda Grass Using Three Different Leaching Solutions that were Changed Each 24 Hours (Test Series 1)

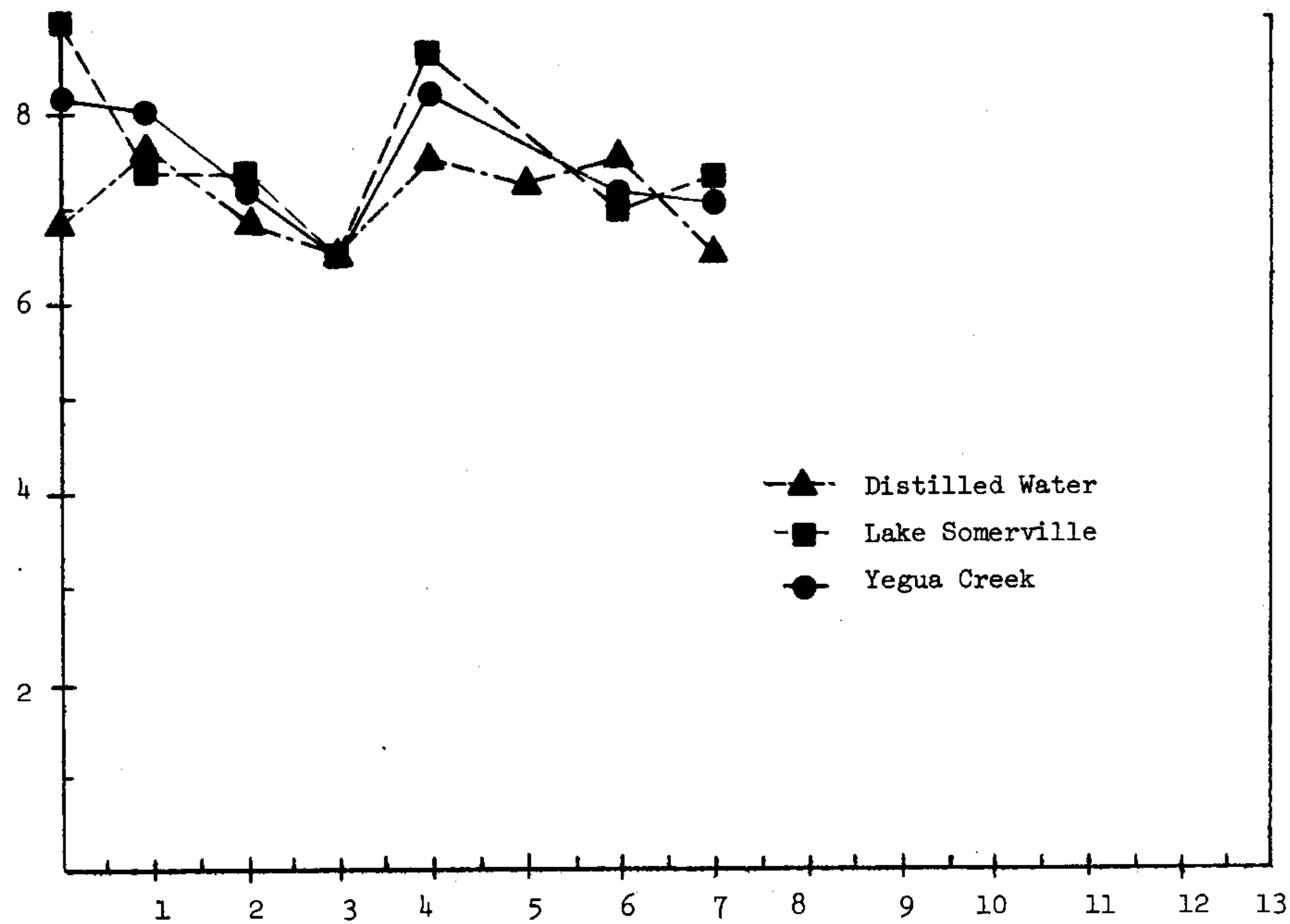


Figure 9: Dissolved Oxygen Concentration Release with Time for Coastal Bermuda Grass Using Three Different Leaching Solutions Under Aeration (Test Series 1)

Somerville water. A comparison between aerated samples or samples in which the water was changed showed no significant difference in nitrogen release rates over the eleven day period. For the unaerated jars, dissolved oxygen concentrations decreased rapidly over the first two to three days of leaching before leveling off somewhat over the remainder of the leaching run. Oxygen depletion in the tank containing Yegua Creek water was significantly greater than for the other two jars.

Yegua Creek water contained a slightly greater BOD and somewhat higher initial nitrogen and phosphorous concentrations than did Lake Somerville water or distilled water. In general, it could be said that the water from Yegua Creek was more eutrophic than the other two waters. A higher rate of activity in Yegua Creek water could be responsible for the more rapid decomposition of vegetation and the higher rate of nitrogen released. The fact that Yegua Creek water was not a more effective leaching solution than the other waters in the tanks that underwent aeration or water change indicates that anaerobic conditions may be amenable to higher nitrogen leaching rates. Another explanation was that much of the organic nitrogen and ammonia measured by the Kjeldahl method may have been oxidized in the more highly aerated tanks and was not measured.

Based on the first test series, Lake Somerville water was chosen as the leaching solution for the remainder of the study. The reasons were that the water was readily available and it would be expected that little variation in water quality would probably occur making different leaching runs more comparable. The Lake Somerville water should contain some organisms and trace elements necessary to promote biological growth in the leaching vessels.

The purpose of the second preliminary study (test series 2) was to test the effects of vegetation loading on leaching rate and to determine the effects of aeration and stirring on nutrient leaching. Eight aquaria were used with four under artificial aeration and four that were constantly stirred with a mechanical mixer. Coastal Bermuda Grass was selected as the test vegetation. Three loadings of Bermuda Grass were applied to the four stirred and four aerated tanks with one tank of each type used as a control with no vegetation. Total phosphorous, Kjeldahl nitrogen, and dissolved oxygen concentrations were monitored over a period of thirteen days with the results shown in Figures 10-13.

It was expected that nutrient release would be directly proportional to the vegetation loading with Figures 12 and 13 more nearly representing what was expected. The amount of nitrogen release for 0.8 grams/l of grass was almost double the amount released for 0.4 grams/l of grass for the aerated and stirred vessels. Figure 12 shows a doubling of concentration between loadings of 0.4 and 0.2 grams of grass. However, the phosphorous data was more obscure with a significant difference between 0.4 and 0.8 grams/l of grass for the aerated sample in Figure 12 and almost no difference until the 13th day for the stirred sample shown in Figure 13. It was concluded that the rate of leaching did not appear to be concentration limiting and that organic loadings of 0.8 grams/l of grass would be preferred for further tests to better ensure that sufficient nutrients would be released to be easily distinguishable above background nutrient levels. Kjeldahl nitrogen values showed little variation between stirred and aerated tanks. In each tank, leaching was rapid with the maximum concentrations being observed between 7 and 9 days

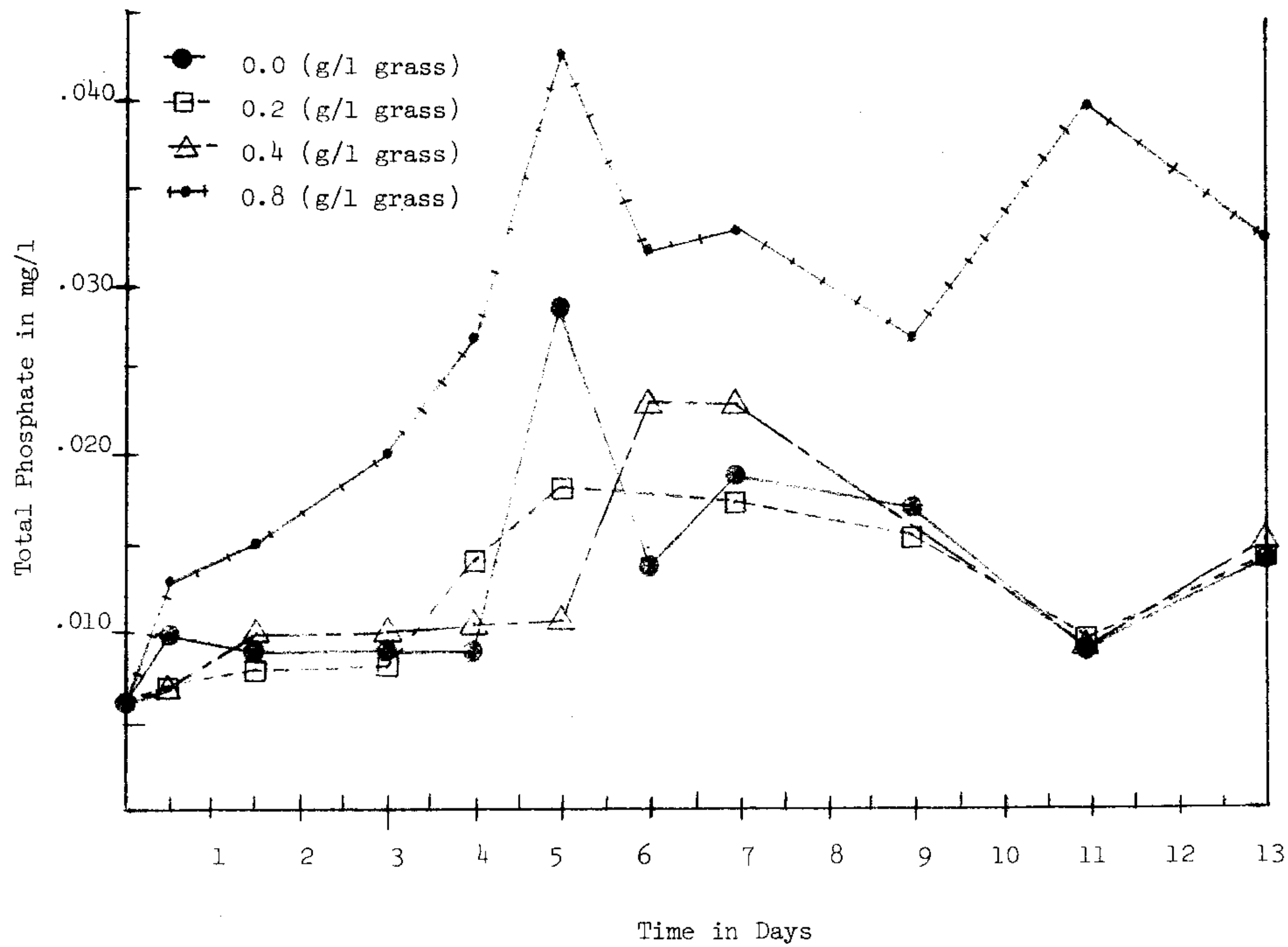


Figure 10: Total Phosphate Concentration with Time for Four Loadings of Coastal Bermuda Grass in Aerated Leaching Vessels (Test Series 2)

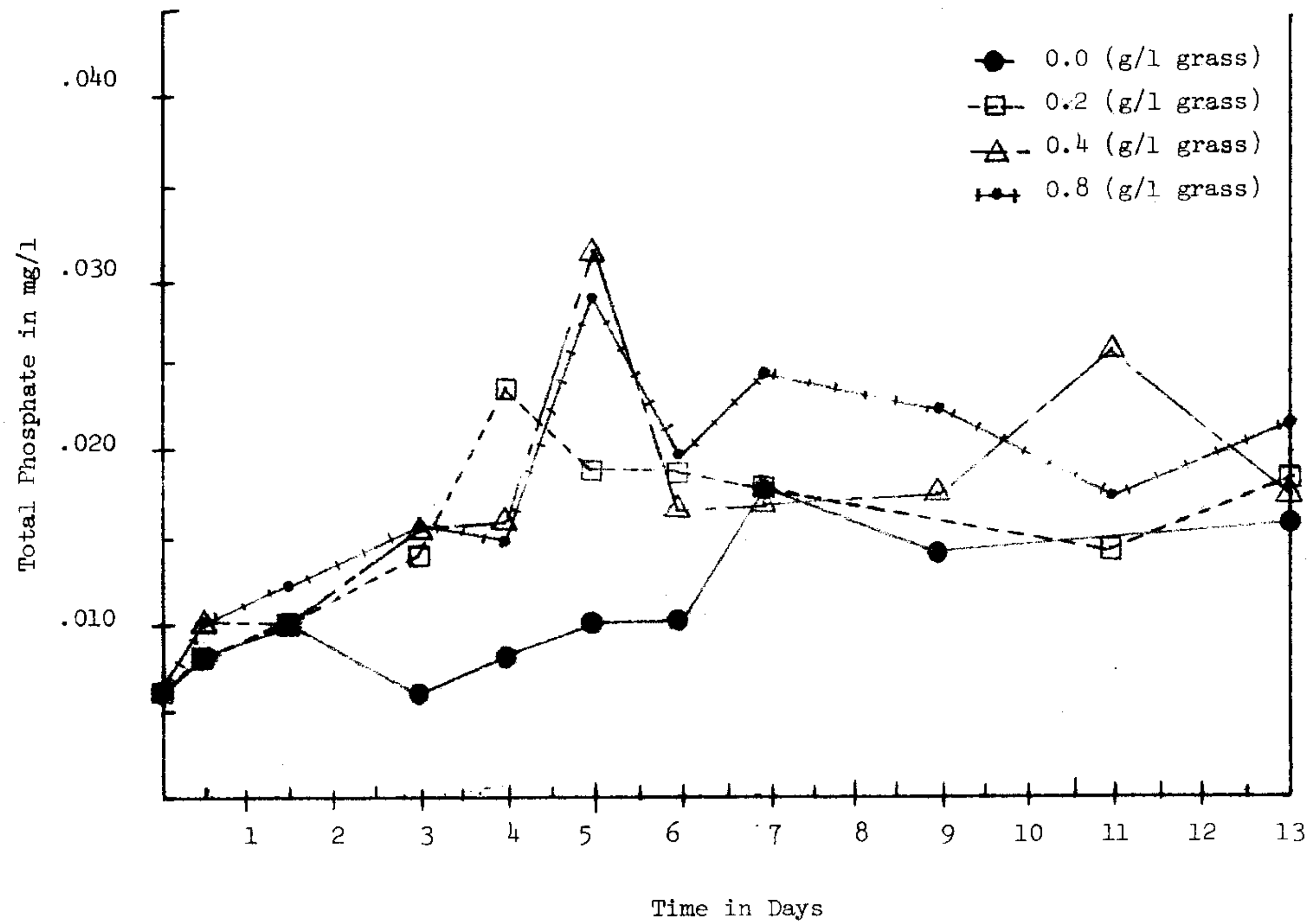


Figure 11: Total Phosphate Concentration with Time for Four Loadings of Coastal Bermuda Grass in Stirred Leaching Vessels (Test Series 2)

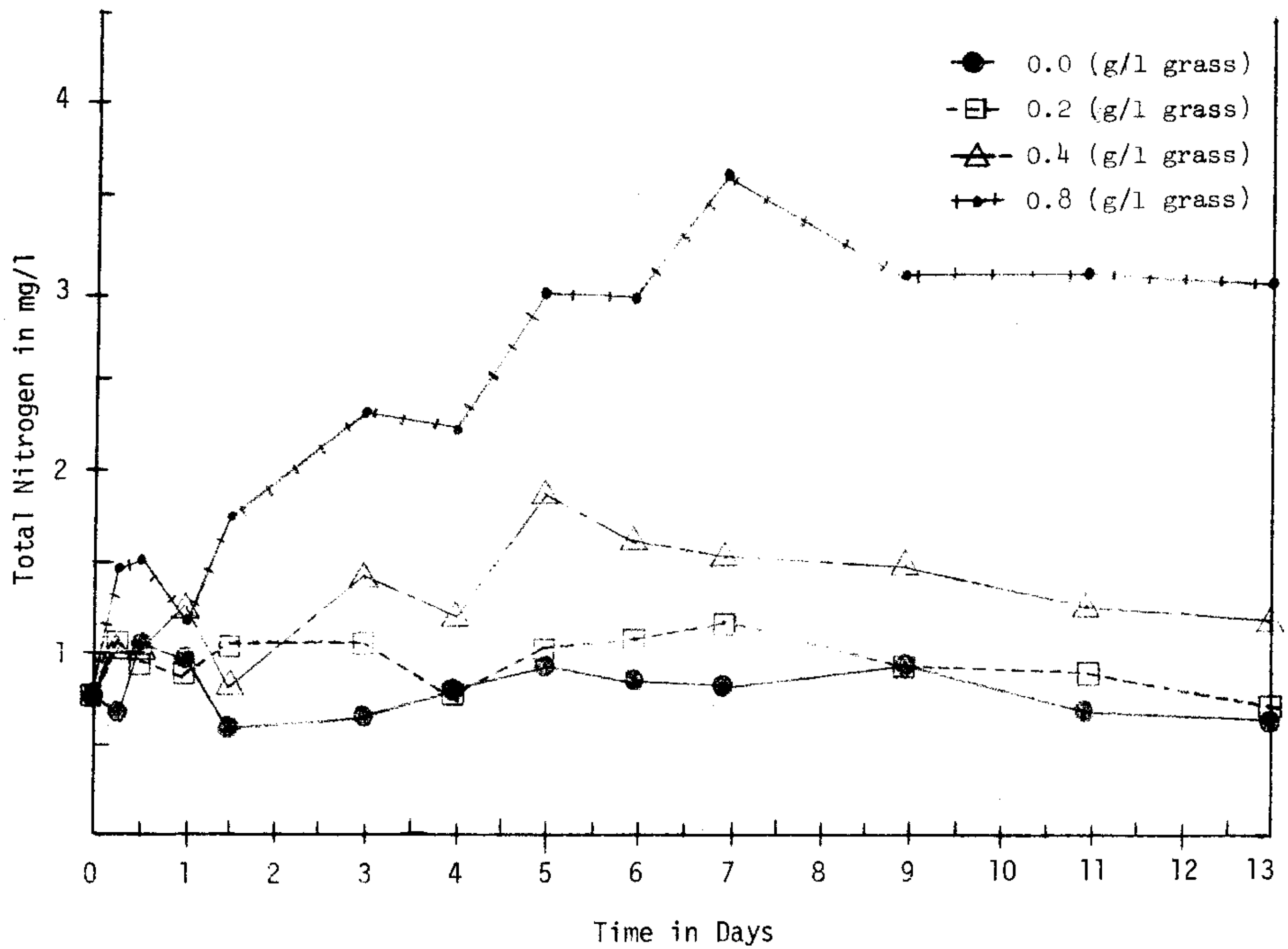


Figure 12: Total Nitrogen Concentration with Time for Four Loadings of Coastal Bermuda Grass in Aerated Leaching Vessels (Test Series 2)

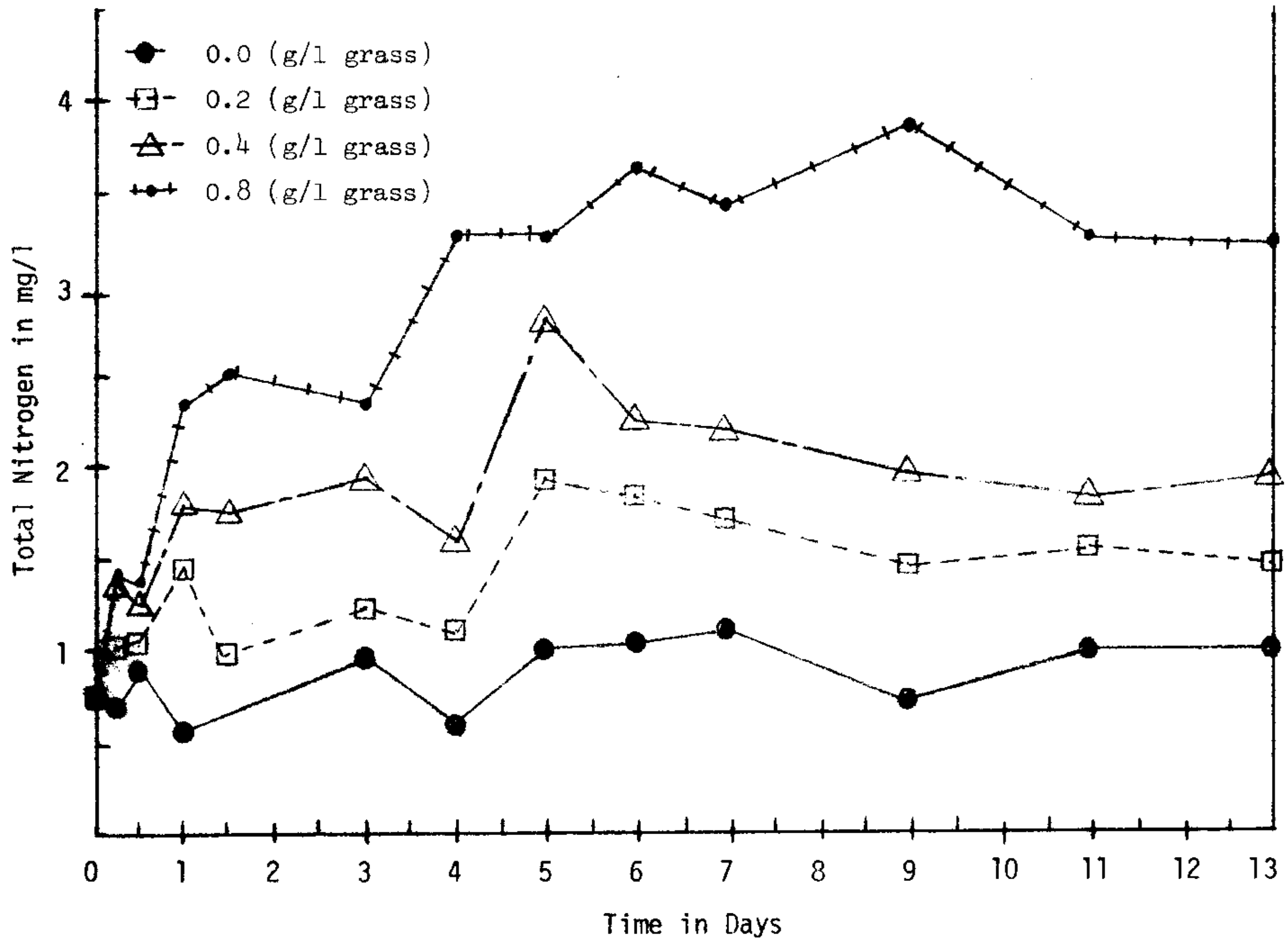


Figure 13: Total Nitrogen Concentration with Time for Four Loadings of Coastal Bermuda Grass in Stirred Leaching Vessels (Test Series 2)

into the test. Results show that phosphate leaching was somewhat greater in the tanks which were aerated but the difference could be from experimental error.

Figures 14 and 15 present a better comparison of the total phosphate and nitrogen concentrations with time at the highest vegetation loadings of 0.8 grams/l showing similar trends for aerated and stirred vessels. Results from stirred tanks showed slightly less variability indicating possibly better mixing and more homogeneous samples. On the basis of this data as well as practical considerations, aeration was chosen for use for the remainder of the leaching studies. Aeration provided fewer mechanical difficulties and allowed dissolved oxygen levels to be more constant. After this run, it was decided that a more thorough stirring in each tank prior to sampling would help reduce sampling errors.

Dissolved oxygen concentrations in aerated tanks were maintained at or near saturation over the leaching period. Dissolved oxygen concentrations for series 2 in each of the four stirred tanks are given in Figure 16. It appears that higher loadings cause an increase in oxygen consumption as would be expected. However, stirring maintained oxygen levels above 5.0 mg/l, unlike oxygen concentrations in tanks in test series 1 that were not stirred and that had oxygen concentrations approaching zero mg/l.

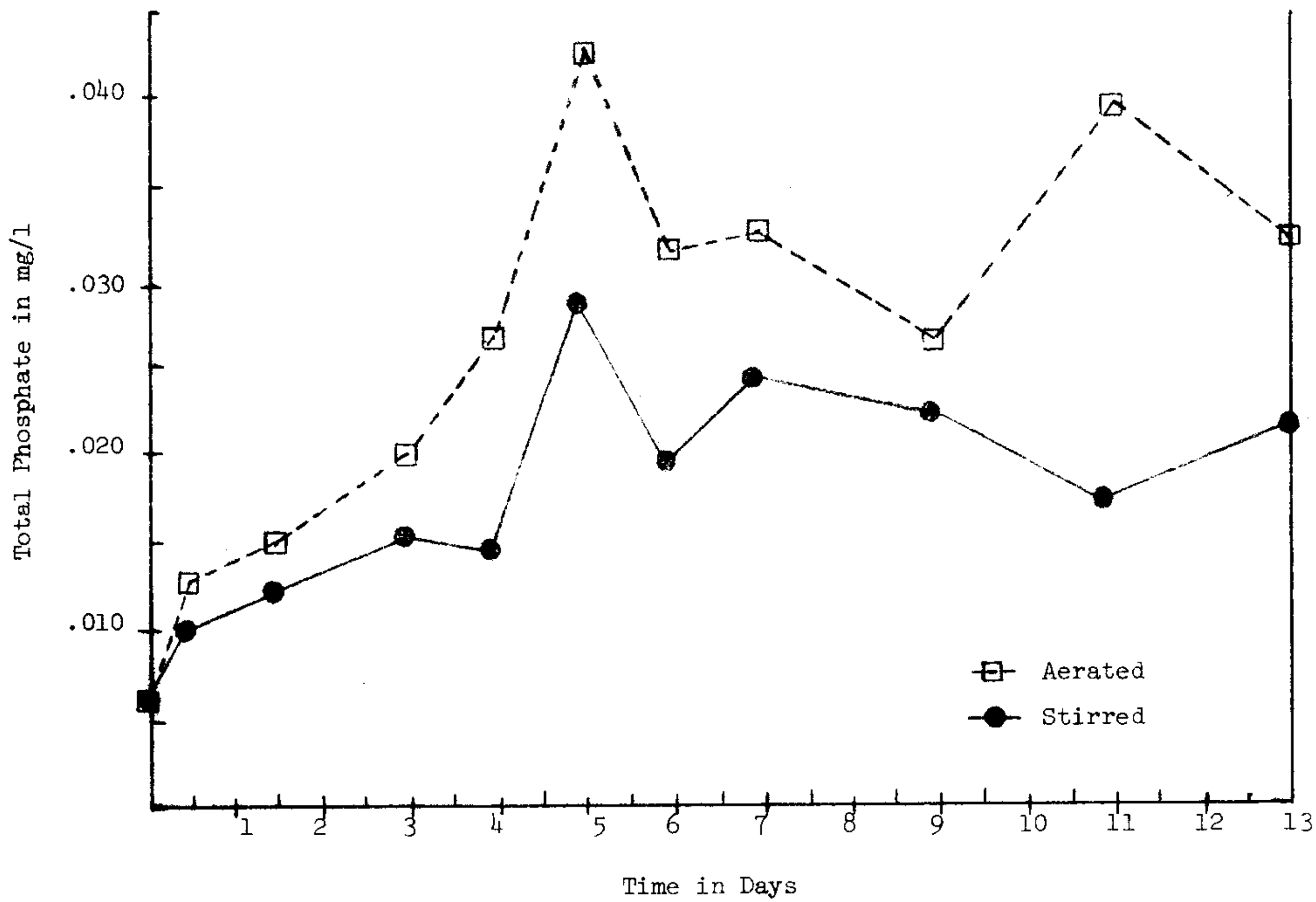


Figure 14: Comparison of Total Phosphate Concentrations Between Aerated and Stirred Samples for Coastal Bermuda Grass at 0.8 grams/l (Test Series 2)

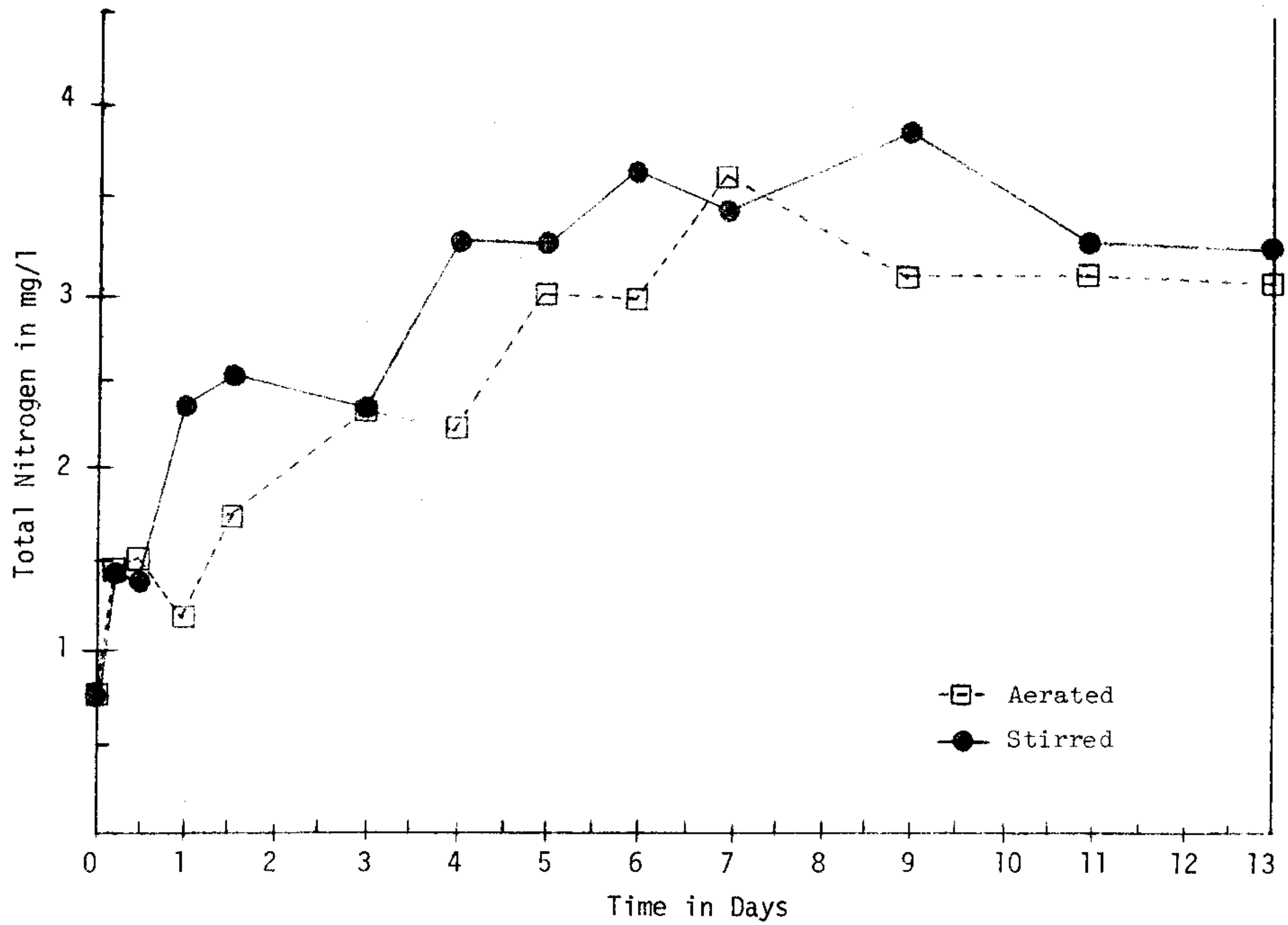


Figure 15: Comparison of Total Nitrogen Concentrations Between Aerated and Stirred Samples for Coastal Bermuda Grass at 0.8 grams/l (Test Series 2)

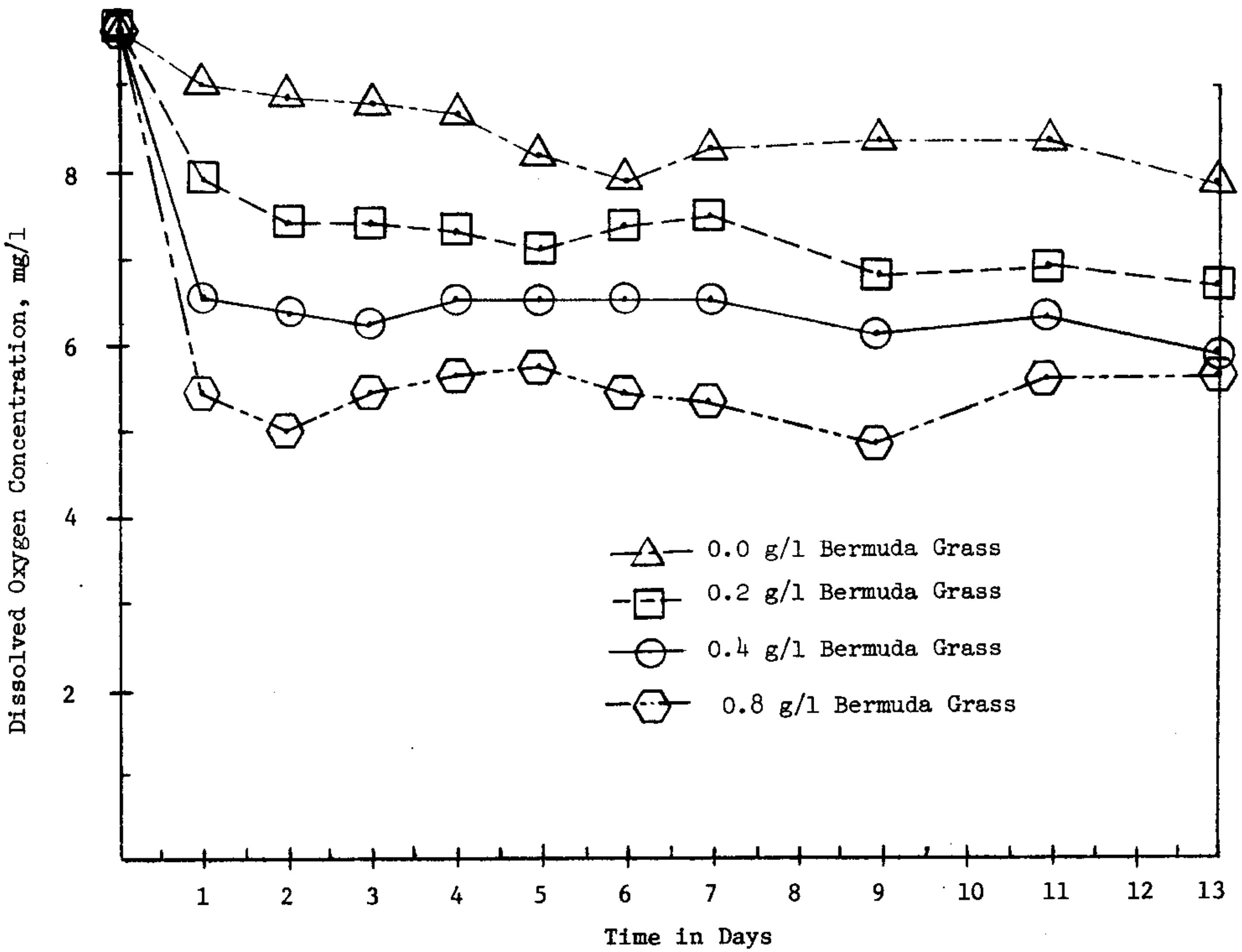


Figure 16: Dissolved Oxygen Concentrations with Time for Stirred Samples of Bermuda Grass at Different Vegetation Loadings (Test Series 2)

Nutrient Leaching from Tree Leaves

Seven species of trees were chosen for this leaching run. Trees were chosen on the basis of abundance in Texas, morphology of the leaves, taxonomy, and habitat. Table 4 presents the trees used in test series 3 giving their common names, a description of their range, and habitat preference. Generally, trees were chosen that represented a wide range of species common to Texas reservoir sites.

Tree leaves were leached using the same apparatus and procedures used in the other runs. Leaching was continued for a period of seventeen days. Total Kjeldahl nitrogen, nitrate-nitrogen, nitrite-nitrogen and total phosphorous were measured at intervals over the seventeen day period. Weight of vegetation and volume of leaching water were identical to weights and volumes used in all other leaching runs. Figures 17-24 present the results of the leaching run for each species of vegetation and for the control tank.

Results indicate that no significant leaching of phosphorous occurred from any of the leaves over the seventeen day period. Very little visible deterioration of the leaves occurred. Lee and Cowen found that dried leaves and cut-up leaves leach significant amounts of phosphorous over short time intervals as discussed in Chapter II (10). However, these results indicate that whole green leaves show no significant leaching of phosphorous. It may be that phosphorous only leaches if the leaf is damaged or in a state of decomposition where membrane boundaries have lost their selective permeability. Many leaves are covered by a glossy cuticle which would also inhibit leaching of nutrients across the leaf surface.

Nitrogen, which is much more soluble than phosphorous, was leached

Table 4

Trees Used in Test Series 3

Common Name	Scientific Name	Habitat and Range (Texas) Descriptions
Loblolly Pine	*Pinus taeda*	Habitat - wet bottomlands and drier outdoor and abandoned areas, mixed with pines and hardwoods Range - East Texas and Cross Timbers
Red Cedar	*Juniperus virginiana*	Habitat - poor dry soils, found in pure or mixed with hardwoods such as oak and hickory Range - East and East Central Texas
Post Oak	*Quercus stellata*	Habitat - varies from dry sandy plains to moist river bottoms Range - all Texas except for extreme southern Texas, west Texas, and the Panhandle
Hackberry	*Celtis lindheimeri*	Habitat - moist river bottoms to drier plains Range - All Texas except west Texas and the Panhandle
Mesquite	*Prosopis chilensis*	Habitat - arid and semi-arid plains below 6000 feet Range - All Texas
Black Willow	*Salix nigra*	Habitat - wet areas such as stream banks, ditches, and lake shores Range - Throughout Texas except northwestern corner of the Panhandle
American Elm	*Ulmus americana*	Habitat - bottomlands and other moist areas Range - Central and East Texas

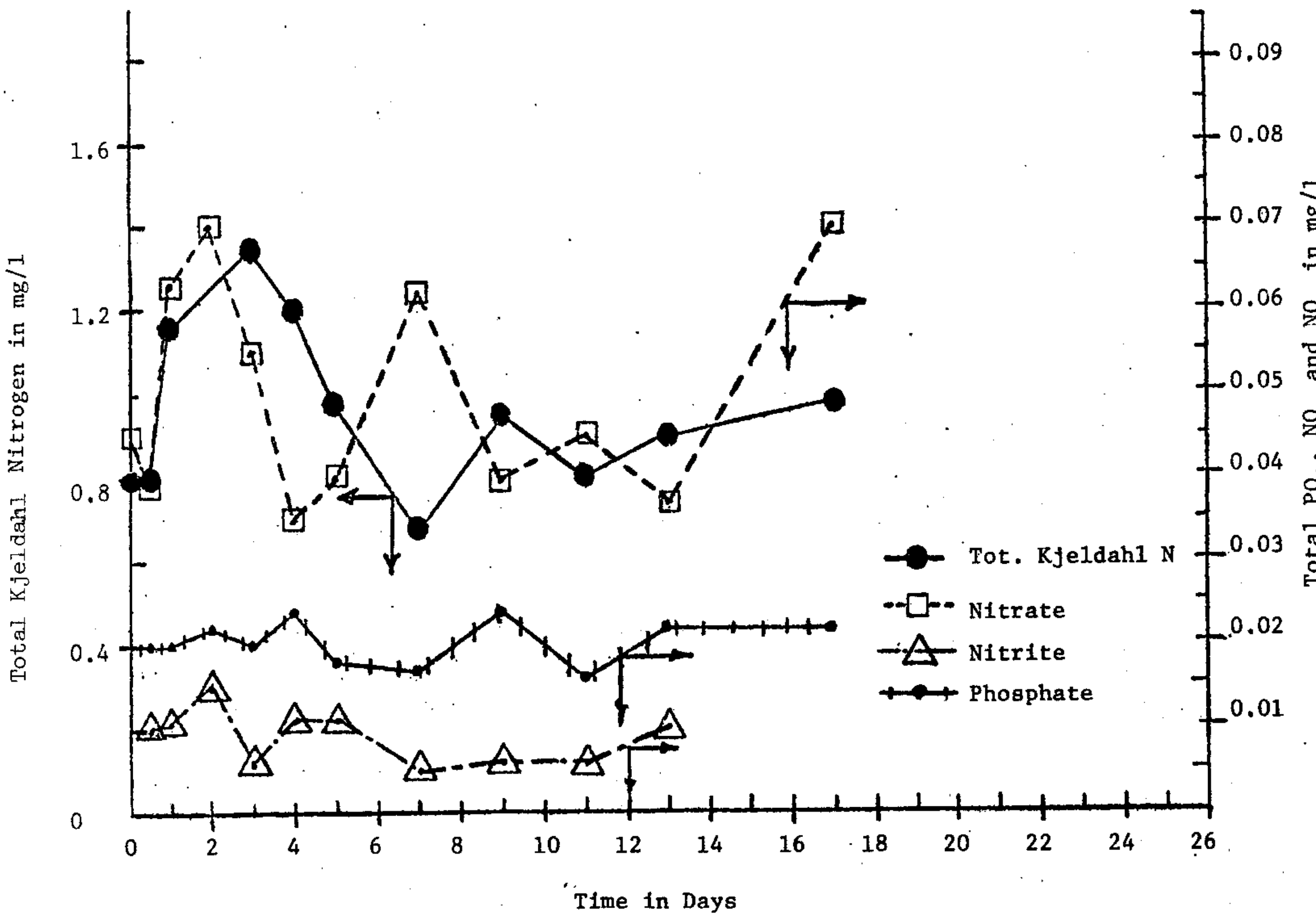


Figure 17: Nutrient Concentrations with Time for Aerated Samples of Pine Needles (Test Series 3)

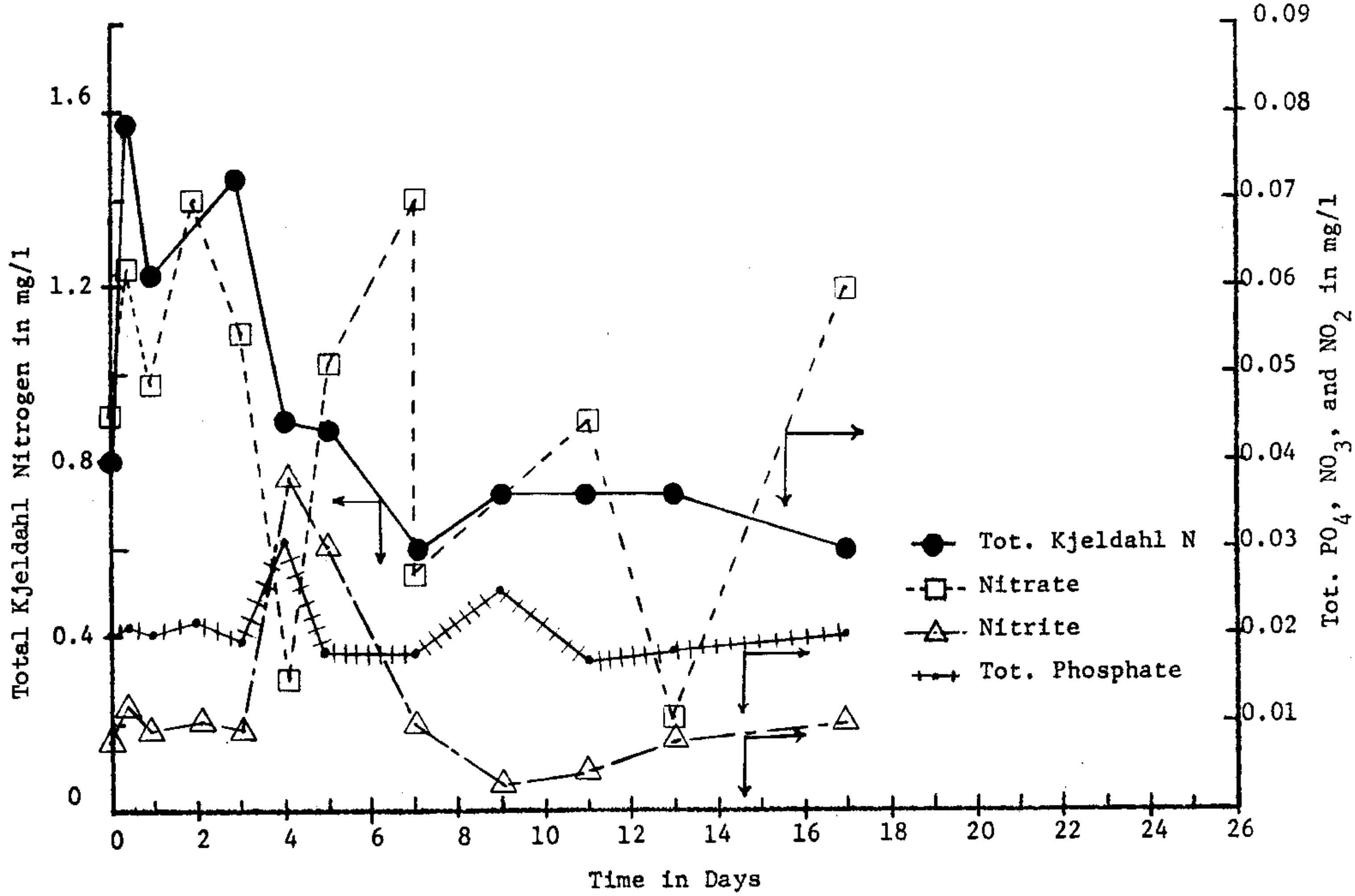


Figure 18: Nutrient Concentrations with Time for Aerated Samples of Cedar Leaves (Test Series 3)

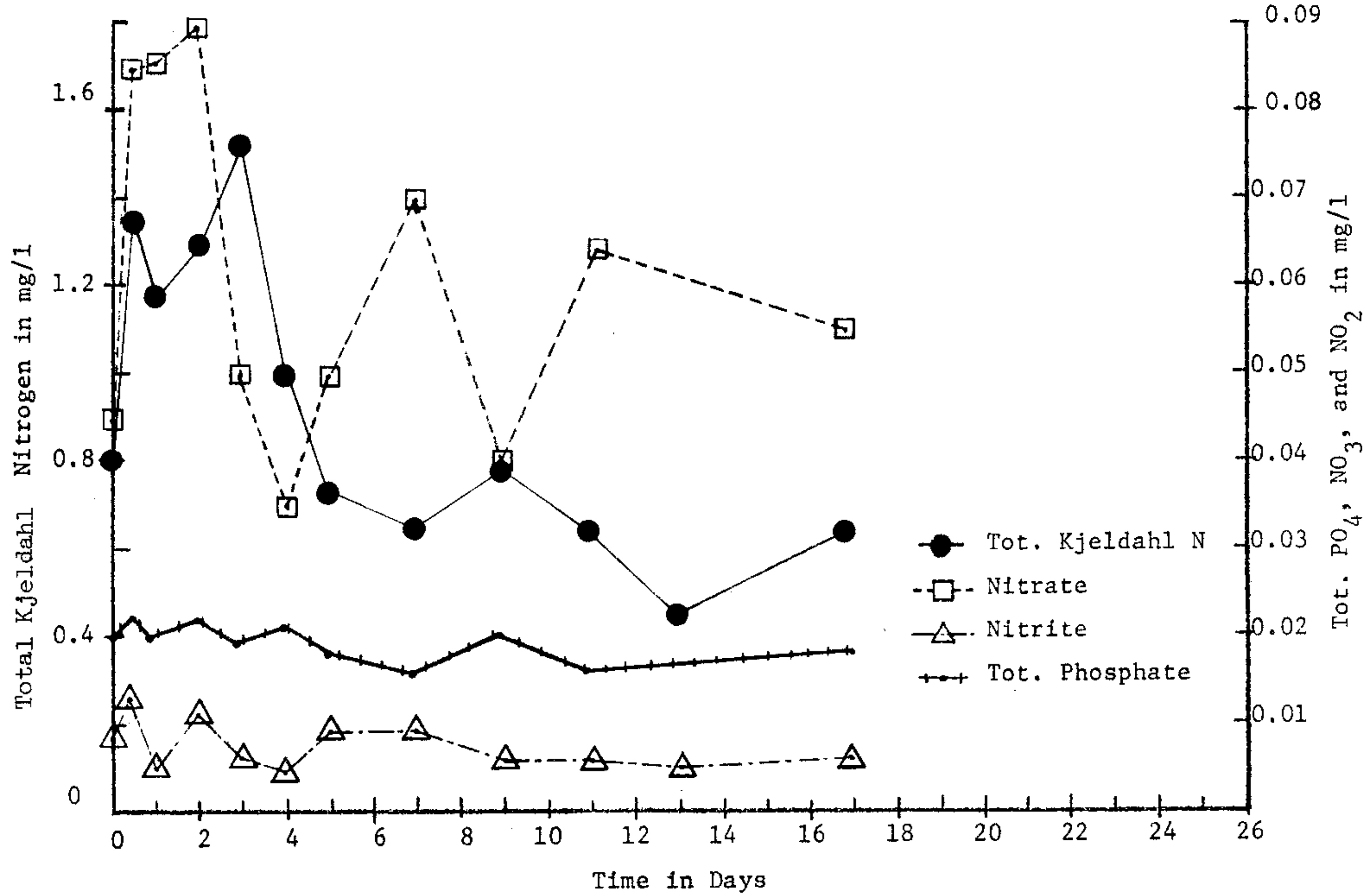


Figure 19: Nutrient Concentrations with Time for Aerated Samples of Post Oak Leaves (Test Series 3)

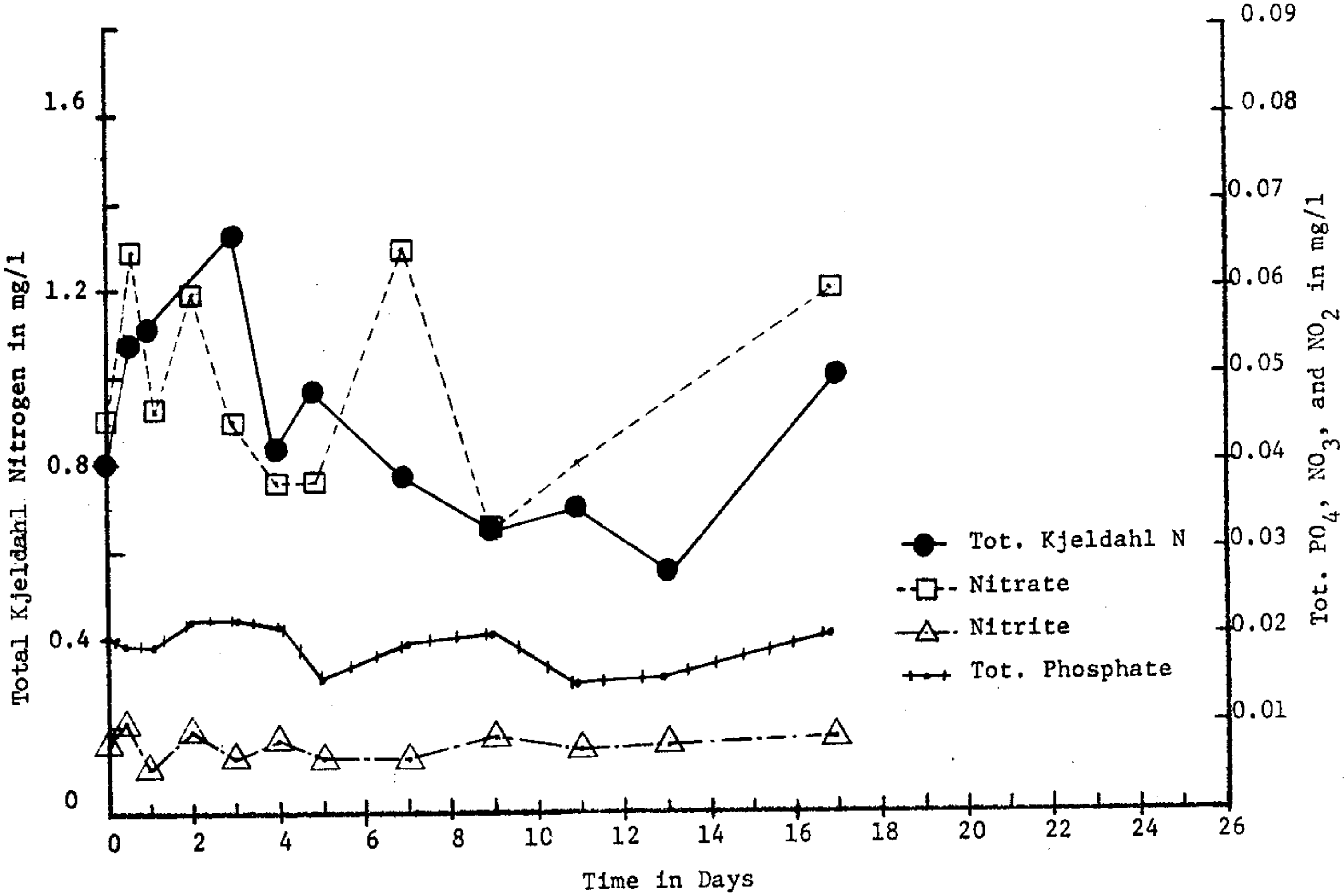


Figure 20: Nutrient Concentrations with Time for Aerated Samples of Mesquite Leaves (Test Series 3)

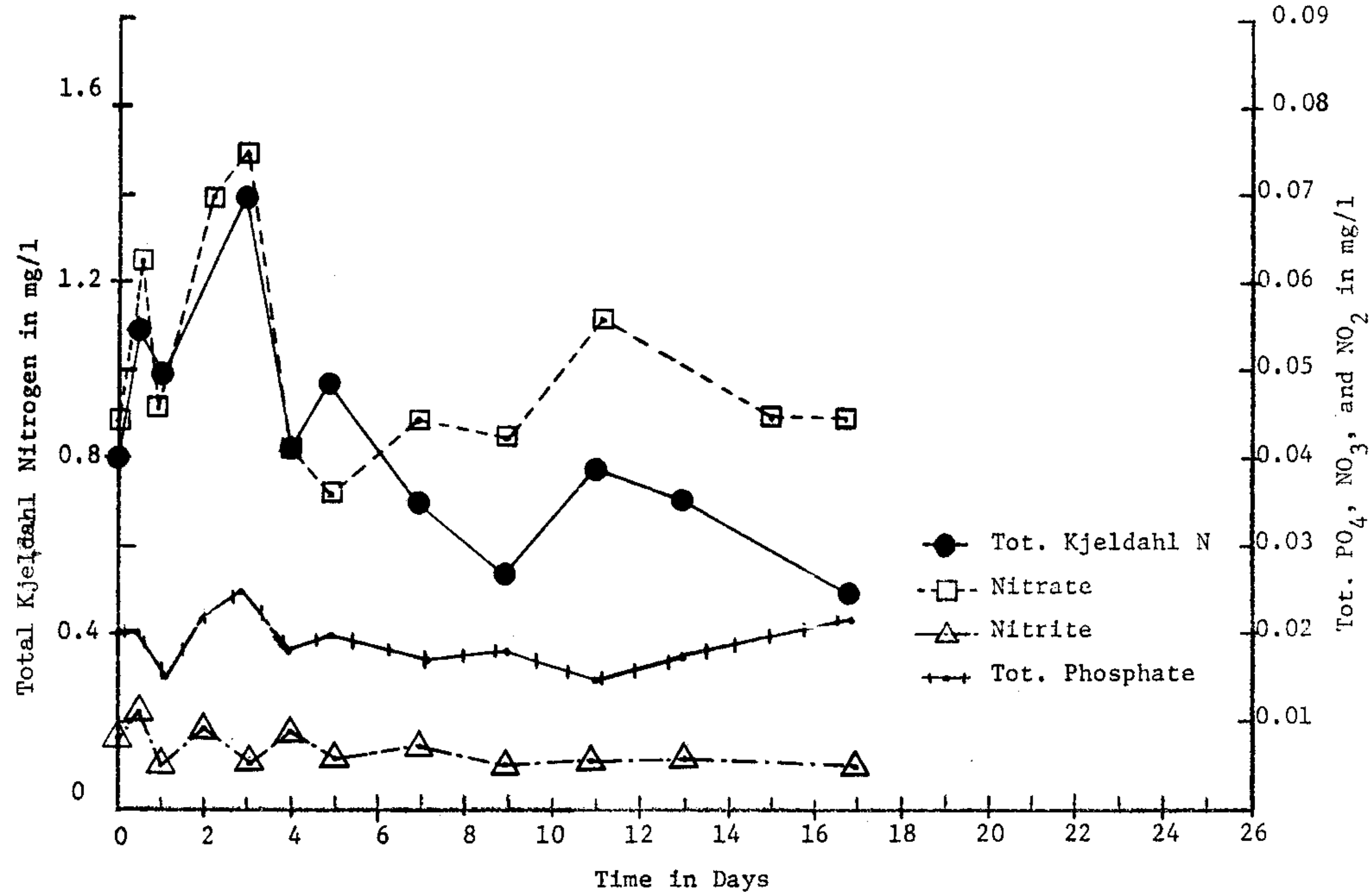


Figure 21: Nutrient Concentrations with Time for Aerated Samples of Hackberry Leaves (Test Series 3)

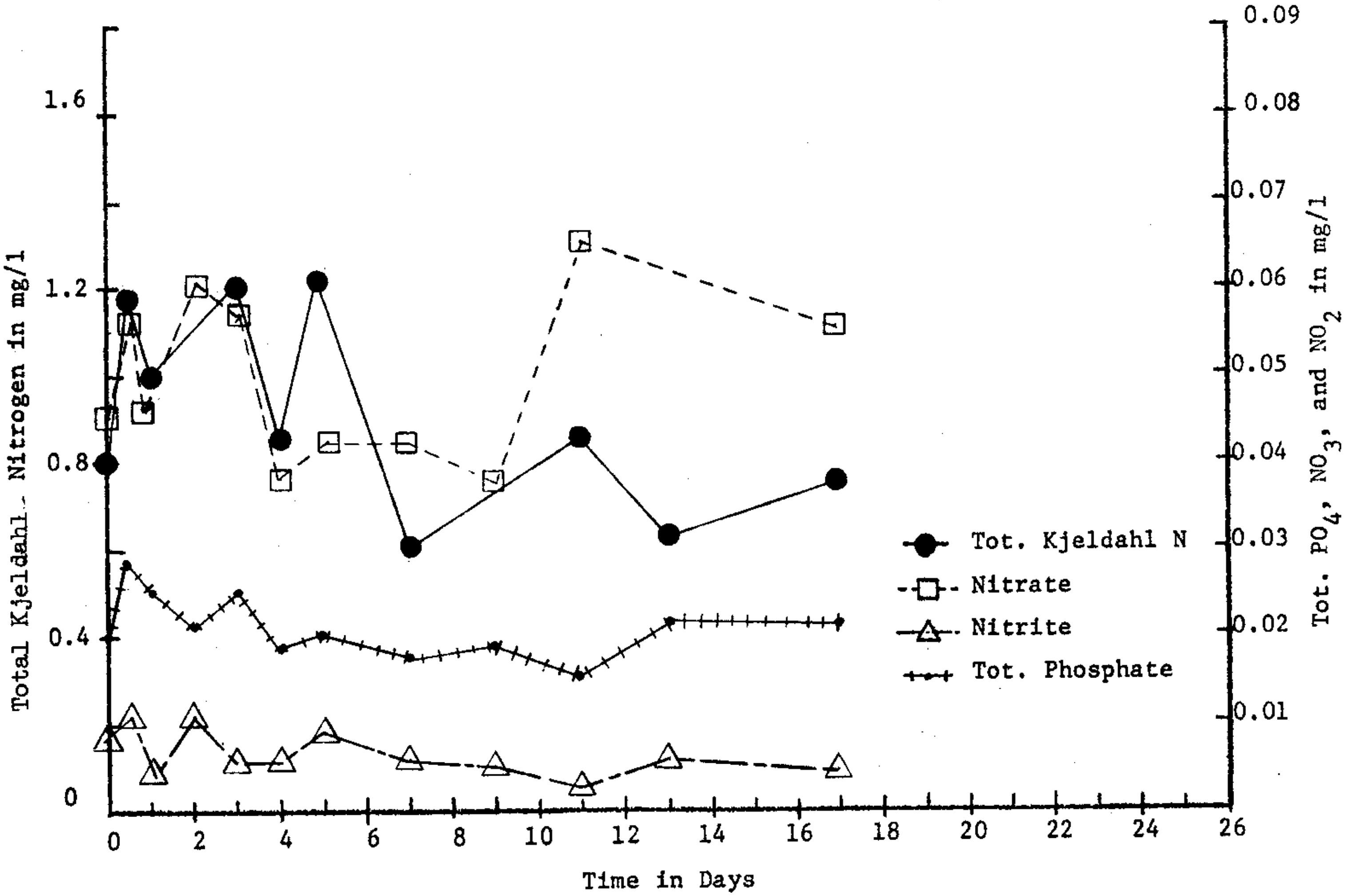


Figure 22: Nutrient Concentrations with Time for Aerated Samples of American Elm Leaves (Test Series 3)

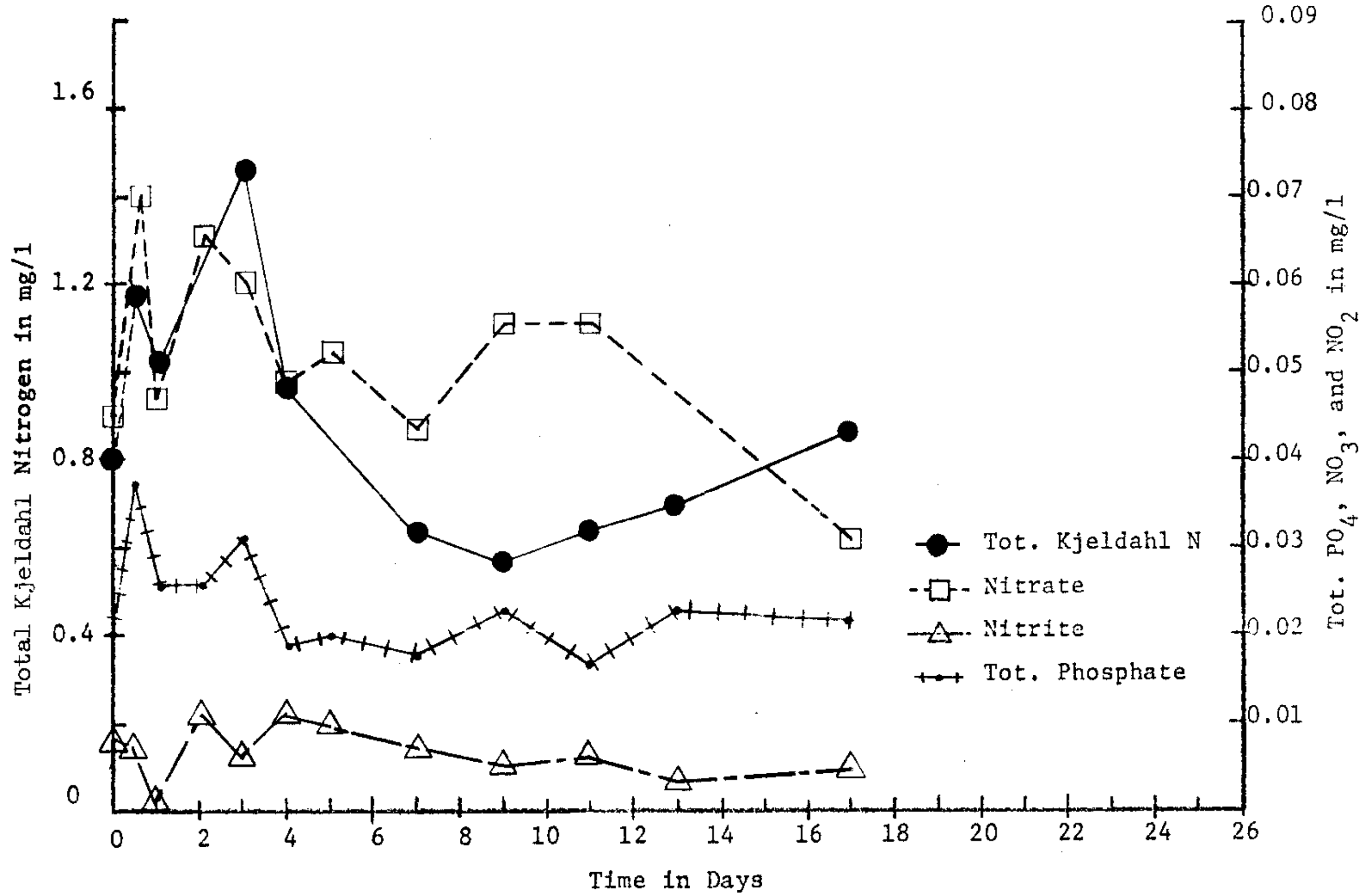


Figure 23: Nutrient Concentrations with Time for Aerated Samples of Black Willow Leaves (Test Series 3)

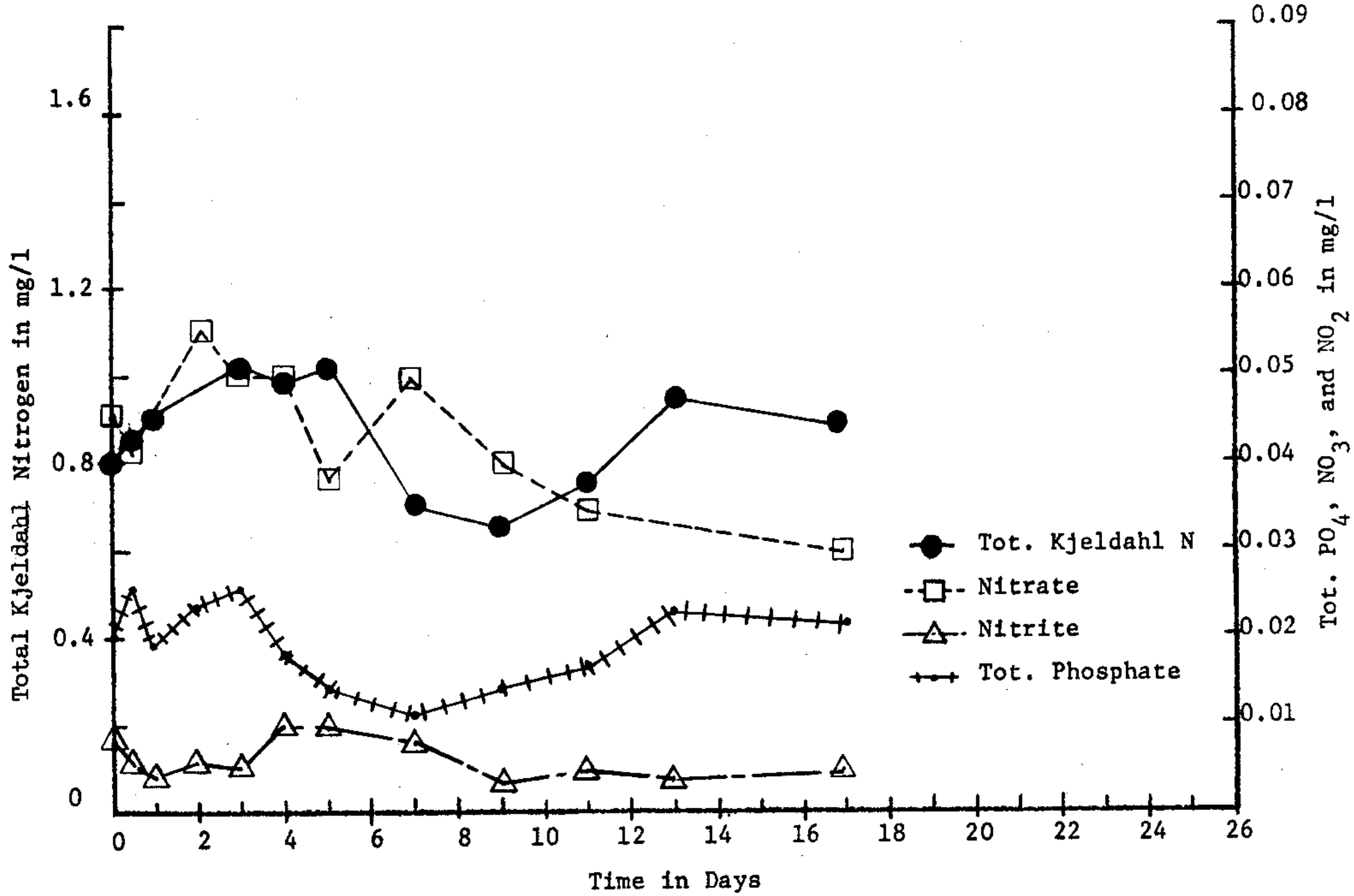


Figure 24: Nutrient Concentrations with Time for Control Sample (Test Series 3)

from all tree leaves but in smaller quantities than from Bermuda grass. The data shows that Kjeldahl nitrogen leached rapidly over the first three or four days and then leveled off to a concentration at or below the original concentration in the water. Nitrate concentrations increased during leaching and tended to remain at a concentration at the end of the run slightly higher than the nitrate concentration in the control. Nitrite concentrations showed no significant change during the leaching period. This may be due to the aerobic conditions. Quantitatively, the leaves added a maximum of 0.4 mg/l total Kjeldahl nitrogen to the water from 0.8 grams of leaves per liter of solution.

Nutrient Leaching from Grasses and Weeds

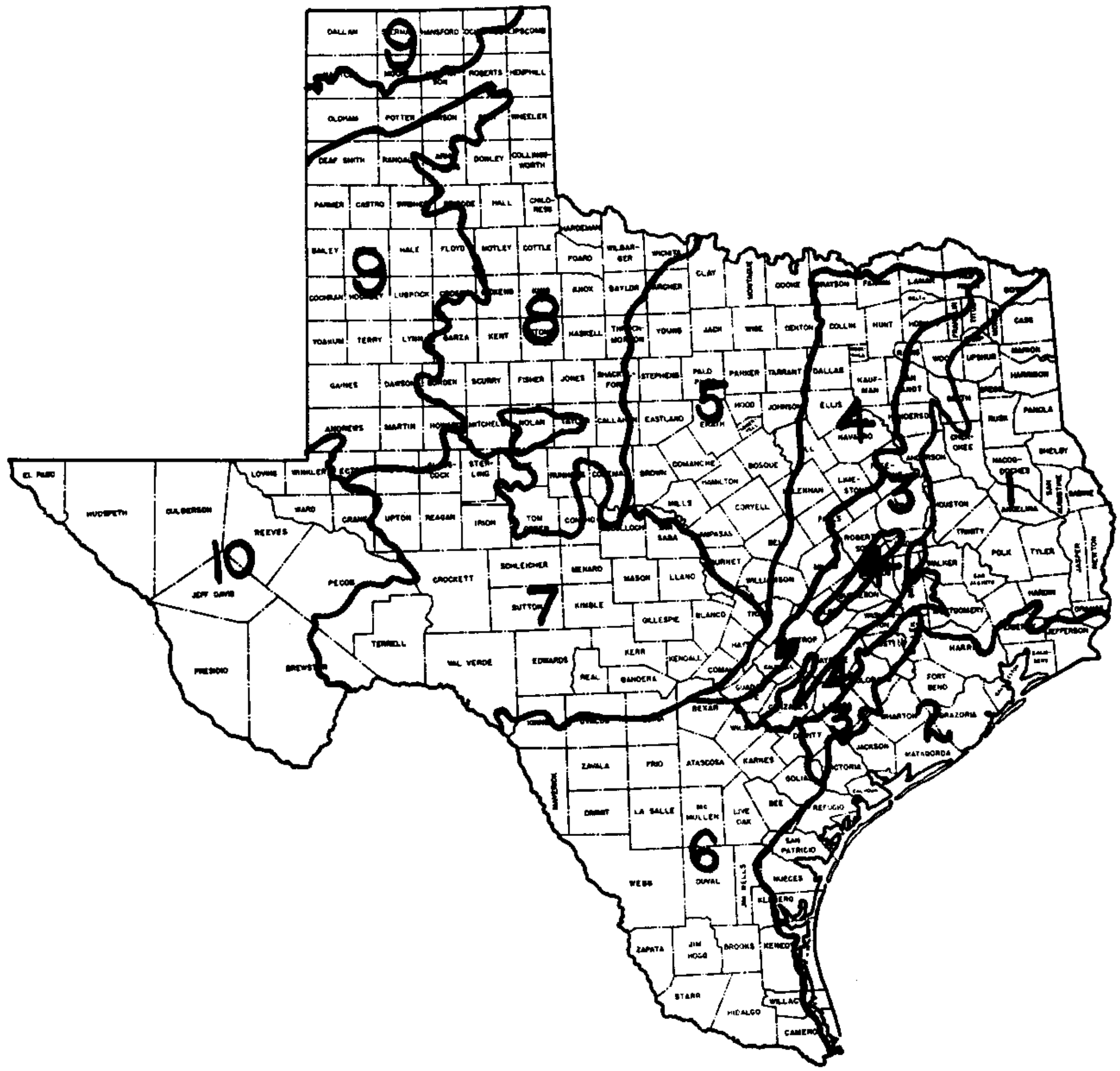
Five species of grasses and two common weeds were chosen for leaching series 4. Table 5 presents the grasses and weeds used listed by common names, scientific names, and areas of Texas where commonly found. The areas listed in the table correspond to areas shown on the map of Texas in Figure 25. Grasses were chosen on the basis of: 1) geographical range, 2) morphological aspects, 3) taxonomic relationship, and 4) abundance in Texas. Generally, the grasses were representatives of a common group such as the love grasses, panicums, and blue stems. The weeds were selected based on geographical range and abundance. Practical consideration severely limited the number of species used in this series of leaching runs.

The grasses and weeds were leached over a fifteen day period beginning on July 16, 1974. Total Kjeldahl nitrogen, nitrate-nitrogen, nitrite-nitrogen, and total phosphorous were determined at intervals over the fifteen day period. Figures 26-33 present the results of leaching

Table 5

Grasses Used in Test Series 4

Common Name	Scientific Name	Areas
Silver Bluestem	*Bothriochloa saccharoides var. torreyana*	All areas
Bermuda Grass	*Cynodondactylon*	All areas
Plains Love Grass	*Eragrostis intermedia*	2,3,4,5,6,7,8,10
Meadow Dropseed	*Sporobolus asper lookeri*	1,2,3,4,5,6,7,8
Blue Paricum	*Panicum antidotale*	2,3,4,6,7,8,9



Vegetational Areas of Texas

1. Pineywoods
2. Gulf Prairies and Marshes
3. Post Oak Savannah
4. Blackland Prairies
5. Cross Timbers and Prairies
6. South Texas Plains
7. Edwards Plateau
8. Rolling Plains
9. High Plains
10. Trans-Pecos, Mountains and Basins

Adapted from TAES L-492, "Vegetational Areas of Texas."

Figure 25: Vegetation Areas of Texas

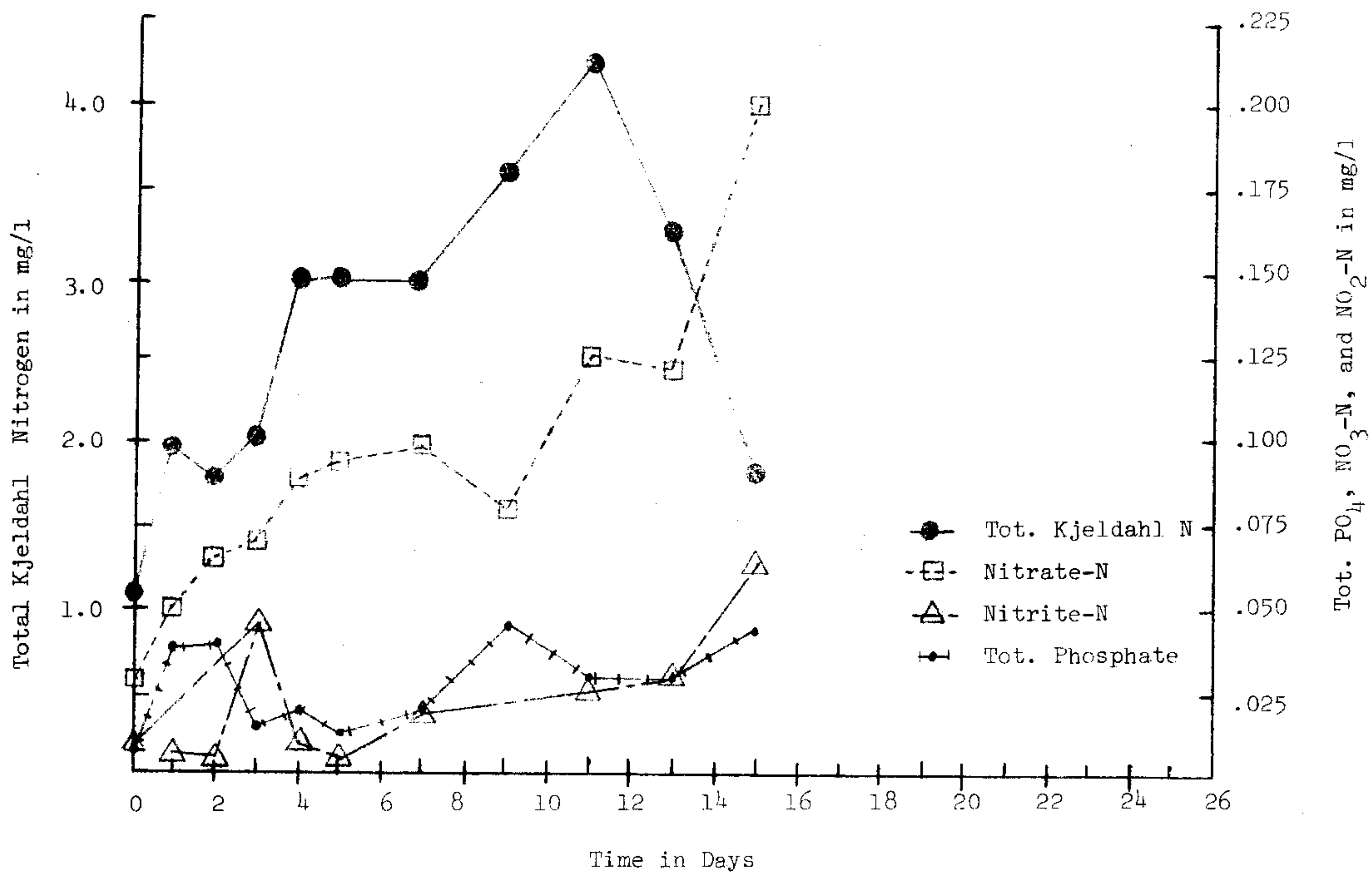


Figure 26: Nutrient Concentrations with Time for Aerated Samples of Plains Love Grass (Test Series 4)

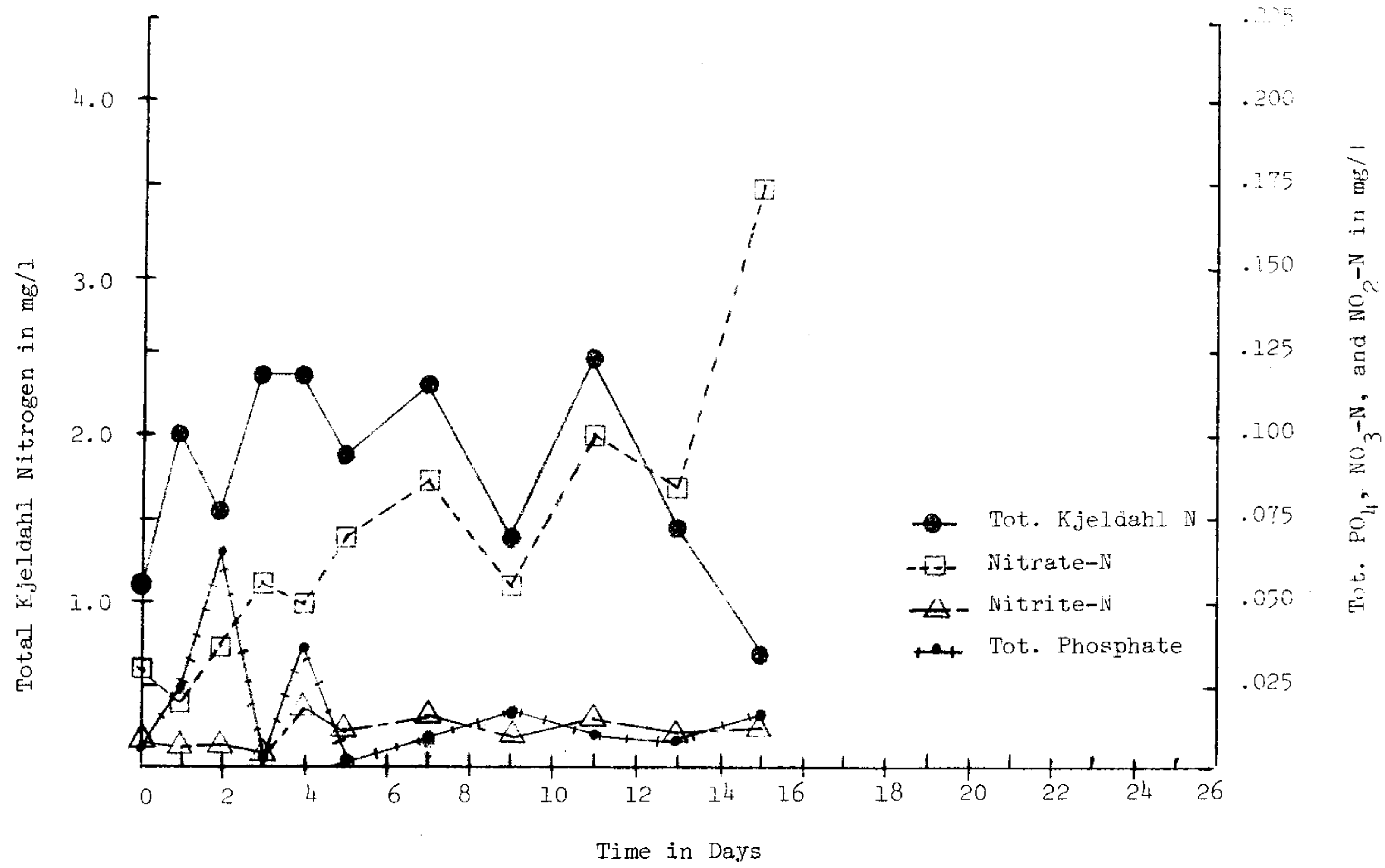


Figure 27: Nutrient Concentrations with Time for Aerated Samples of Meadow Dropseed Grass (Test Series 4)

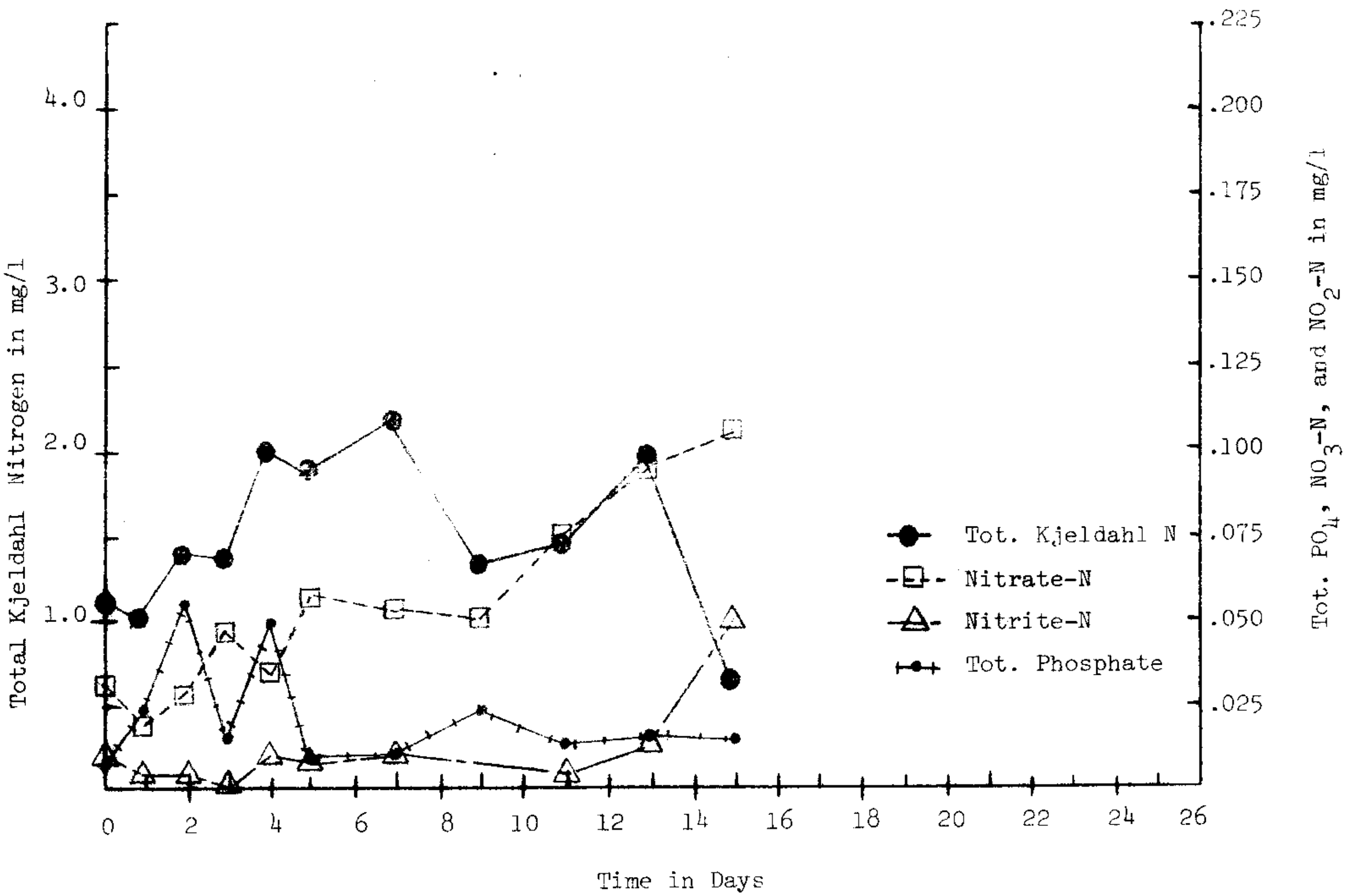


Figure 28: Nutrient Concentrations with Time for Aerated Samples of Bermuda Grass (Test Series 4)

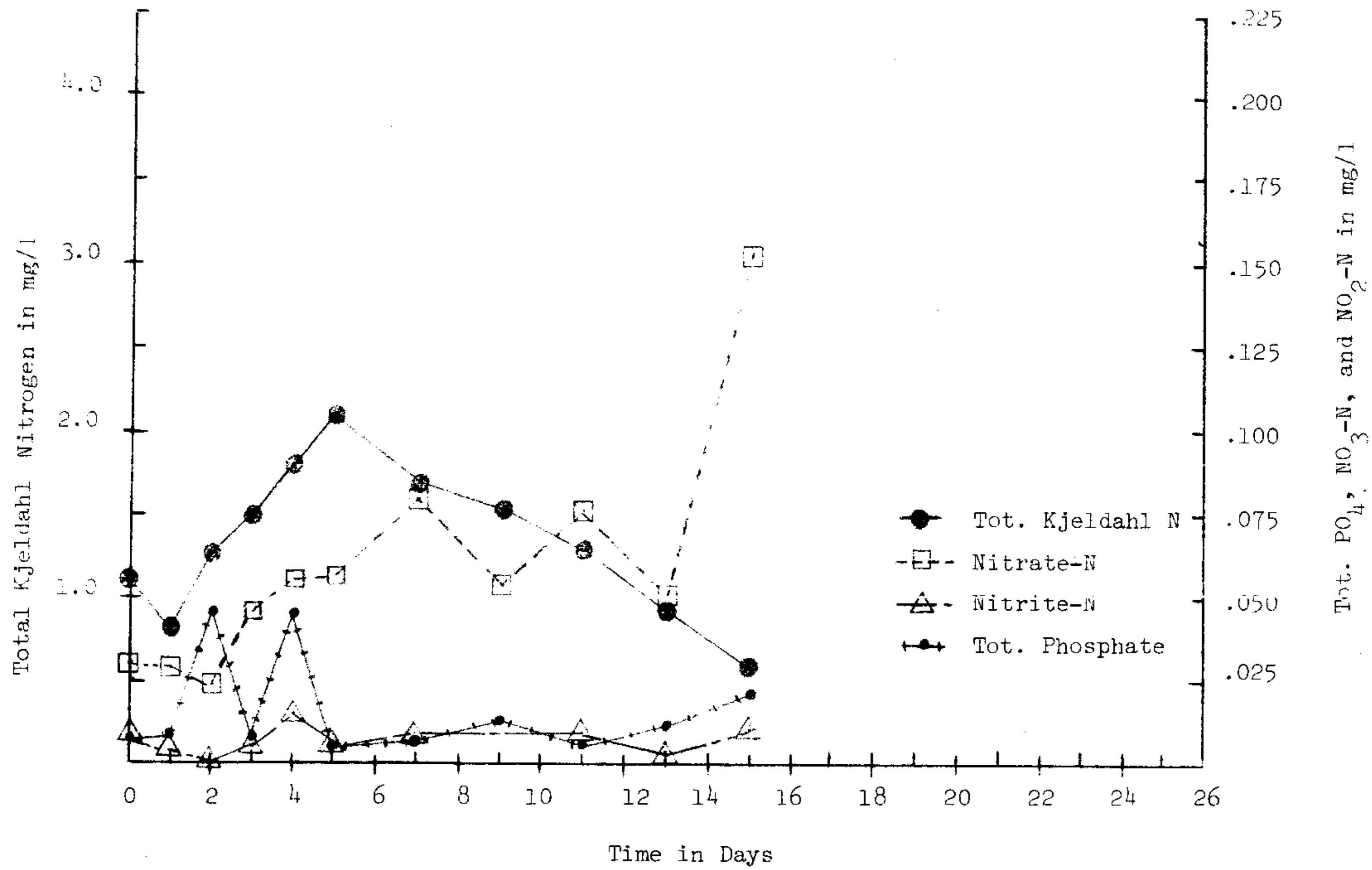


Figure 29: Nutrient Concentrations with Time for Aerated Samples of Silver Bluestem Grass (Test Series 4)

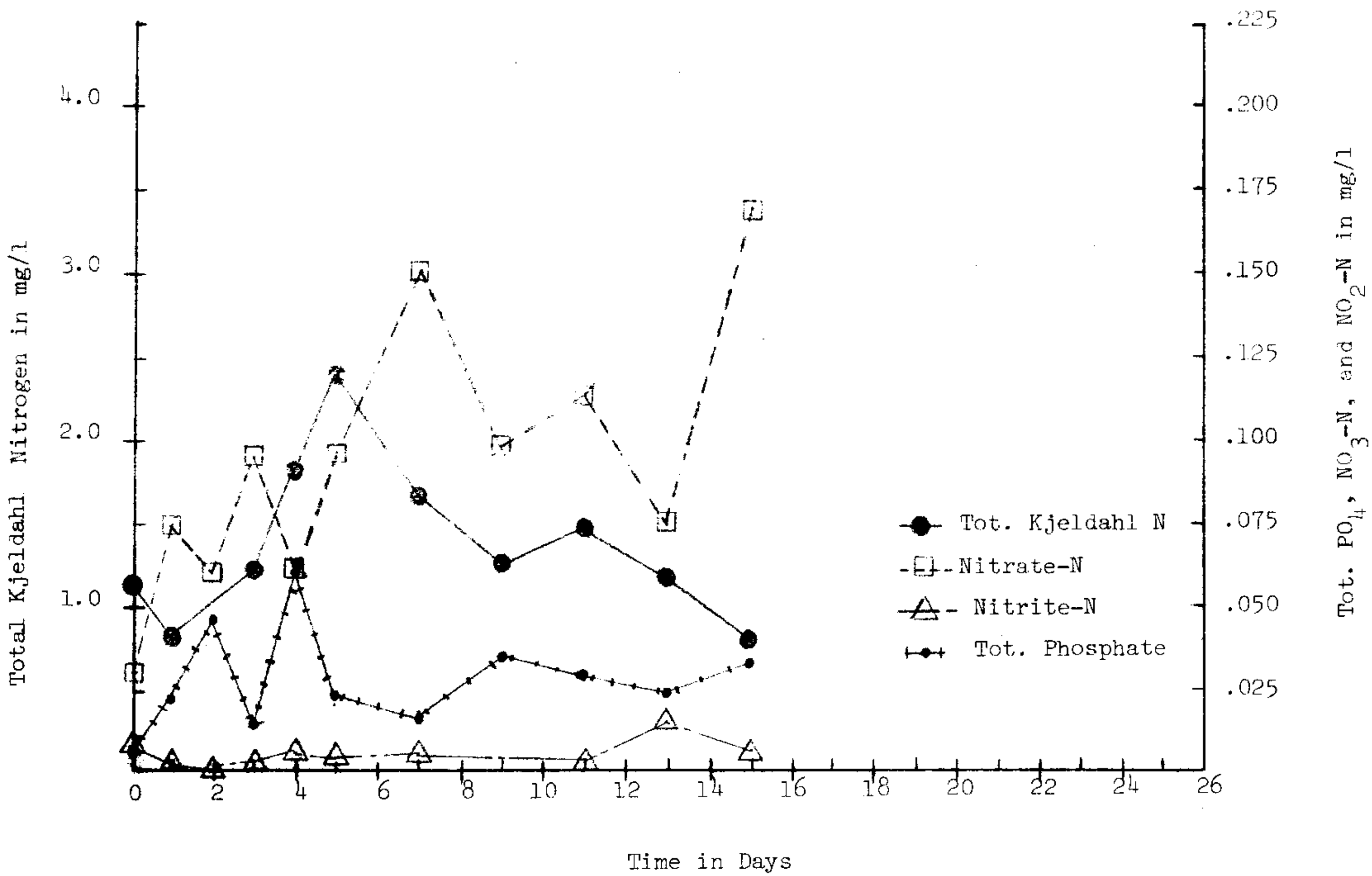


Figure 30: Nutrient Concentrations with Time for Aerated Samples of Blue Panicum Grass (Test Series 4)

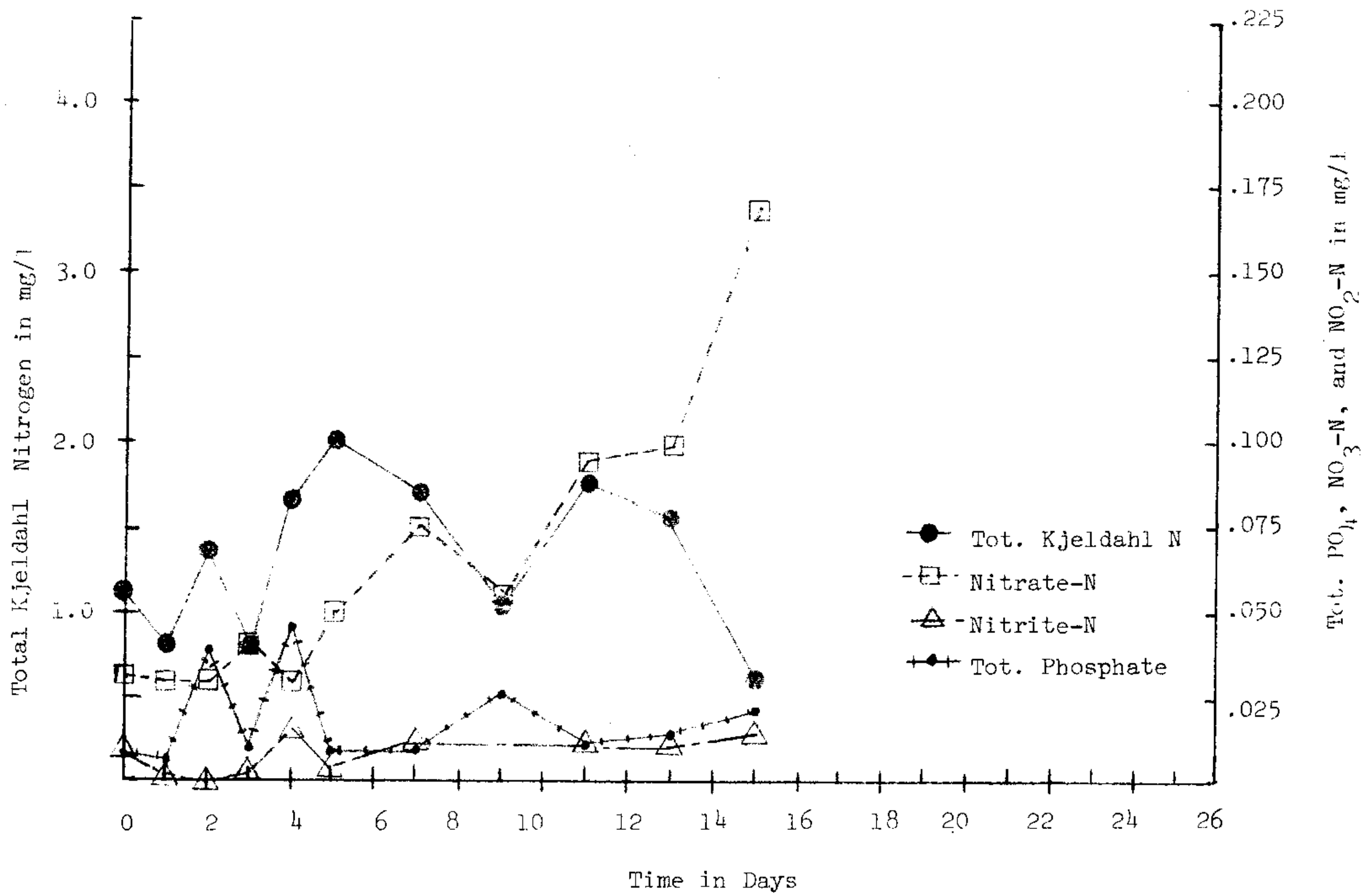


Figure 31: Nutrient Concentrations with Time for Aerated Samples of Goatweed (Test Series 4)

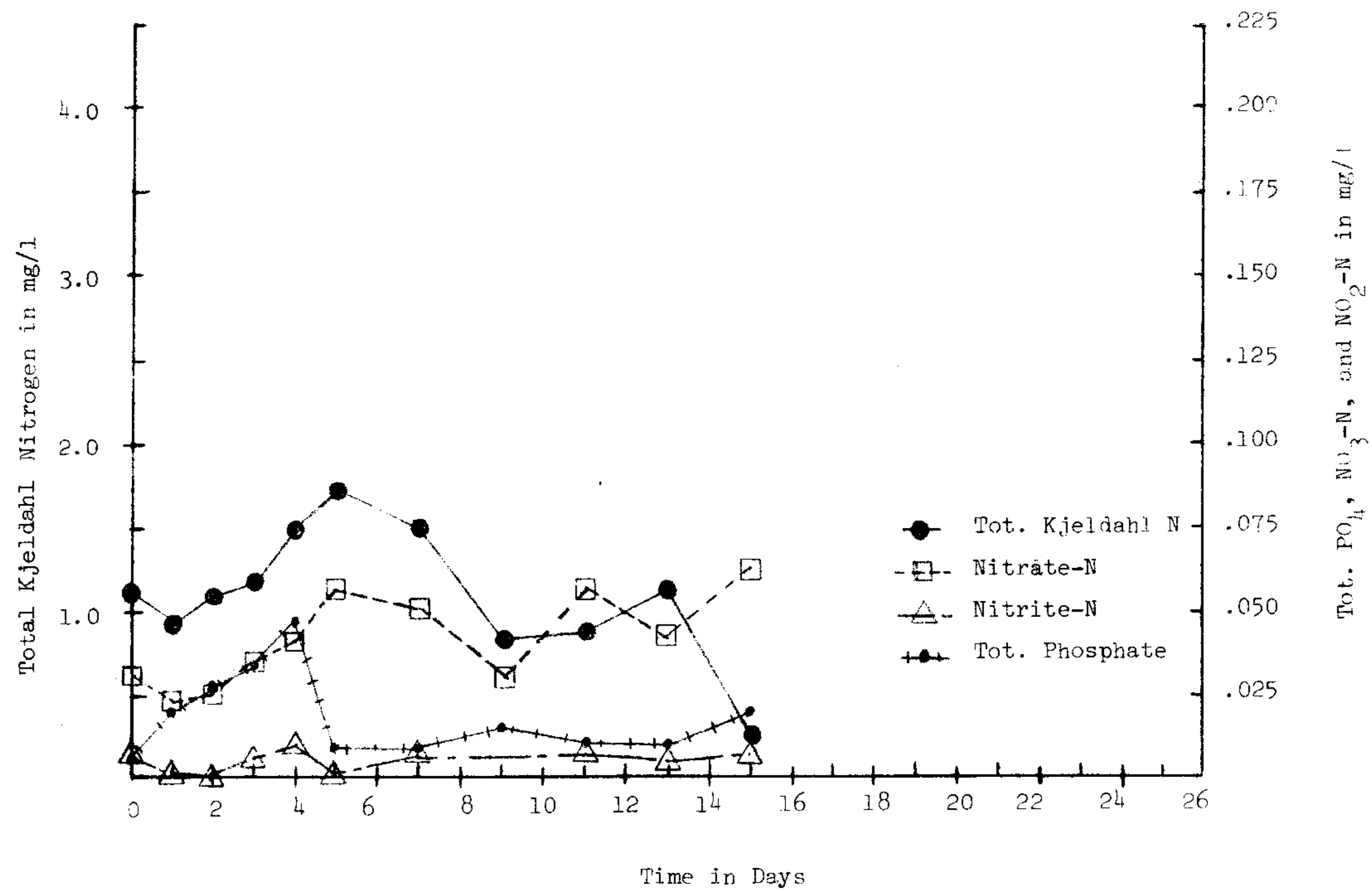


Figure 32: Nutrient Concentrations with Time for Aerated Samples of Giant Ragweed (Test Series 4)

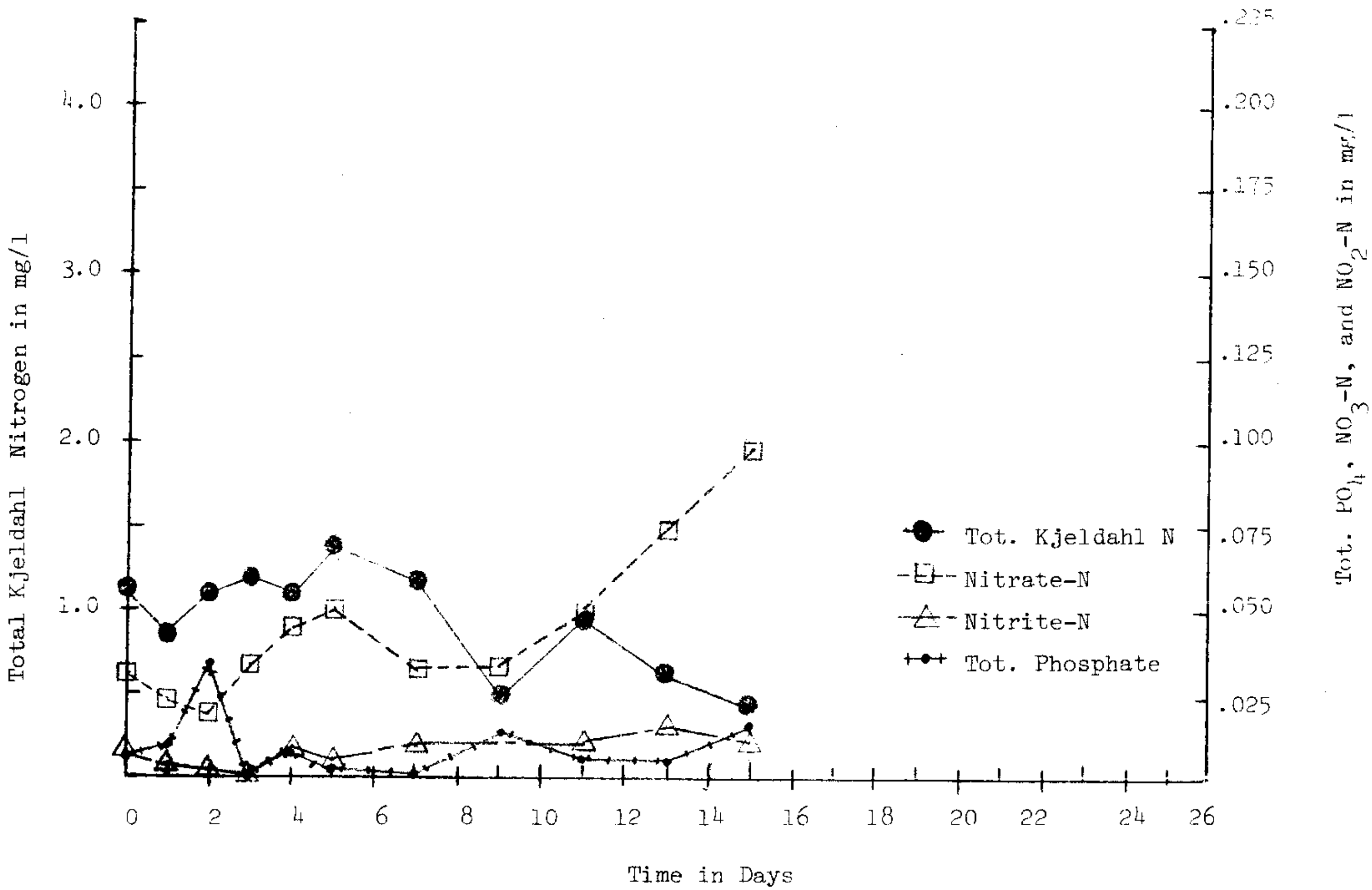


Figure 33: Nutrient Concentrations with Time for Aerated Control (Test Series 4)

series 4 for each species tested and for the control tank which contained Lake Somerville water only.

Results indicate that little phosphorous leached in the tanks containing vegetation. Several tanks indicated a double spike at days two and four; however, this may be due to experimental error as indicated by the fact that a spike in total phosphorous concentration appears at day 2 in the control tank. The maximum leaching of total phosphorous at the end of the 14 day period occurred in the tank containing Plains Love Grass. This also corresponded to a higher level of nitrogen leaching for this vegetation. Blue Panicum grass also indicated a definite trend toward releasing phosphorous over the period.

Kjeldahl nitrogen concentrations showed little variation between tanks except in the tank containing Plains Love Grass where significantly more nitrogen was released. While all species released measurable quantities of nitrogen, this species released nearly twice as much nitrogen as the others. The two weeds released smaller amounts of nitrogen than the grasses. Although leaching of nitrogen varied, a definite pattern for Kjeldahl and nitrate-nitrogen concentrations was observed. In each tank, Kjeldahl nitrogen concentration reached a maximum level after five to eight days and then gradually decreased to near or below initial levels by the end of the fifteen day period. The exception to this was the tank containing Plains Love Grass which achieved a maximum Kjeldahl concentration on the twelfth day and then decreased rapidly until the end of the period. Nitrate-nitrogen concentrations in each tank generally increased slowly over the first ten to twelve days and then increased rapidly to the fifteenth day. Nitrite levels showed little change over the run except for a slight increase at the end of the period. The above data trend is commonly explained by the nitrogen being initially released as organic nitrogen and/or ammonia, only to be readily oxidized to nitrite and nitrate-nitrogen. A six week leaching run, to be discussed later, shows this pattern of nitrogen release and conversion more clearly.

When comparing leaching data for grass, weeds, and leaves under similar conditions, it appears that grass leaches nutrients at a faster rate than tree leaves. Phosphate leaching from both grasses and tree leaves was minimal although grasses leached somewhat more phosphorous. This may be explained by the more rigid structure and thicker protective layers found in tree leaves. Surface area to volume ratios are also probably a significant factor.

Long Term Leaching Series

The final leaching run (series 5) was performed over a period of six weeks beginning September 28, 1974. The following plant species or tissue types were used as vegetation samples:

Grasses:

1. Green Bermuda grass
2. Dry Bermuda grass

Needles and Leaves:

3. Green Pine needles
4. Dry Pine needles
5. Green Post Oak leaves
6. Dry Post Oak leaves

Twigs and Bark:

7. Green Post Oak twigs
8. Dry Post Oak twigs
9. Green Pine twigs

10. Dry Pine twigs
11. Mesquite bark
12. Post Oak bark
13. Pine bark

Samples were collected at weekly intervals and analyzed for total Kjeldahl-nitrogen, nitrate-nitrogen, nitrite-nitrogen, and total-phosphorous. In addition, percent composition of nitrogen and phosphorous for leaves was determined.

The objectives of this leaching series were to:

1. Compare leaching rates of grasses, tree leaves, twigs, and bark,
2. Determine the effects of decomposition state on leaching rates of different vegetation types, and
3. Determine the percentage of total weight for nitrogen and phosphorous in leaves and grasses.

Phosphorous. Figures 34-37 present leaching rates for total phosphorous from grasses, tree leaves, twigs and bark, respectively. The results show that Bermuda grass, whether green or dry, releases much greater amounts of total phosphorous than tree leaves, twigs or bark which released small amounts. Table 6 shows that Bermuda grass leached about 7% of its total phosphorous content in the six week period. This percentage was obtained by subtracting the total amount of phosphorous in the control tank from the amount in the other tanks at the end of the six week period. The weight of phosphorous leached from each sample was then calculated. The weight percentage of phosphorous in each type of vegetation was determined analytically and a total weight of phosphorous obtained for each sample. The percentage of phosphorous leached was then

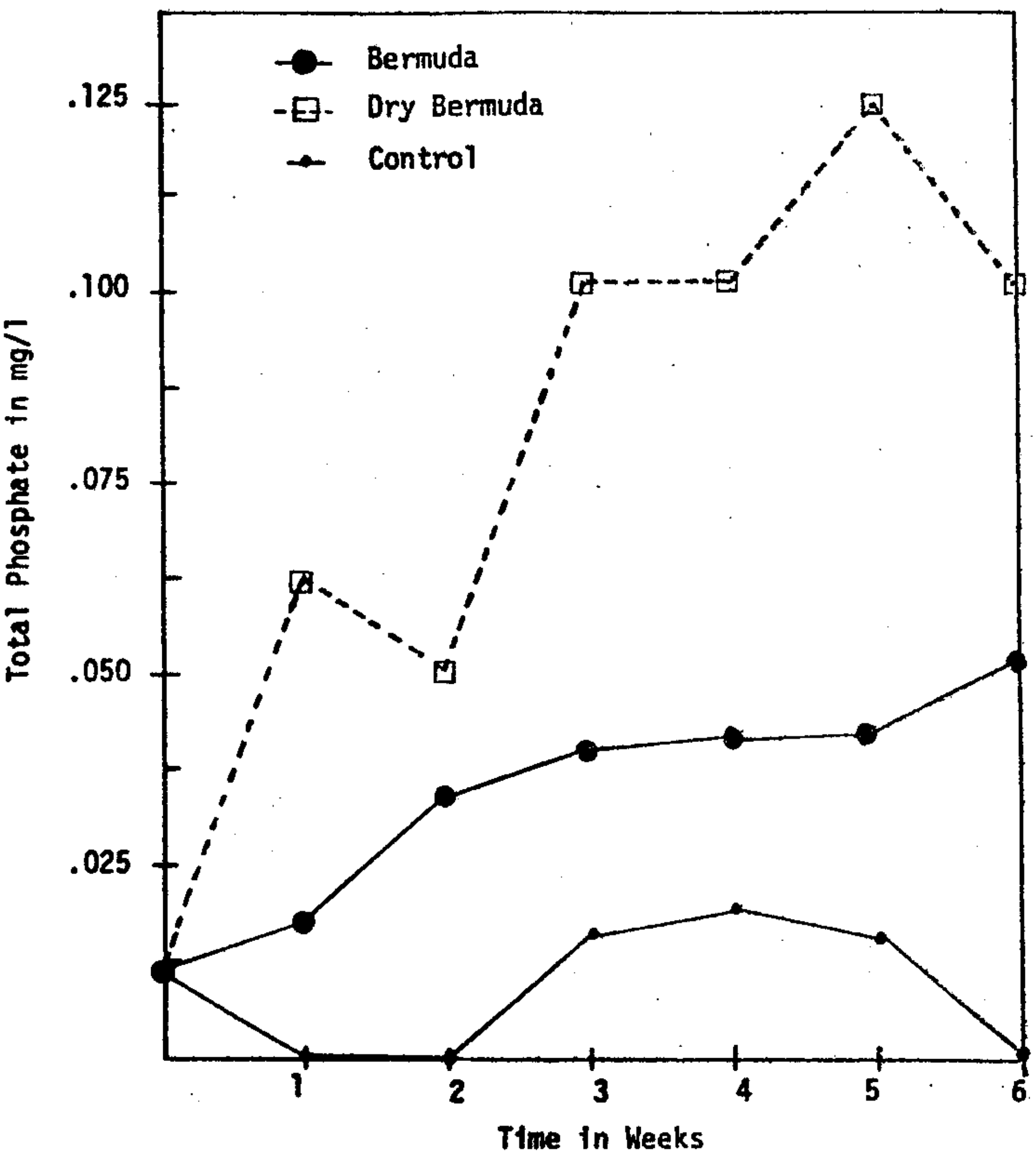


Figure 34: Total Phosphorous Concentration with Time for Aerated Samples of Green and Dry Bermuda Grass and Control (Test Series 5)

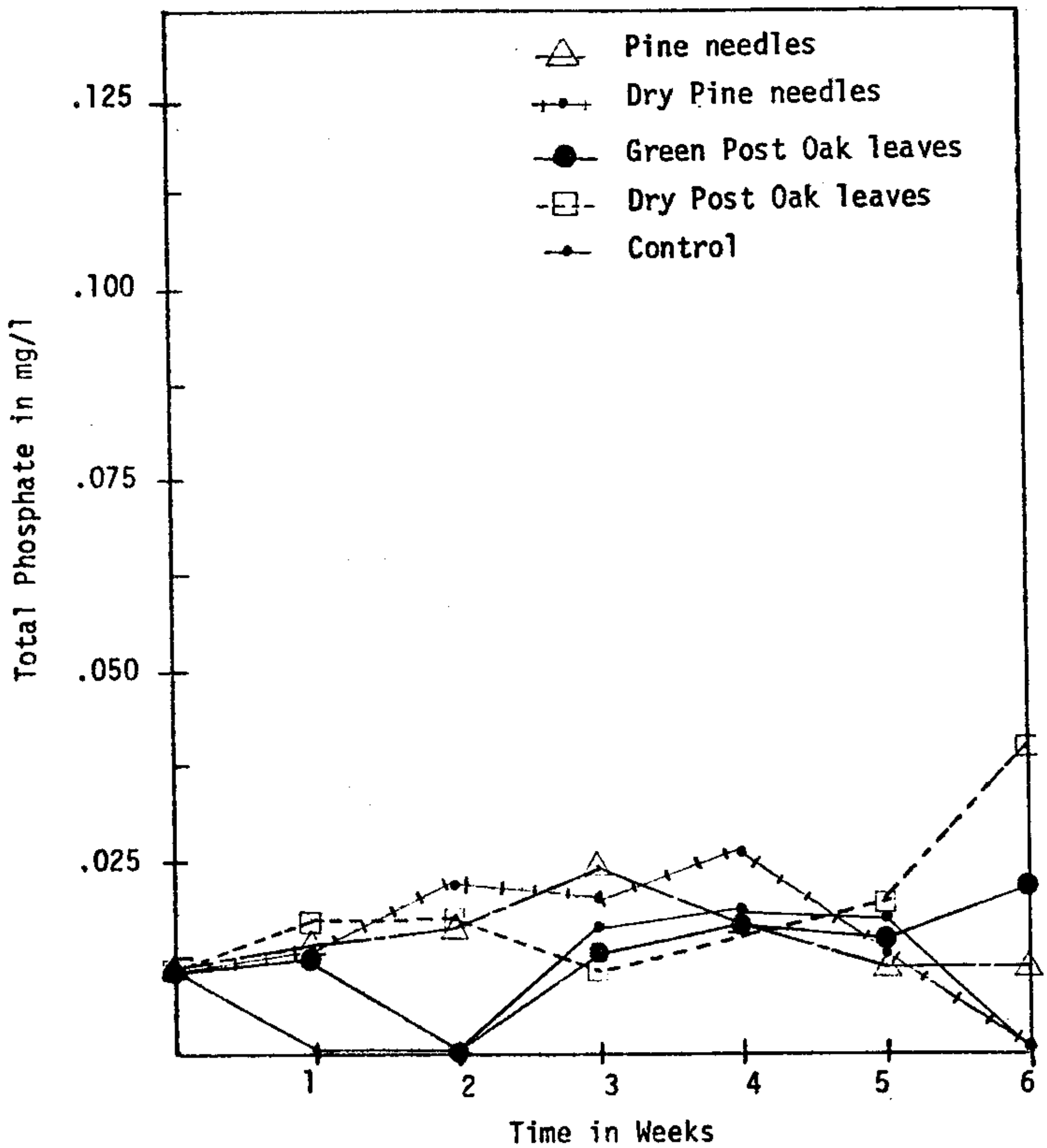


Figure 35: Total Phosphorous Concentration with Time for Dry and Green Pine Needles and Dry and Green Post Oak Leaves and Control (Test Series 5)

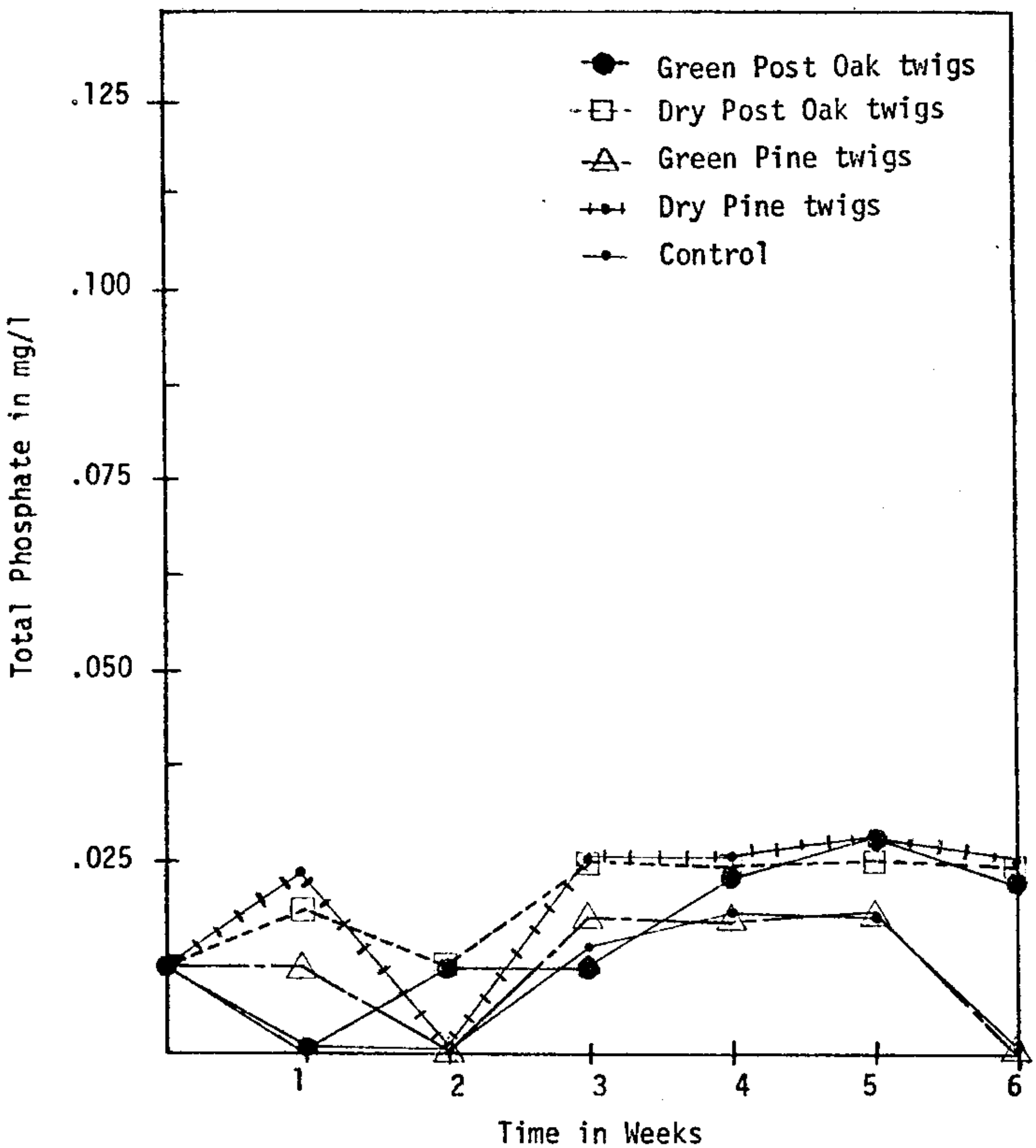


Figure 36: Total Phosphorous Concentràtion with Time for Dry and Green Post Oak Twigs and Dry and Green Pine Twigs and Control (Test Series 5)

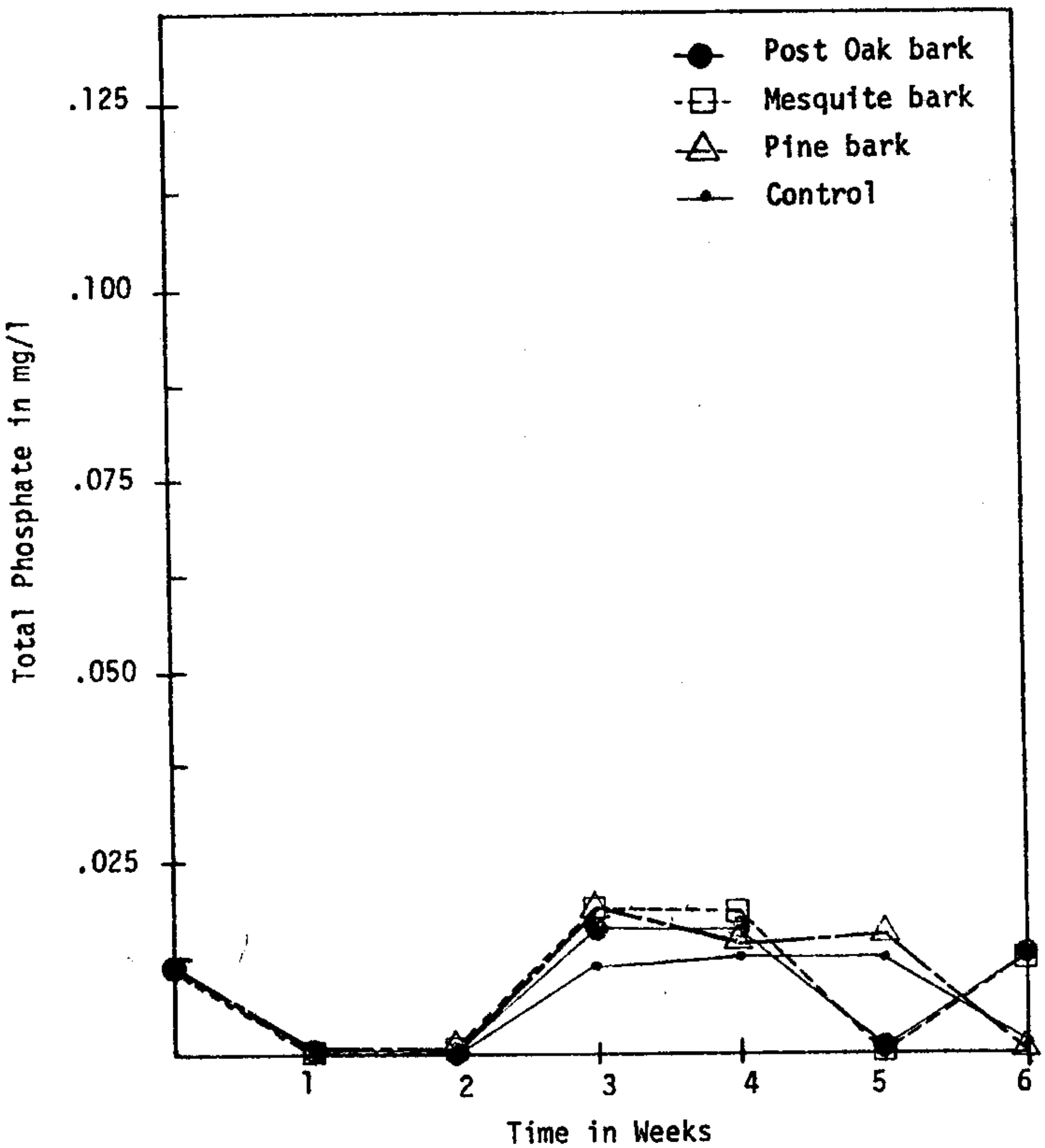


Figure 37: Total Phosphorous Concentration with Time for Post Oak, Mesquite and Pine Bark and Control (Test Series 5)

TABLE 6

PERCENTAGE OF PHOSPHOROUS LEACHED FROM VEGETATION FOR TEST SERIES 5

Sample	Dry Weight grams	P leached milligrams	P leached as a % of dry weight	% P dry weight	% P Leached of Total P
Bermuda grass (green)	6.2632	1.225	.02	.27	7.3
Bermuda grass (dry)	16.452	2.550	.02	.25	6.2
Pine Needles (dry)	18.654	0	0	.06	0
Pine Needles (green)	8.400	.025	0	.08	.4
Post Oak leaves (dry)	17.425	.875	.005	.12	4.2
Post Oak leaves (green)	10.320	.300	.003	.12	2.1
Post Oak twigs (dry)	19.235	.350	.003	---	---
Post Oak twigs (green)	16.570	.250	.002	---	---
Pine twigs (dry)	18.960	.275	.001	---	---
Pine twigs (green)	16.980	0	0	---	---

TABLE 6 (cont.)

Sample	Dry Weight grams	P leached milligrams	P leached as a % of dry weight	% P dry weight	% P Leached of Total P
Mesquite Bark	19.250	.025	0	---	---
Post Oak Bark	19.652	.075	0	---	---
Pine Bark	19.155	0	0	---	---

calculated from the ratio of phosphorous leached to the total weight of phosphorous in the original sample. An explanation for grass leaching a greater percentage of phosphorous could be that grasses possess a greater ratio of surface area to mass than other vegetation. The percentage of phosphorous leached from Bermuda grass was about the same for green or dry samples. The only other samples that leached significant percentages of phosphorous were dry and green post oak leaves. Dry leaves leached about twice as much of their potential phosphorous as green leaves.

Nitrogen. Figures 38-41 present the Kjeldahl nitrogen concentrations over the six week period. Results show that Bermuda grass leached nitrogen at a faster rate than the other vegetation types tested. Kjeldahl concentrations rose rapidly up to the third week in the tanks containing dry and green Bermuda grass. Tree leaves, bark, and twigs exhibited a slow increase in Kjeldahl concentrations up to the third or fourth week followed by a rapid increase toward the end of the leaching period. At the end of the six week period, Kjeldahl concentrations had either leveled off or were still rising depending upon the vegetation leached. Results indicate that with respect to release of Kjeldahl nitrogen, little difference exists between green and dry samples.

Unlike phosphorous leaching, bark released substantial amounts of nitrogen. This was particularly evident with Mesquite bark which showed Kjeldahl nitrogen concentration equivalent to those of Bermuda grass at the end of the leaching period. This may have been caused by leaching from large amounts of sap contained in the bark. Tree leaves leached less nitrogen than did bark or twigs, and post oak leaves, twigs, and bark leached greater amounts than did pine leaves, bark and twigs.

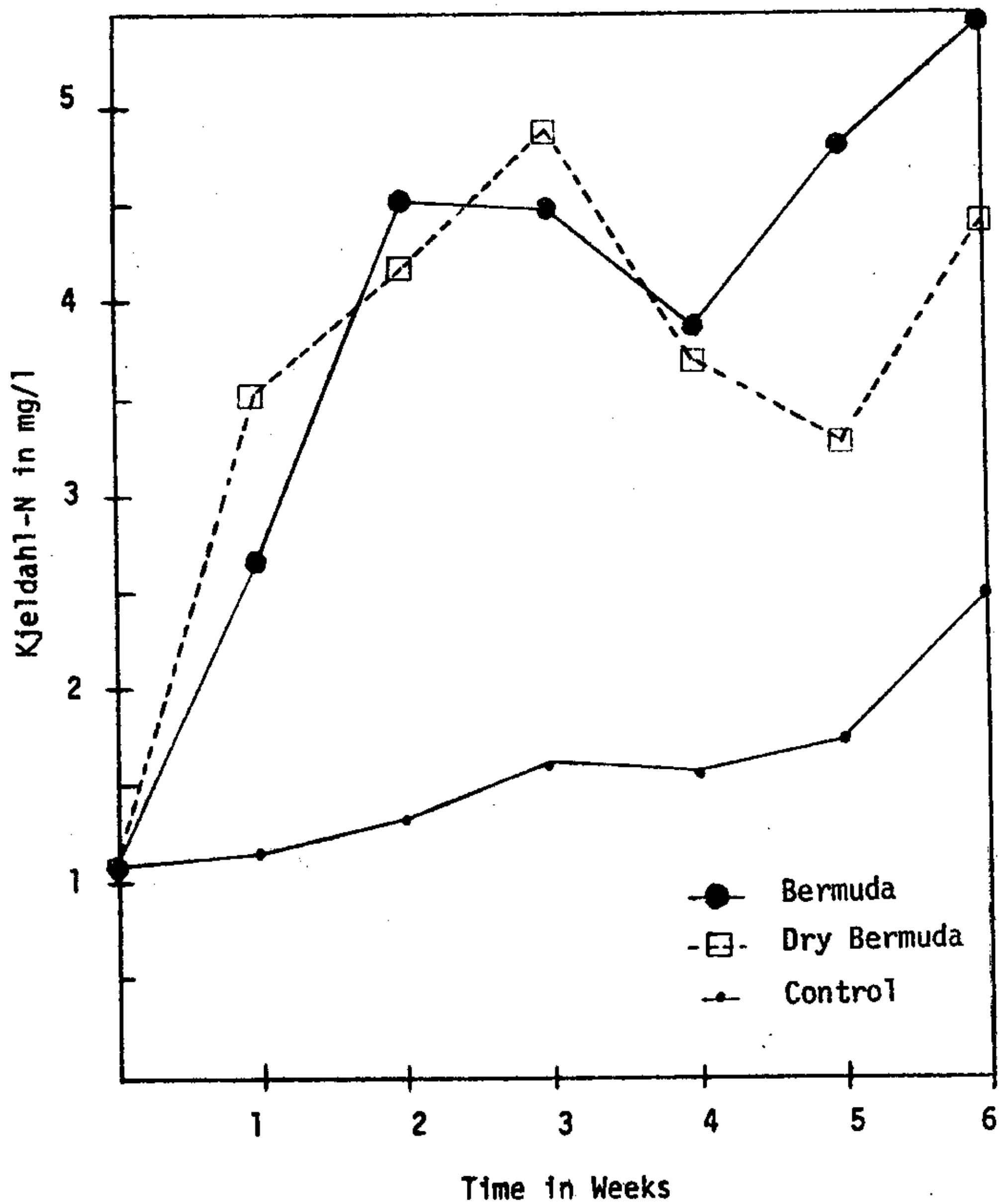


Figure 38: Kjeldahl Nitrogen Concentration with Time for Aerated Samples of Dry and Green Bermuda Grass and Control (Test Series 5)

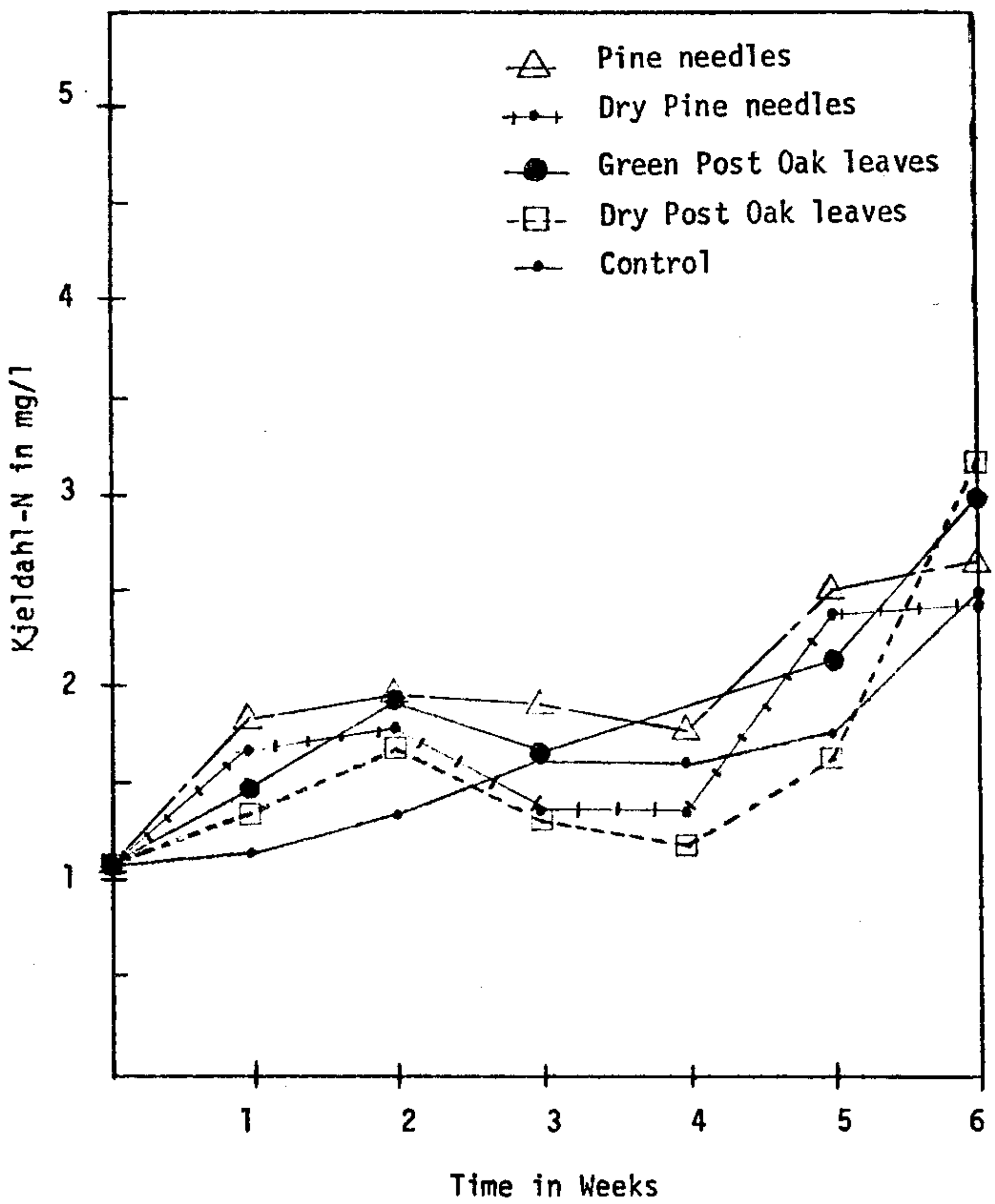


Figure 39: Kjeldahl Nitrogen Concentration with Time for Aerated Samples of Dry and Green Pine Needles, Dry and Green Post Oak Leaves and Control (Test Series 5)

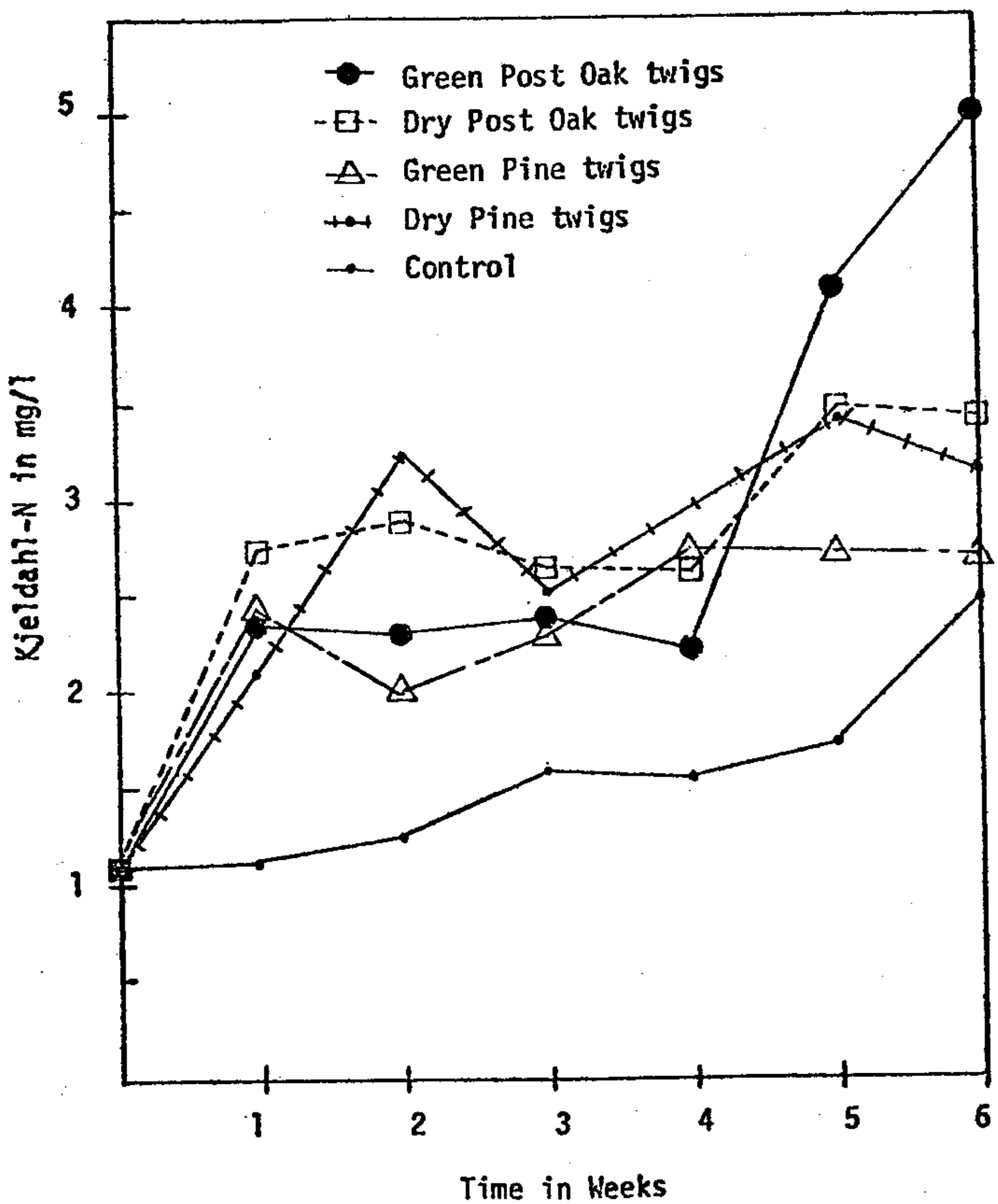


Figure 40: Kjeldahl Nitrogen Concentration with Time for Aerated Samples of Dry and Green Post Oak Twigs and Dry and Green Pine Twigs and Control (Test Series 5)

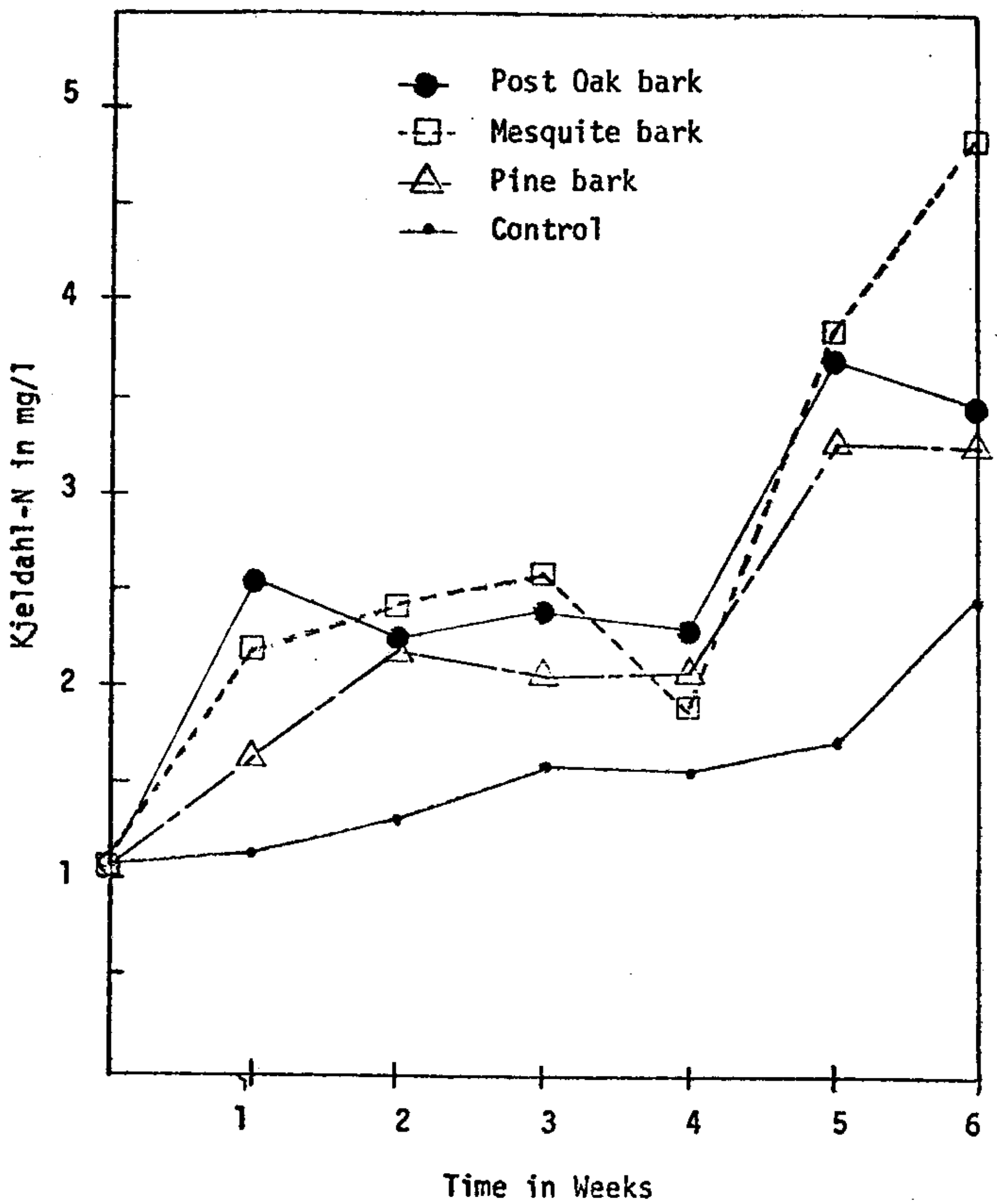


Figure 41: Kjeldahl Nitrogen Concentrations with Time for Aerated Samples of Post Oak Bark, Mesquite Bark, Pine Bark and Control (Test Series 5)

The data also indicated that Kjeldahl concentrations increased in the control tank over the six week period. Since nitrate and nitrite concentrations did not decrease over the six week period, it is possible that nitrogen entered the system from the air via bacterial nitrogen fixation.

Table 7 shows percent nitrogen leached from grass and leaves similar to the data developed for phosphorous in Table 6. Data indicates that Bermuda grass leached a larger percentage of the total nitrogen content of the grass than did post oak or pine leaves. Post oak leaves also leached a greater percentage of nitrogen than did pine needles. In all three species where data is presented, green vegetation leached a higher percentage of its total nitrogen amount than dry or dead vegetation.

Nitrate data is shown in Figures 42-45. Results indicate that most samples showed little release or conversion to nitrate over the six week period. Only in tanks containing Bermuda grass, mesquite bark, and dry post oak twigs were significant increases in nitrate concentrations observed. In each case, nitrate levels remained low over the first three to four weeks of leaching and then rose toward the end of the period. High nitrate concentrations for mesquite bark could have been caused by sap contained in the bark which would probably contain higher concentrations of nitrogen. Results show that nitrate-nitrogen concentrations were over four times higher for dry Bermuda grass than for green at the end of the six week period. However, data indicates that there was about three times as much Bermuda grass on a dry weight basis contained in the tank. Percent leaching data in Table 7 shows that live Bermuda grass leached a greater percentage of nitrogen than did dead grass.

TABLE 7

PERCENTAGE OF NITROGEN LEACHED FROM VEGETATION FOR TEST SERIES 5

Sample	Dry Weight grams	N leached milligrams	N leached as a % dry weight	% N of Dry Weight	% N leached of Total N
Bermuda Grass (green)	6.263	92	1.5	2.80	52
Bermuda Grass (dry)	16.452	154	.95	2.4	40
Pine Needles (dry)	18.654	0	0	2.8	0
Pine Needles (green)	8.400	7	.083	3.2	2.6
Post Oak Leaves (dry)	17.425	16	.092	2.2	4.1
Post Oak Leaves (green)	10.320	21	.20	2.7	7.6
Post Oak Twigs (dry)	10.235	73	.38	--	--
Post Oak Twigs (green)	16.570	71	.43	--	--
Pine Twigs (dry)	18.960	25	.13	--	--
Pine Twigs (green)	16.980	4	.023	--	--

TABLE 7 (cont.)

Sample	Dry Weight grams	N leached milligrams	N leached as a %dry weight	% N of Dry Weight	% N leached of Total N
Mesquite Bark	19.250	115	.60	--	--
Post Oak Bark	19.652	35	.18	--	--
Pine Bark	19.155	22	.12	--	--

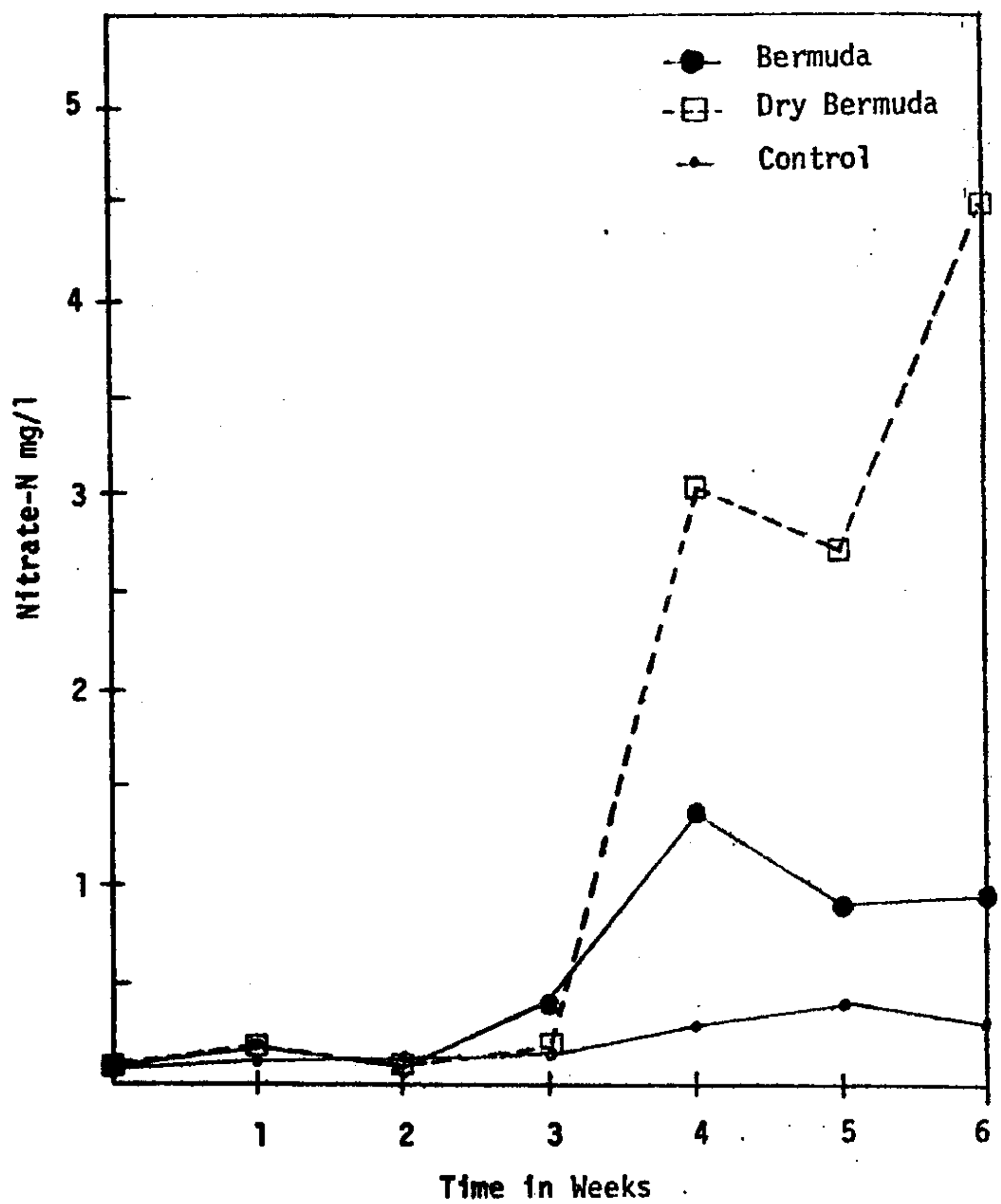


Figure 42: Nitrate-Nitrogen Concentration with Time for Aerated Samples of Dry and Green Bermuda Grass and Control (Test Series 5)

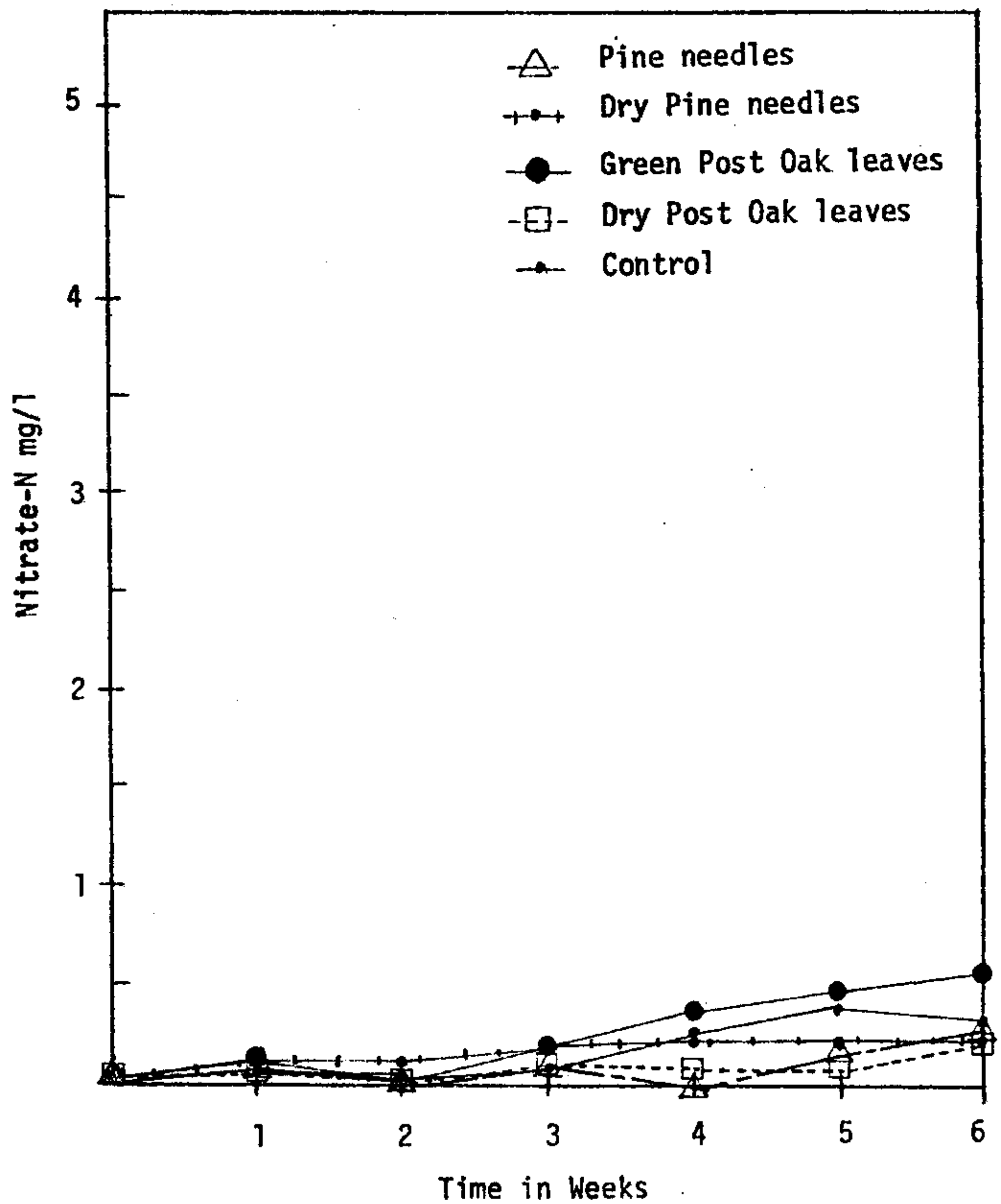


Figure 43: Nitrate-Nitrogen Concentration with Time for Aerated Samples of Dry and Green Pine Needles and Dry and Green Post Oak Leaves and Control (Test Series 5)

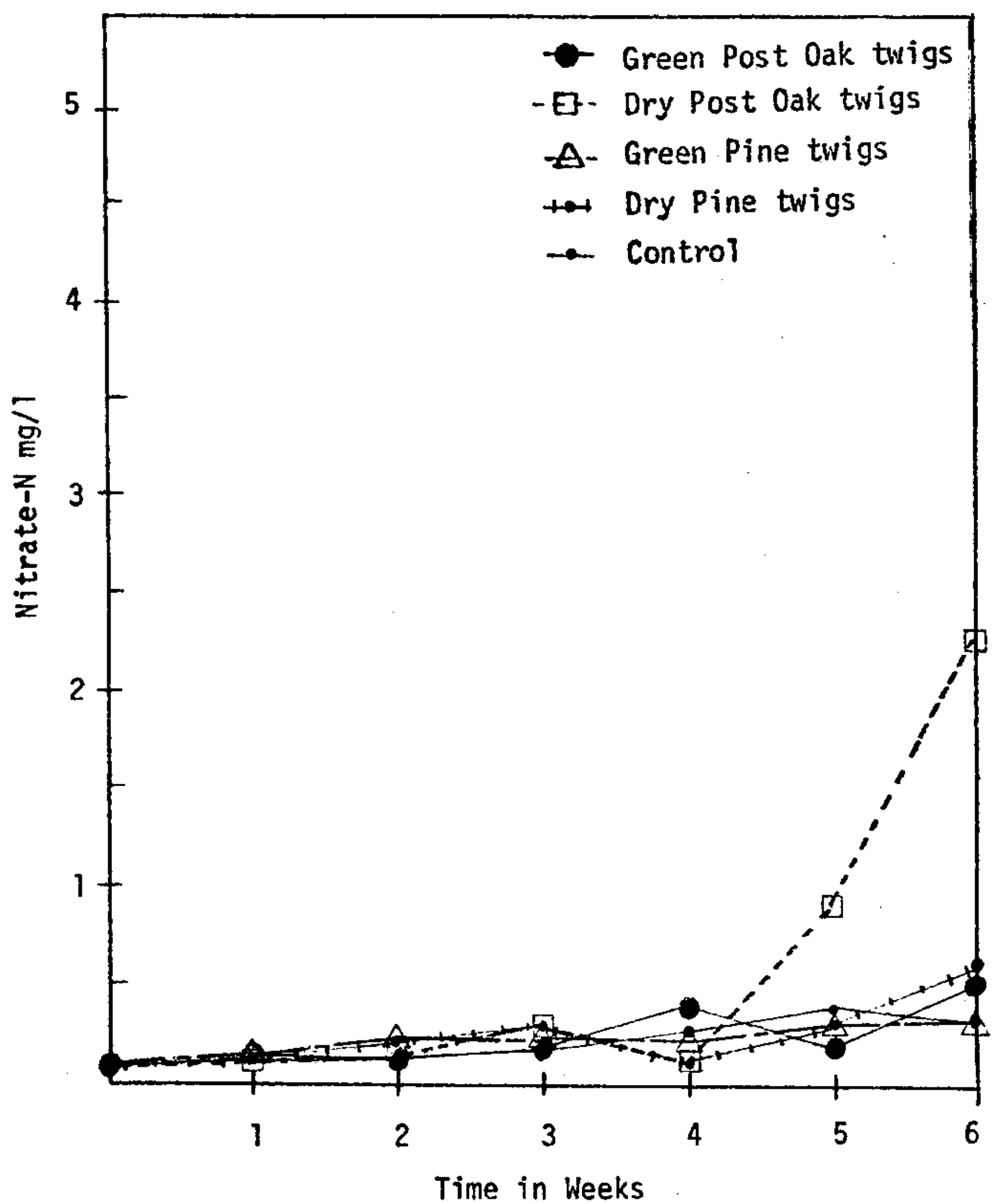


Figure 44: Nitrate-Nitrogen Concentration with Time for Aerated Samples of Dry and Green Post Oak Twigs, Dry and Green Pine Twigs and Control (Test Series 5)

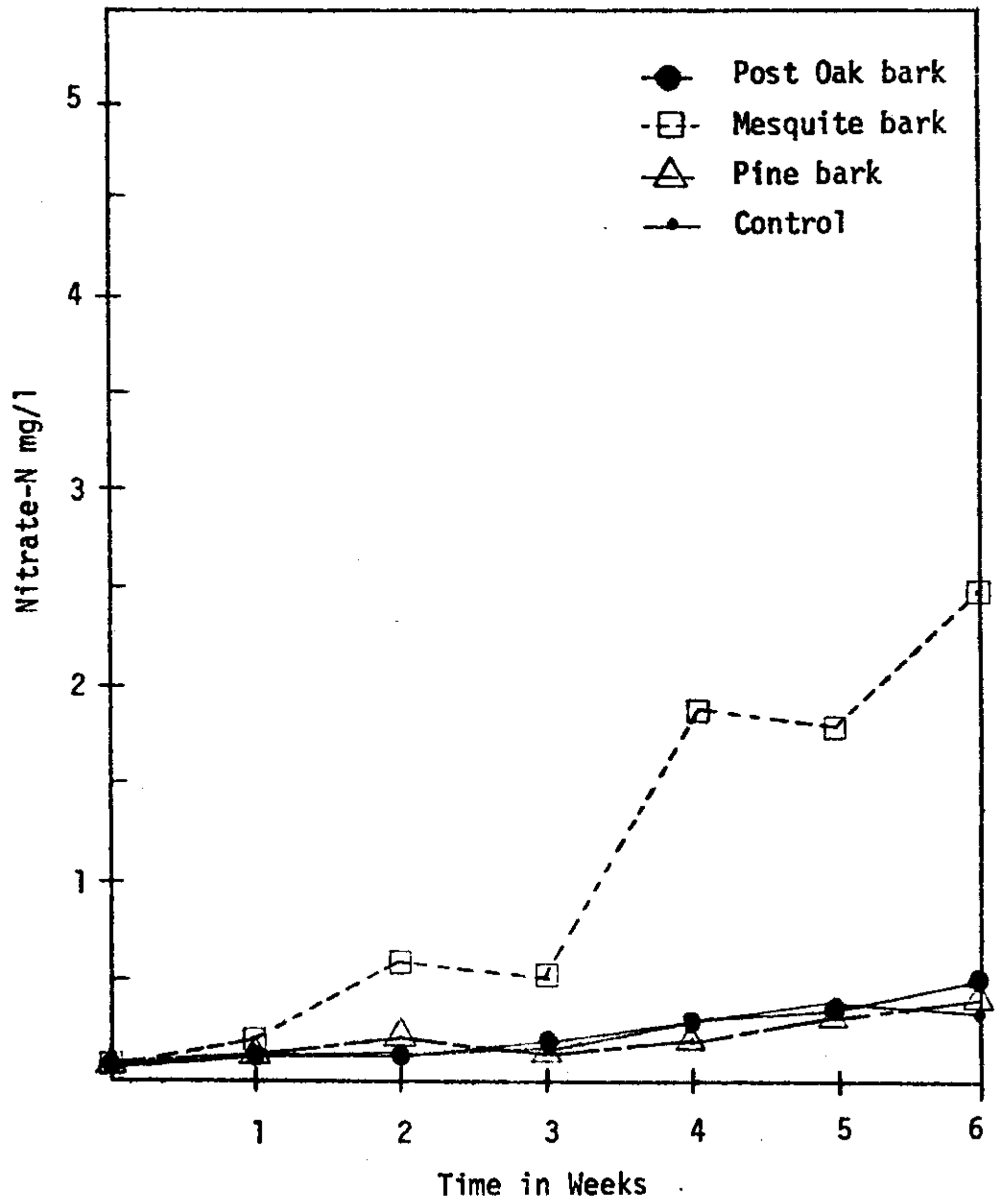


Figure 45: Nitrate-Nitrogen Concentration with Time for Aerated Samples of Post Oak Bark, Mesquite Bark, Pine Bark and Control (Test Series 5)

Nitrite-nitrogen data is presented in Figures 46-49. Data indicates that nitrite-nitrogen was present in large concentrations in several of the tanks probably due to the result of the oxidation of ammonia and organic nitrogen to nitrite and then to nitrate. The conversion of Kjeldahl nitrogen to nitrite and nitrate-nitrogen is shown dramatically in Figures 38, 42, and 46 which show Kjeldahl, nitrate, and nitrite concentrations for live and dry Bermuda grass. Results show that a peak in Kjeldahl nitrogen concentrations occurs at two to three weeks for dry and green Bermuda grass samples. A peak in nitrite-nitrogen concentrations occurs at three to four weeks and a peak for nitrate-nitrogen concentrations occurs from four to six weeks. This data indicates that rapid leaching of organic nitrogen is likely occuring over the first three weeks of the test period. The organic nitrogen is probably converted to ammonia which also appears as Kjeldahl nitrogen. This conversion may possibly be explained by the breadth of the Kjeldahl peak at two to three weeks. Bacteria probably oxidize a portion of the ammonia to nitrite and nitrate-nitrogen. In the case of the tank containing mesquite bark where large concentrations of nitrate and nitrite-nitrogen occurred, this process is augmented by leaching of nitrite directly from the bark itself.

Field Investigations

In addition to the laboratory study, a field study was conducted on three test reservoirs for the purpose of determining the effect of original vegetation on reservoir water quality. There were a number of problems in designing a meaningful experiment because of the difficulty of selecting comparable reservoirs. An ideal approach would be to select several reservoirs of similar area, depth, mean temperature, and watershed

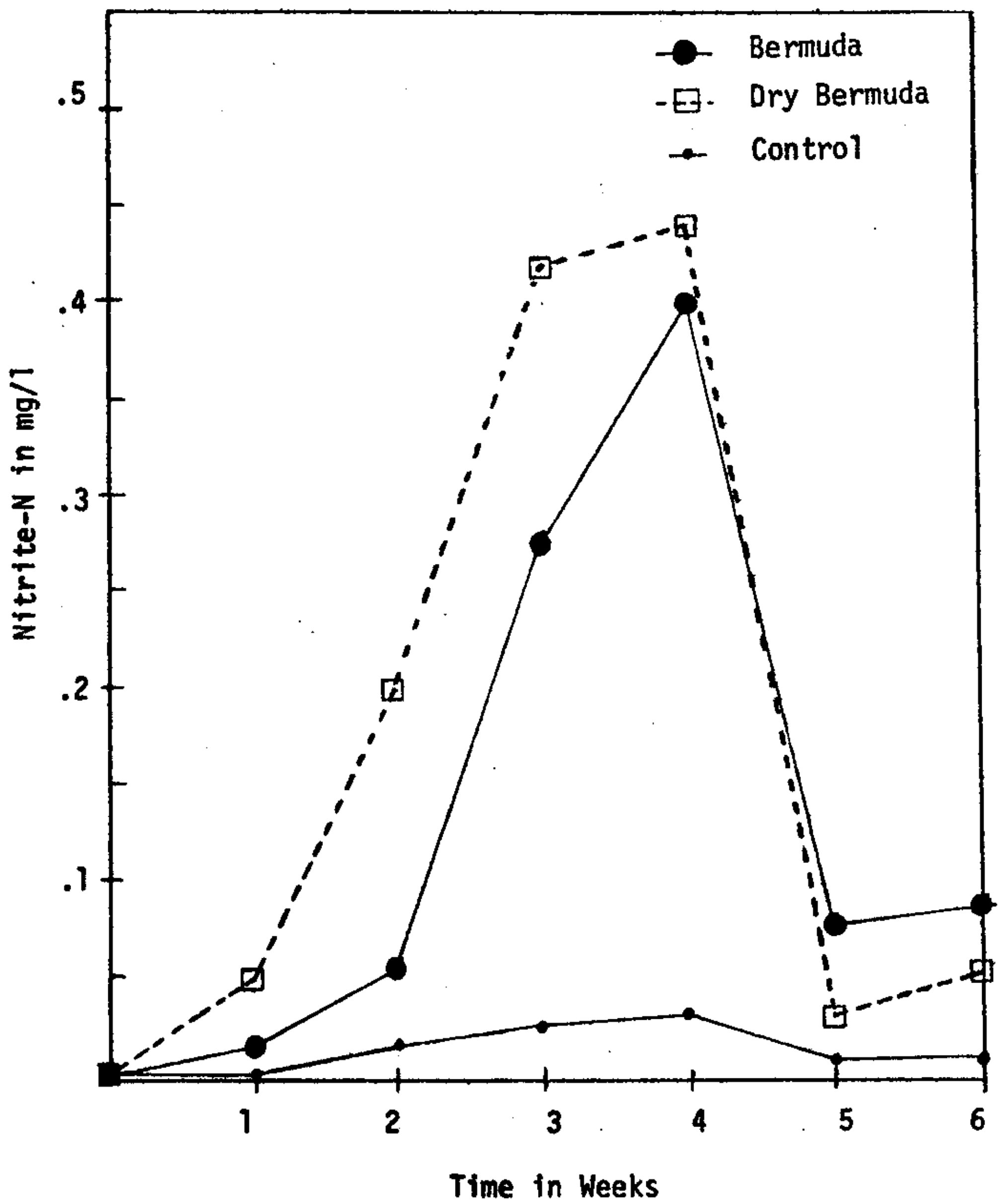


Figure 46: Nitrite-Nitrogen Concentration with Time for Aerated Samples of Dry and Green Bermuda Grass and Control (Test Series 5)

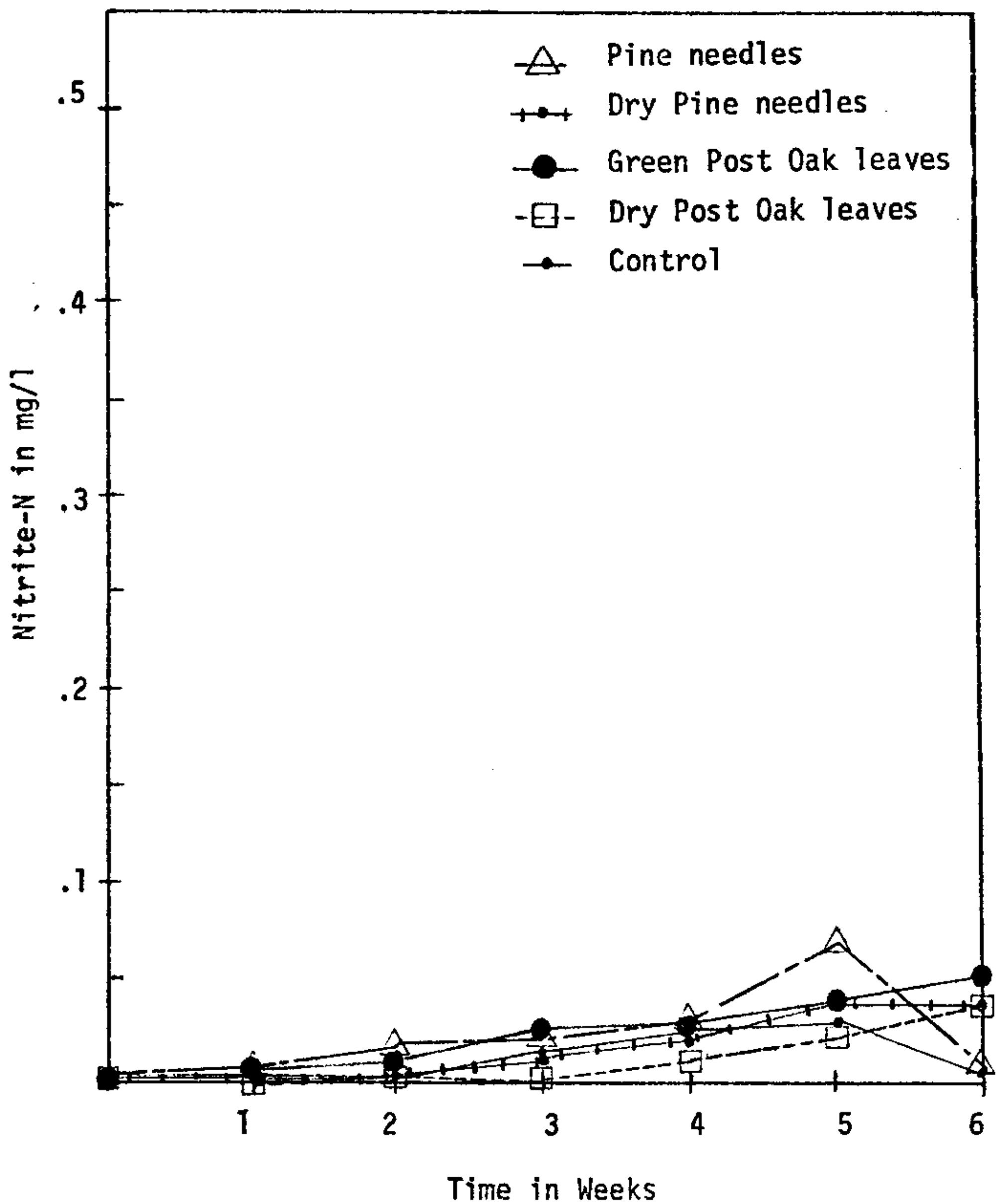


Figure 47: Nitrite-Nitrogen Concentration with Time for Aerated Samples of Dry and Green Pine Needles, Dry and Green Post Oak Leaves and Control (Test Series 5)

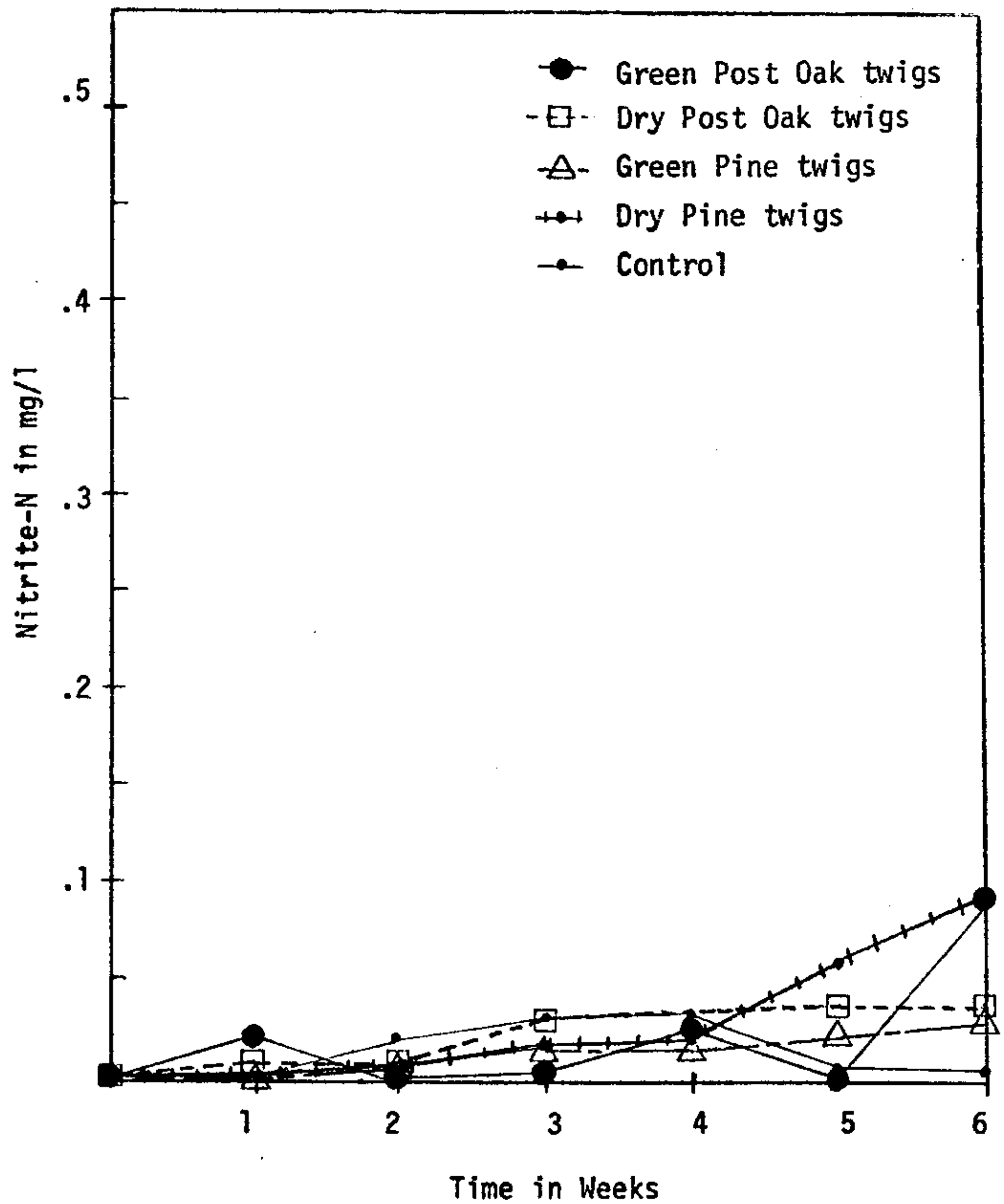


Figure 48: Nitrite-Nitrogen Concentration with Time for Aerated Samples of Dry and Green Post Oak Twigs, Dry and Green Pine Twigs and Control (Test Series 5)

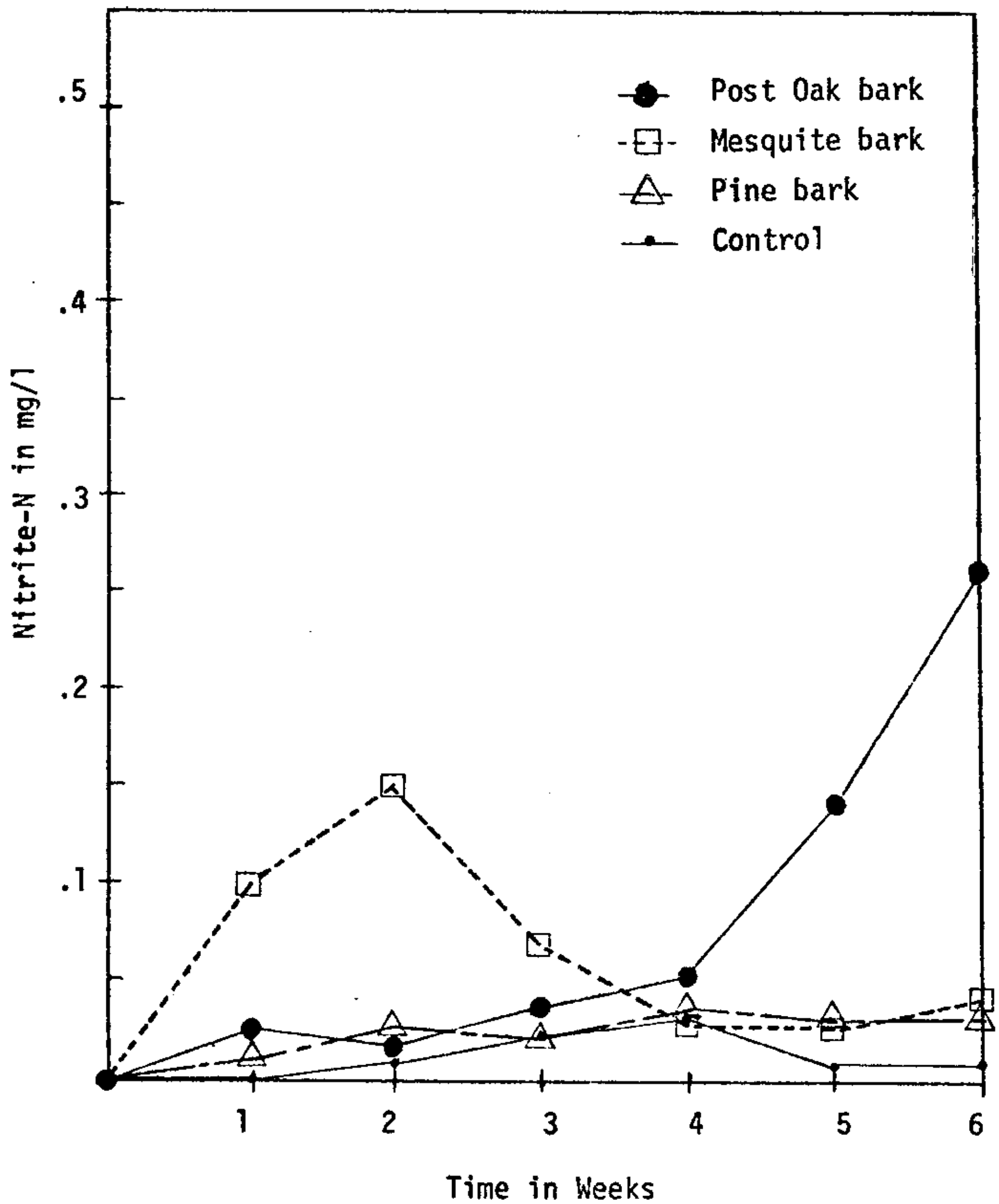


Figure 49: Nitrite-Nitrogen Concentration with Time for Aerated Samples of Post Oak Bark, Mesquite Bark, Pine Bark and Control (Test Series 5)

characteristics with varying age and vegetation loadings. Problems with this approach are: 1) that each reservoir is unique, making comparisons difficult, if not impossible, 2) most reservoirs of any size have numerous nutrient inputs in addition to original vegetation such as from upstream water courses, storm runoff, agricultural runoff, septic tank drainage and livestock waste, and 3) the difficulty of selecting reservoirs with certain ages.

An alternate approach was to select three relatively small reservoirs with limited watersheds in close proximity of each other. The reservoirs had similar original vegetation loadings but were of different age. Details of the reservoirs, the sampling program and the detailed results are presented in Appendix A. The reservoirs were sampled on three separate occasions at various depths and positions within the reservoirs. Nutrient data did not indicate significant differences in nutrient concentrations that could be correlated to vegetation loadings.

Palmetto Bend Vegetation Inventory

An original vegetation baseline inventory was conducted for the Palmetto Bend Reservoir site near Edna, Texas. The purpose of the inventory was to obtain a detailed accounting of the amount, type and distribution of the vegetation prior to construction of the Reservoir as an initial step in a succeeding study. Details of the Palmetto Bend Reservoir, methods used to take the inventory, and the results of the inventory are presented in Appendix B. The follow-up study that would use the inventory data would consist of a field investigation of the water quality in the reservoir during filling and for an extended period of time after the reservoir is in service. The purpose of the study would be to determine the cause and effect relationship of original vegetation on water quality.

Chapter V

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

This study has provided a base of data on relative rates of nutrient release for representative types of vegetation common to Texas reservoir sites. Application of this data to reservoir construction and clearing policy should be made based on an understanding of the limitations of the information. The leaching studies were performed under laboratory conditions which will give an indication of what can occur in the field. The information must be calibrated to field conditions. The following conclusions were drawn from the study:

1) Productive or eutrophic waters leach nitrogen from vegetation at a faster rate than less productive waters.
2) Nutrients appear to leach rapidly from vegetation beginning the first day. After an initial rapid release, which may cover a two week period, the nutrients tend to leach at a slower rate.
3) Nutrient leaching occurs while oxygen is being utilized. If sufficient vegetation is present, and natural reaeration slows, a significant DO problem could occur in a lake. During unaerated tests, the DO concentration dropped rapidly within twenty-four hours.
4) Nutrient release was not found to be concentration dependent up to loading rates of 0.8 grams Bermuda grass per liter of water.

5) Nitrogen was found to leach from vegetation at a higher rate than phosphorous.

6) Nitrogen release from grasses was rapid initially but essentially complete within six to ten days after adding the vegetation.

7) Surface area to mass ratio characteristics appear to be an important factor in leaching rates for vegetation.

8) Nitrogen concentrations were found to range from 2.2 to 3.2 percent by dry weight for the grass and leaves tested.

9) Nitrogen leached from the grass and leaves ranged from 2.6 to 7.6 percent of total nitrogen present for leaves and from 40 to 52 percent for Bermuda grass.

10) Phosphorous concentrations were found to range from 0.08 to 0.27 percent by dry weight for the grass and leaves tested.

11) Phosphorous leached from the grass and leaves ranged from 0.4 to 7.3 percent of the total phosphorous present.

12) Nitrogen and phosphorous leaching as a percent of total dry weight for the sample is presented below in Table 8.

TABLE 8

NITROGEN AND PHOSPHOROUS LEACHED OVER A SIX WEEK PERIOD

Vegetation	Condition	Nitrogen Leached as a % of Dry Weight	Phosphorous Leached as a % of Dry Weight
Bermuda Grass	green	1.5	0.02
	dry	0.95	0.02
Pine needles	green	0.08	--
	dry	--	--
Post oak leaves	green	0.20	0.003
	dry	0.09	0.005

TABLE 8 (cont.)

Vegetation	Condition	Nitrogen Leached as a % of Dry Weight	Phosphorous Leached as a % of Dry Weight
Post oak twigs	green	0.43	0.002
	dry	0.38	0.003
Pine twigs	green	0.02	---
	dry	0.13	0.001
Mesquite bark		0.60	---
Post oak bark		0.18	---
Pine bark		0.12	---

13) Field studies indicated that a cause and effect relationship between field data, reservoir age, etc. is difficult to quantify unless complete vegetation information is known and tests are started as the reservoir is filled.

14) The background vegetation study for the proposed Palmetto Bend Reservoir showed that methods are available to conduct a detailed inventory of original vegetation.

Recommendations

The following recommendations have been developed based on the information from this study:

1) If vegetation is removed from a reservoir site to reduce effects of nutrient leaching, grass should be cut, baled, and removed, as well as bushes and trees.

2) Since leafy vegetation, twigs, etc. leach at a reasonably rapid rate, it may be more economical to partially fill the reservoir, wait several months for leaching to occur, and drain the reservoir completely prior to refilling for use.

3) A more detailed investigation of the effects to expect from

original vegetation can be performed as follows:

Step 1: Conduct a quantitative study similar to the Palmetto Bend vegetation inventory as presented in Appendix B.

Step 2: Estimate the amount of nitrogen and phosphorous that would be expected to be released from the vegetation in total pounds based on the laboratory information from this study.

Step 3: Determine the nitrogen and phosphorous concentrations that may be expected in the lake.

Step 4: Compare the estimated concentrations to maximum nutrient concentrations from the literature that would preclude excess algal growth.

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APPENDIX A

FIELD INVESTIGATIONS

Appendix A

FIELD INVESTIGATIONS

The first step in the field investigation was to select reservoirs that could be effectively used to develop useful data. The reservoirs chosen should be filled under much the same conditions and have characteristics as similar as possible. This applies to such factors as soil, climate, water quality of the stream dammed, basin morphometry, vegetation, and other parameters that would affect water quality in a reservoir. If proper test reservoirs could be chosen, differences in water quality among the reservoirs would be a function of reservoir age and the effects of decay of vegetation. By quantifying each type of vegetation inundated in each reservoir and applying data generated by the laboratory leaching studies on similar types of vegetation, it was hoped that the effects of certain types and amounts of original vegetation upon water quality could be correlated.

However, the ideal experimental situation in which several reservoirs would differ with respect to only one variable is impossible to achieve as was discussed in the results and conclusions section. In an attempt to approach the ideal, the following criteria were used in the selection of reservoirs for the field study:

1) Reservoirs should be located in the same watershed to minimize differences in climate, soil, vegetation, and other factors influenced by location,
2) Reservoirs should be of known age,
3) Engineering data on reservoir basin topography and volume should be accessible,

4) Land use surrounding reservoirs should be similar,

5) Reservoirs should be of approximately the same size, and

6) Reservoirs should be small enough to permit good sampling coverage.

It was found that selection of reservoirs which met the above criteria was difficult. However, three reservoirs located near Garrison, Texas were selected for the study based on a compromise of the criteria. All three reservoirs were flood control projects conducted by the U. S. Soil Conservation Service. Sketches of Lakes Bill Stinnett, Herring, and Reaves are shown in Figures 50 to 52 respectively. Data describing each reservoir was available from the local office of the USSCS at Nacogdoches, Texas. The three reservoir sites were on the Attoyac Bayou watershed where soil, climate, and vegetation varied little from reservoir to reservoir. Table 9 gives the basic engineering data for the three reservoirs.

Sampling Program

A sampling program was developed for the purpose of monitoring changes in trophy state measured by water quality in the test reservoirs. The following parameters were monitored over the sampling period:

1) Temperature
2) Dissolved Oxygen
3) Color
4) BOD
5) Total Kjeldahl Nitrogen
6) Nitrate-nitrogen
7) Nitrite-nitrogen
8) Total Phosphorous
9) Hardness
10) Alkalinity

Sampling runs were made at monthly intervals over a three month period beginning July 5, 1974. The summer months were chosen for the field study because these are generally the most critical months with

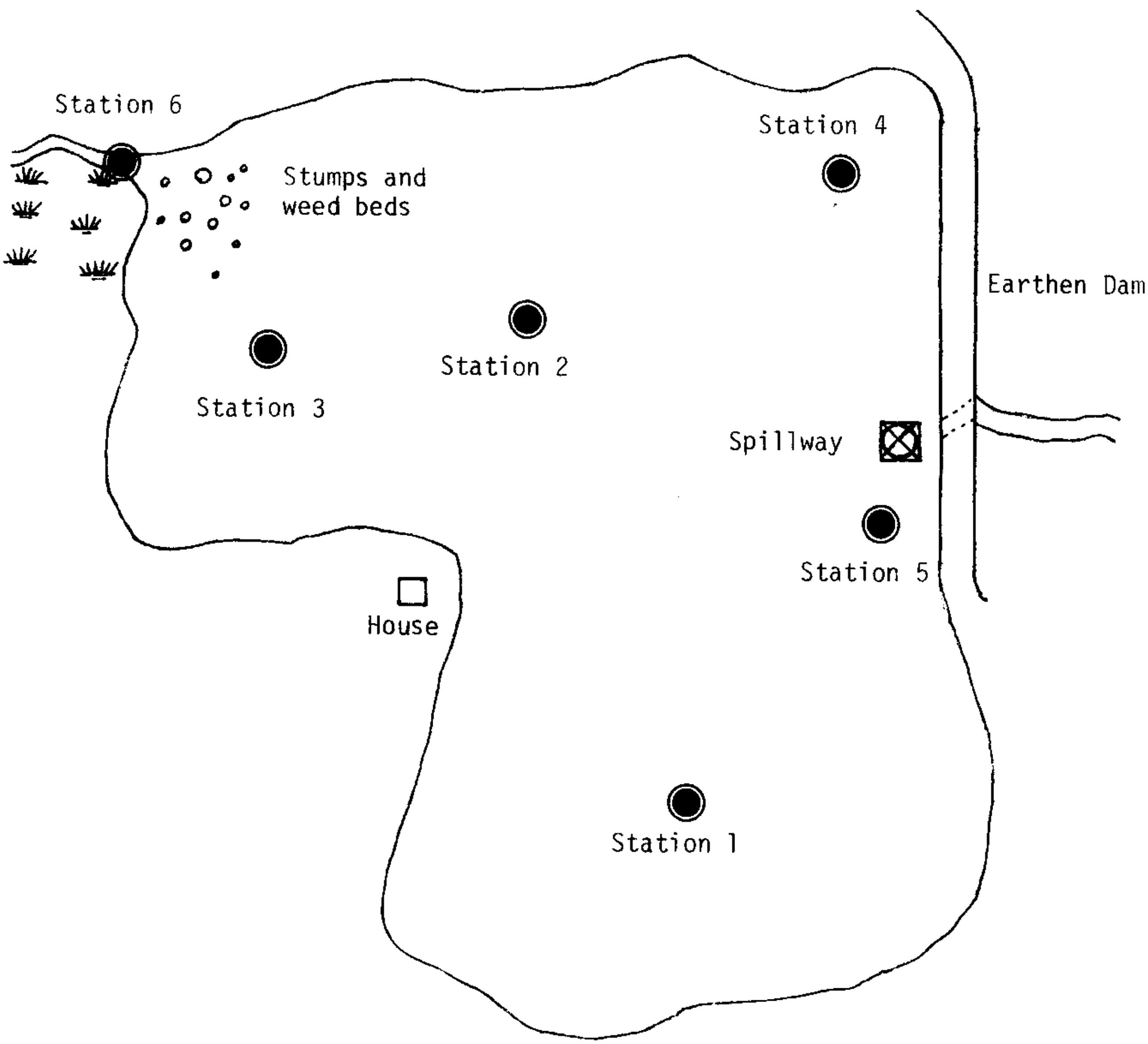

Figure 50: Lake Bill Stinnett Used in Field Investigation

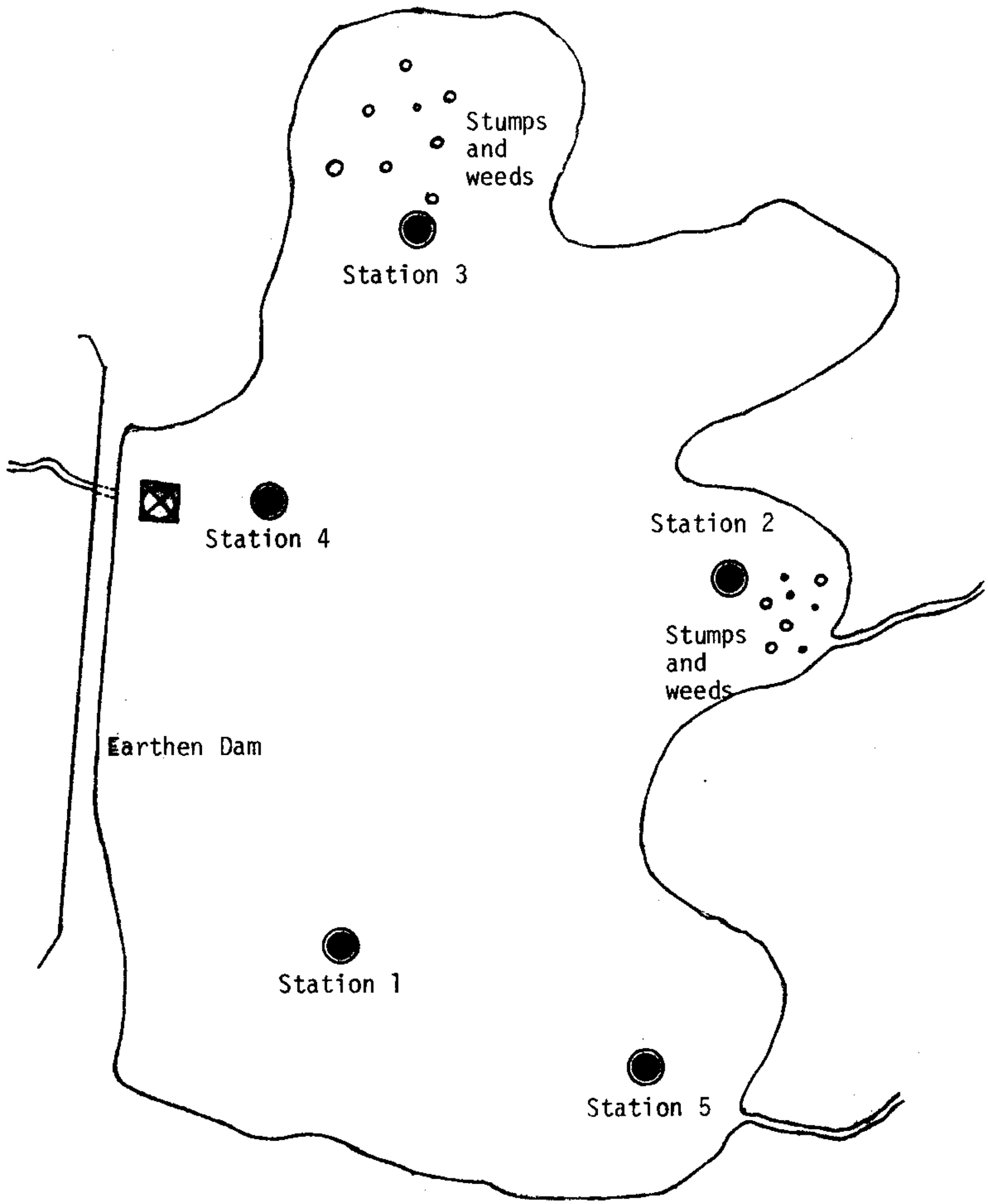

Figure 51: Herring Lake Used in Field Investigation

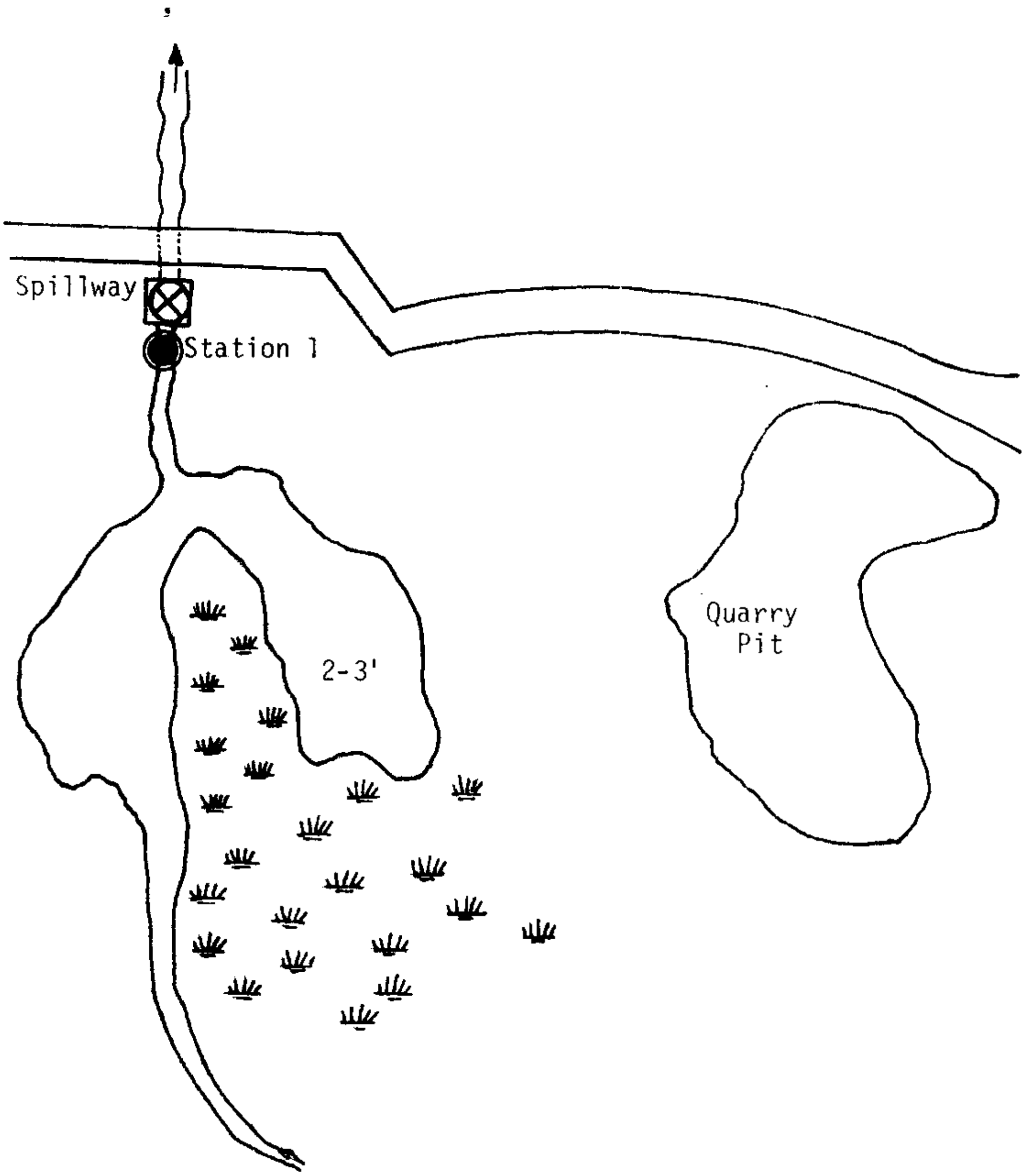

Figure 52: Reaves Lake Used in Field Investigation

TABLE 9

STRUCTURE DATA FOR THREE LAKES USED IN FIELD INVESTIGATION

Item	Unit	Lake Herring	Reeves Lake	Lake Bill Stinnett
Drainage Area	Sq. Mi.	2.10	6.20	5.52
Storage Capacity				
Sediment Pool (50-year or 200 acre-feet)	Ac. Ft.	34	63	91
Sediment Reserve (below river)	Ac. Ft.	33	66	100
Sediment in Detention Pool	Ac. Ft.	11	26	36
Floodwater Pool	Ac. Ft.	773	1,367	2,084
Total	Ac. Ft.	851	1,793	2,311
Surface Area				
Sediment Pool (50-year or 200 acre-feet)	Acre	16	23	34
Floodwater Pool	Acre	83	157	243
Volume of Fill	Cu. Yd.	91,000	119,000	100,000
Elevation Top of Dam	Foot	398.8	432.4	341.2
Maximum Height of Dam	Foot	26	29	27
Emergency Spillway Hydrograph				
Storm Rainfall (6-hour)	Inch	7.7	7.7	7.7
Storm Runoff	Inch	4.32	3.22	5.12
Freeboard Hydrograph				
Storm Rainfall (6-hour)	Inch	17.2	16.2	16.4
Maximum Water Surface Elevation	Foot	398.8	432.4	341.2

respect to water quality in reservoirs. Ideally, the reservoirs should have been monitored over at least a one year period. However, this was not possible.

Sampling stations were chosen at each reservoir so that any local differences existing within a reservoir could be observed. One station was chosen for Reaves Lake because of the fact that filling did not begin until the final month of sampling and the area inundated was so small that one sampling station was adequate.

Samples were taken and temperature and dissolved oxygen were measured at the surface and at the bottom of all stations where the depth exceeded 4 feet. When the depth at a station was less than 4 feet, sampling was performed midway between the bottom and the surface.

Results and Discussion

Results of the sampling program are shown in Tables 10-12. Data indicates that Lake Bill Stinnett which was filled in 1971 was generally more eutrophic than Herring Lake which was filled in 1973. Reaves Lake showed very high nitrogen concentrations, however these were probably caused from cattle manure deposited in the basin. Because of this problem, it was not possible to correlate Lake Reaves results with those from the other two reservoirs. To conduct a meaningful study, it is recommended that either test reservoirs be constructed for study or that extended field studies be conducted for a well-documented reservoir beginning before filling.

TABLE 10

SAMPLING DATA FOR LAKE BILL STINNETT (BS), HERRING LAKE (HERR), AND REAVES LAKE FROM JULY 5, 1974

Station	Depth ft	Dissolved Oxygen mg/l	Temperature °C	BOD mg/l	Hardness mg/l	Alkalinity mg/l	PO_4 mg/l	NO_3-N mg/l	NO_2-N mg/l	Kjeldahl mg/l
BS1T *	6	6.5	26.5	4.2	90	55	.056	.08	.015	.95
BS1B ***		6.1	25.5	3.5			.094	.10	.013	.75
BS2T	4.5	8.2	27.0	4.0			.090	.10	.015	.55
BS2B		7.0	26.0	3.8			.072	.07	.016	.68
BS3M **	3.5	6.5	26.5	3.8			.084	.10	.018	.65
BS4T	8	7.1	26.5	3.4			.084	.08	.020	.50
BS4B		1.9	25.5	3.7			.084	.09	.019	.77
BS5T	7	7.3	27.0	3.5			.075	.08	.016	.50
BS5B		2.3	25.5	3.6			.085	.30	.017	.45
BS6M	1.5	3.8	23.0	3.8			.080	.38	.017	.75
Herr1T	10	7.1	29.5	2.4	66	18.9	.072	.02	.013	.80
Herr1B		5.2	23.0	2.5			.066	.07	.012	.85
Herr2	3	6.5	29.0	2.3			.056	.01	.011	.85
Herr3	3.5	7.0	29.0	2.4			.072	.03	.010	.98
Herr4T	8	7.3	29.5	2.7			.069	.01	.014	.85
Herr4B		5.1	25.5	2.3			.059	.02	.012	.80
Herr5	3	7.4	30.0	2.8			.062	.02	.013	.75
Reaves	2.5	6.8	29.0	23.0	50	4.4	.084	.40	.020	.70

* Top

** Middle

*** Bottom

TABLE 11

SAMPLING DATA FOR LAKE BILL STINNETT (BS), HERRING LAKE (HERR), AND REAVES LAKE FROM AUG. 3, 1974

Station	Depth ft	Dissolved Oxygen mg/l	Temperature °C	Color Units	BOD mg/l	Hardness mg/l	Alkalinity mg/l	PO_4 mg/l	NO_3-N mg/l	NO_2-N mg/l	Kjeldahl mg/l
BS1T *	4	7.9	29.5	40	5.0	106	85.8	.095	.020	.028	1.10
BS1B ***		7.8	29.0	30	2.9			.080	.070	.020	1.01
BS2T	6	8.1	29.5	35	4.2			.100	.020	.015	.89
BS2B		7.9	29.0	40	3.4			.125	.020	.018	.94
BS3M **	3	8.8	29.0	30	3.9			.130	.015	.015	.88
BS4T	8	8.6	29.5	30	3.5			.085	.015	.020	.90
BS4B		3.5	28.5	40	3.5			.075	.017	.026	1.05
BS5T	7	8.2	29.5	30	3.7			.080	.013	.018	.85
BS5B		6.9	29.0	35	3.5			.085	.015	.013	.88
BS6M	2	3.6	27.0	30	3.4			.105	.035	.016	.74
Herr1T	11	7.2	31.5	25	2.5	70	44.2	.065	.020	.006	.85
Herr1B		3.6	25.0	40	2.3			.100	.023	.008	.88
Herr2M	4	8.3	32.0	30	2.2			.120	.015	.009	.65
Herr3M	2.5	8.6	32.0	30	2.5			.090	.017	.010	.60
Herr4T	8	8.5	32.0	30	2.4			.095	.016	.008	.62
Herr4B		3.6	27.0	35	2.1			.080	.010	.007	.50
Herr5M	3	8.4	30.5	35	3.4			.100	.020	.007	.72
Reaves	2	6.9		35	2.8	60	15.6	.090	.150	.022	.94

* Top

** Middle

*** Bottom

TABLE 12

SAMPLING DATA FOR LAKE BILL STINNETT (BS), HERRING LAKE (HERR), AND REAVES LAKE FROM SEPT. 9, 1974

Station	Depth ft	Dissolved Oxygen mg/l	Temperature °C	Color Units	BOD mg/l	Hardness mg/l	Alkalinity mg/l	PO_4 mg/l	NO_3-N mg/l	NO_2-N mg/l	Kjeldahl mg/l
BS1T*	4.5	7.8	28.0	40	4.3	110	62	.062	.065	.022	.55
BS1B***	7.2	26	26.0	40-	2.9			.058	.080	.015	.65
BS2T	6.0	7.9	26.0	40	4.0			.040	.045	.013	.85
BS2B		7.7	23.5	40	3.8			.065	.040	.014	.88
BS3M**	4.0	8.5	25.5	40	3.7			.065	.035	.016	.57
BS4T	7.0	8.7	27.5	45	3.5			.055	.030	.020	.68
BS4B		5.2	24.5	40	3.8			.050	.025	.016	.77
BS5T	6.0	8.3	28.0	40	3.4			.060	.035	.017	.74
BS5B		7.1	24.5	60	3.6			.070	.050	.016	.98
BS6M	2.0	5.3	26.0	100+	3.6			.075	.065	.018	.77
Herr1T	12	7.6	25.5	50	2.7	75	40.1	.050	.030	.015	.43
Herr1B		4.2	23.0	50	2.6			.060	.030	.013	.42
Herr2M	3.5	8.6	25.5	50	2.4			.055	.055	.010	.51
Herr3M	2.5	8.6	25.0	50	2.5			.040	.075	.010	.40
Herr4T	8	8.2	25.5	50	2.7			.050	.060	.012	.38
Herr4B		6.0	24.0	50	2.3			.040	.045	.013	.77
Herr5M	3	8.0	26.5	40	2.6			.065	.050	.105	.52
Reaves	2.5	7.8	28.0	40	3.1	55	12.3	.050	.075	.018	.88

* Top

** Middle

*** Bottom

APPENDIX B

PALMETTO BEND VEGETATION INVENTORY

Appendix B

PALMETTO BEND VEGETATION INVENTORY

Introduction

A baseline inventory of original vegetation was undertaken at the Palmetto Bend Reservoir site. The purpose of the inventory was to complete the first phase of future case studies for a typical Texas reservoir. The additional phases would be to: 1) calculate a total nutrient release potential for the reservoir, 2) predict nutrient concentrations in the reservoir with time based on the potential for release and release rates observed in this study, and 3) monitor the reservoir nutrient concentration with time through a field sampling program to compare actual nutrient release with predicted values.

The specific objectives of the baseline study were to determine the amount and distribution of vegetation at the Palmetto Bend Reservoir site and propose a method for combining this data with the leaching rates. The study consisted of two parts; the analysis of aerial photographs and the field study. Sample sites were randomly selected from aerial photographs according to zones of similar vegetation. In the field study, several samples of vegetation and distance measurements to obtain density values were obtained randomly within each zone. Details of the sampling method and results will be presented in this Appendix.

The Proposed Reservoir

The Palmetto Bend Reservoir is an important impoundment project planned by the Bureau of Reclamation and approved by the Secretary of the Interior for the Navidad and Lavaca River Basins in Jackson County, Texas. The location of the proposed reservoir is shown in Figure 53.

Municipal and industrial water supplies are the major uses for the Palmetto Bend project; however, recreation and wildlife propagation are a secondary consideration. Reimbursable costs as of January 1, 1975 include approximately $56,080,000 allocated to municipal and industrial water supply and $14,020,000 for recreation and wildlife propagation (15).

The project will be completed in two stages. The first stage will be the impoundment of the Navidad River and the second stage the impoundment of the Lavaca River including the Post Oak Branch. At the proposed dam site, the Navidad River is only 10,000 ft from the Lavaca River and 3,000 ft from Post Oak Branch. As a result of the close proximity of the basins, stage two will be constructed by extending the levee of stage 1 westward to enclose the two remaining basins as shown in Figure 53.

Relocation of pipelines, oil wells, power transmission lines, and cemeteries began in 1973. Navidad River bridges began to be raised on State Highway 59 and 111 beginning in 1974. Specifications for the dam are scheduled to be issued in February 1975 and major construction scheduled for April 1975.

The dam will be a compacted earth fill with separate concrete spillways located in the channels of the Navidad and Lavaca Rivers. The top of the embankment will reach elevation 55.00 MSL and have a maximum height of 64 feet. The crest of the dam will be 30 feet wide with a total length of 15 miles for both stages and 7.9 miles for the first stage (16). The Navidad and Lavaca spillways will have automatic float-operated radial gates numbering 13 and 11 respectively. Each gate will be 35 feet wide and 22 feet high with gate sills at elevation 23.00 MSL. Elevation 44.00 MSL will be the top of the conservation pool and the area

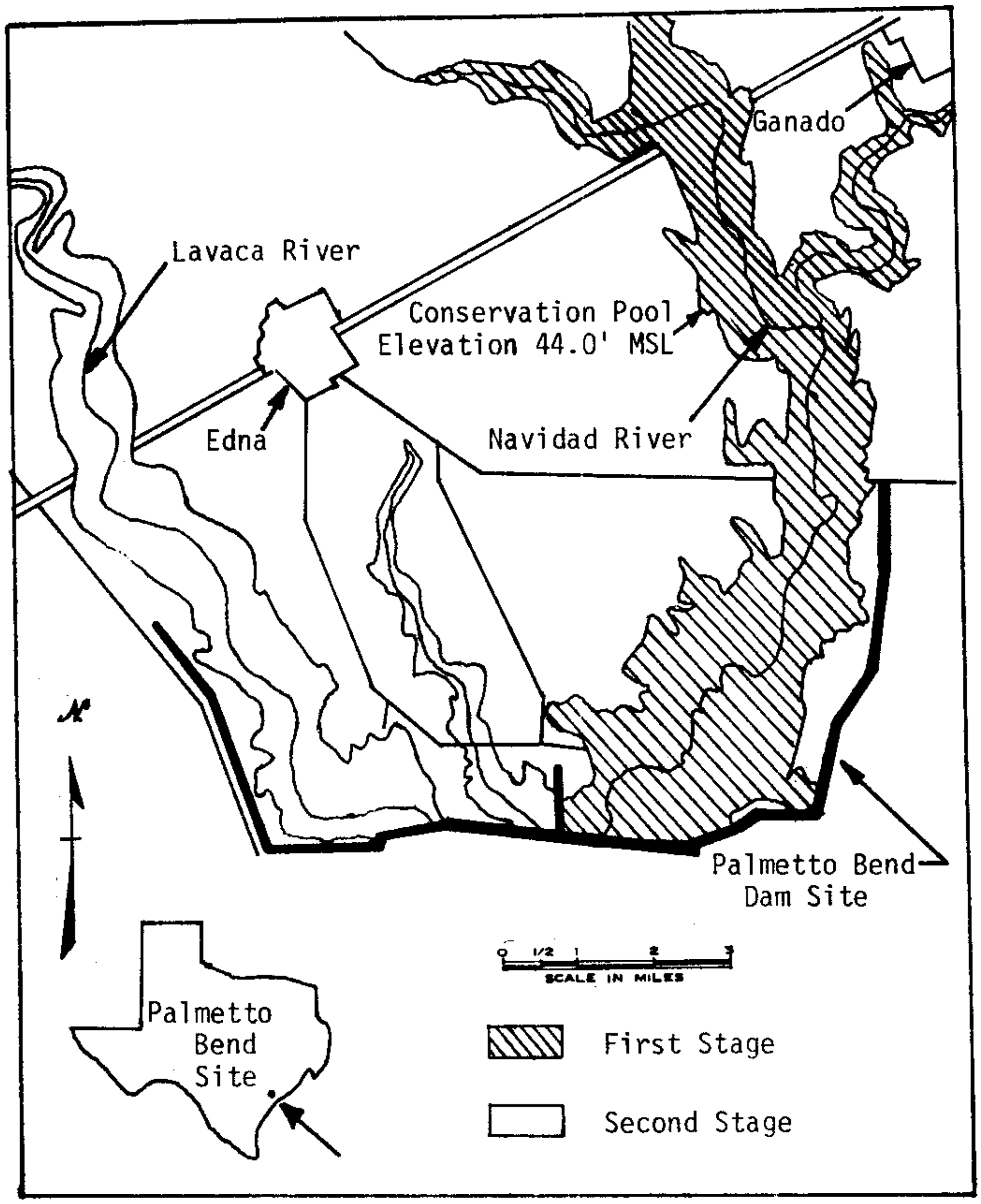

Figure 53: Proposed Palmetto Bend Project

covered by the reservoir at that elevation will be 11,000 acres in the Navidad basin and 6,900 acres in the Lavaca basin. The first stage, the Navidad impoundment, will store 172,000 acre-feet of water in the conservation pool, with the Lavaca impoundment designed to hold 93,000 acre-feet in the conservation pool (16).

Aerial Photographic Study

Aerial photographs of the Palmetto Bend Reservoir site were purchased from the U.S.D.A.-Soil Conservation and Stabilization Service, and were studied stereoscopically to determine the boundaries of the major vegetation zones. An aerial mosaic was made by mounting the photographs on a large board in such a manner that they formed an aerial map of the reservoir site. The boundaries of vegetation zones were determined by stereoscopic observation of the tone and texture of the photographs and were delineated on the aerial mosaic. The mosaic was then overlaid with a grid of 0.25 square inch divisions and 55 of the grid squares were selected randomly (17). Grid squares were marked on the mosaic and one field sample station was assigned to each square.

Field Study

Random sampling of vegetation was accomplished by the point-centered quarter method as outlined in Smith, 1974 (17). The point-centered quarter method is a plotless empirical technique developed and introduced into the United States by Grosengaugh, 1952 (18). The primary assumption is that sample stations must be distributed randomly throughout the area to be sampled. At each station a point was established and a pair of perpendicular axes used to divide the station into four quadrants. In each quadrant of every station, three classes of plants were measured. These included: 1) cover, defined as trees greater than fifteen feet high, 2) understory, defined as trees between five and fifteen feet high, and 3) bushes, defined as trees species less than five feet high and plants with more than one emergent stem. Only one individual of each class was measured per quadrant, with the individual measured being the one nearest to the point. A sample station is shown in Figure 54. For simplicity, grasses were measured by clip plots. At each station a one square yard frame was placed on the ground, and all of the grasses and herbaceous plants within the frame were clipped at ground level, bagged, and labeled. Samples were taken to the laboratory and dried at 100°C until a constant weight was achieved. Weights were totaled for the thicket, the transition forest, the overall site, and for the grassy pasture zone. Samples were also keyed to determine scientific and common name.

Analysis of Data

Amount of coverage for each type of vegetation was calculated over the four zones: the thicket - dense bottom land hardwood forest, the transition zone - the less dense upland hardwood forest, and the overall reservoir site. This was accomplished in an effort to determine statistical significance for all values calculated. The following formulas were used in the calculation of the corresponding data tables for cover, understory, and bushes (17). Values for number of individuals, density, and dominance, as calculated by the formulas, appear in Tables 13-15.

TABLE 13
COVER SPECIES

Species	Thicket Zone				Transition Zone				Overall Site			
	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre
Celtis lindheimeri Lindheimer Hackberry	10	2.093	9.4	1.965	4	1.260	2.7	0.851	14	3.353	5.5	1.320
Celtis laevigata Sugarberry	2	0.677	1.9	0.644	8	3.519	5.4	2.376	10	4.196	3.9	1.658
Ulmus crassifolia Cedar Elm	26	21.183	24.4	19.886	20	7.066	13.6	4.801	46	28.249	18.2	11.175
Ulmus americana American Elm	9	2.452	8.5	2.312	1	0.165	0.7	0.116	10	2.617	3.9	1.022
Quercus virginiana Live Oak	11	22.822	10.3	21.373	18	43.364	12.2	29.390	29	66.186	11.5	26.243
Quercus nigra Water Oak	3	1.576	2.8	1.470	2	0.076	1.4	0.053	5	1.652	2.0	0.076
Quercus stellata Post Oak	--	--	--	--	13	18.207	8.9	12.469	13	18.207	5.2	7.285
Carya texensis Black Hickory	9	10.735	8.5	10.141	5	2.455	3.4	1.669	14	13.190	5.5	5.181
Carya aquatica Water Hickory	2	0.042	1.9	0.040	--	--	--	--	2	0.042	0.8	0.017
Carya leiodermis Swamp Hickory	2	3.792	1.9	3.602	--	--	--	--	2	3.792	0.8	1.517

TABLE 13 (cont.)
COVER SPECIES

Species	Thicket Zone				Transition Zone				Overall Site			
	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre
Carya illinoensis Pecan Hickory	3	0.932	2.8	0.871	4	2.102	2.9	1.420	7	3.034	2.8	1.212
Jugians nigra Black Walnut	2	2.473	1.9	2.350	--	--	--	--	2	2.483	0.8	0.990
Salix nigra Black Willow	2	7.212	1.9	6.851	--	--	--	--	2	7.212	0.8	2.885
Fraxinas pennsylvanica Green Ash	1	.524	0.9	0.472	2	1.255	1.4	0.879	3	1.779	1.2	0.712
Fraxinas texensis Texas Ash	7	12.297	6.6	11.596	--	--	--	--	7	12.297	2.8	4.920
Ilex vomitoria Yaupon	1	0.040	0.9	0.036	1	0.022	0.7	0.015	2	0.062	0.8	0.025
Platanus occidentialis American Sycamore	--	--	--	--	1	0.402	0.7	0.323	1	0.462	0.4	0.185
Acacia farnesiana Huisache	--	--	--	--	5	4.623	3.4	3.145	5	4.623	2.0	1.850

TABLE 14
UNDERSTORY SPECIES

Species	Thicket Zone				Transition Zone				Overall Site			
	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre
Celtis lindheimeri Lindheimer Hackberry	15	0.763	4.4	0.224	3	0.135	2.8	0.126	18	0.898	4.2	0.210
Celtis laevigata Sugarberry	16	0.534	4.7	0.155	8	0.367	7.4	0.340	24	0.901	5.6	0.213
Ulmus crassifolia Cedar Elm	19	0.898	5.6	0.263	9	0.522	8.3	0.481	28	1.420	6.6	0.337
Ulmus americana American Elm	4	0.069	1.2	0.020	3	0.080	2.8	0.076	7	0.149	1.6	0.034
Quercus virginiana Live Oak	1	0.283	0.3	0.085	--	--	--	--	1	0.283	0.2	0.057
Quercus stellata Post Oak	1	0.016	0.3	0.005	--	--	--	--	1	0.016	0.2	0.003
Quercas marilandica Blackjack Oak	--	--	--	--	1	0.034	1.0	0.034	1	0.034	0.2	0.007
Carya texensis Black Hickory	5	0.198	1.5	0.060	--	--	--	--	5	0.198	1.2	0.048
Carya illinoensis Pecan Hickory	7	0.166	2.1	0.050	--	--	--	--	7	0.166	1.6	0.038
Carya aquatica Water Hickory	1	0.210	0.3	0.063	--	--	--	--	1	0.210	0.2	0.042

TABLE 14 (cont.)
UNDERSTORY SPECIES

Species	Thicket Zone				Transition Zone				Overall Site			
	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre	Number of Individuals	Total Basal Area sq. ft.	Density in trees/acre	Dominance sq. ft. BA/acre
Jug ans nigra Black Walnut	1	0.071	--	--	--	--	--	--	1	0.071	0.2	0.014
Fraxinus xensis Texas Ash	--	--	--	--	1	0.096	1.0	0.096	1	0.096	0.2	0.019
Fraxinus mericana White Ash	1	0.079	0.3	0.024	--	--	--	--	1	0.079	0.2	0.016
Ilex vomi oria Yaupon	17	0.083	5.0	0.025	42	0.280	38.9	0.272	59	0.363	13.9	0.083
Acacia farnesiana Huisache	--	--	--	--	10	1.735	9.3	1.618	10	1.735	2.3	0.400
Prosopis chilensis Mesquite	--	--	--	--	2	0.378	1.8	0.340	2	0.378	0.5	0.095
Sopindus drummondii Western Soapberry	4	0.030	1.2	0.010	--	--	--	--	4	0.030	0.9	0.007

TABLE 15
BUSH SPECIES

Species	Thicket Zone				Transition Zone				Overall Site			
	Number of Individuals	Area per Plant ft^2	Density plants/acre	Dominance* ft^2/acre	Number of Individuals	Area per Plant ft^2	Density plants/acre	Dominance* ft^2/acre	Number of Individuals	Area per Plant ft^2	Density plants/acre	Dominance* ft^2/acre
Celtis lindheimeri Lindheimer Hackberry	1	324	0.5	162	--	--	--	--	1	324	0.4	130
Celtis laevigata Sugarberry	1	900	0.5	450	3	36	4.3	155	4	729	1.6	1,166
Ulmus crassifolia Cedar Elm	3	100	1.6	160	3	9	4.3	387	6	423	2.5	106
Ilex vomitoria Yaupon	30	1009	16.0	16,144	46	435	66.6	28,944	76	632	31.4	19,845
Sabal texana Dwarf Palmetto	27	115	14.4	1,650	1	289	1.4	405	28	119	11.5	1,369
Rosa bracteata Hawthorn Rose Hedge	29	2341	15.5	36,286	27	424	39.0	16,536	56	1225	23.1	28,298
Acacia farnesiana Huisache	--	--	--	--	7	180	10.1	1,818	7	180	2.9	522
Rabas trivialis Dewberry	1	16	0.5	8	--	--	--	--	1	16	0.4	8

* $\frac{\text{areal coverage}}{\text{plant}}$

TABLE 16

DRY WEIGHTS OF GRASSES

Zone	Number of Samples	Total Weight gms	Average Weight Clip Plot gms*	Average Weight Per Acre lbs/acre
Thicket	23	1073	46.7	498.3
Transition	22	1201	54.6	582.6
Pasture	10	375	37.5	400.1
Overall Site	55	2649	48.2	514.3

* Clip plots cover one square yard.

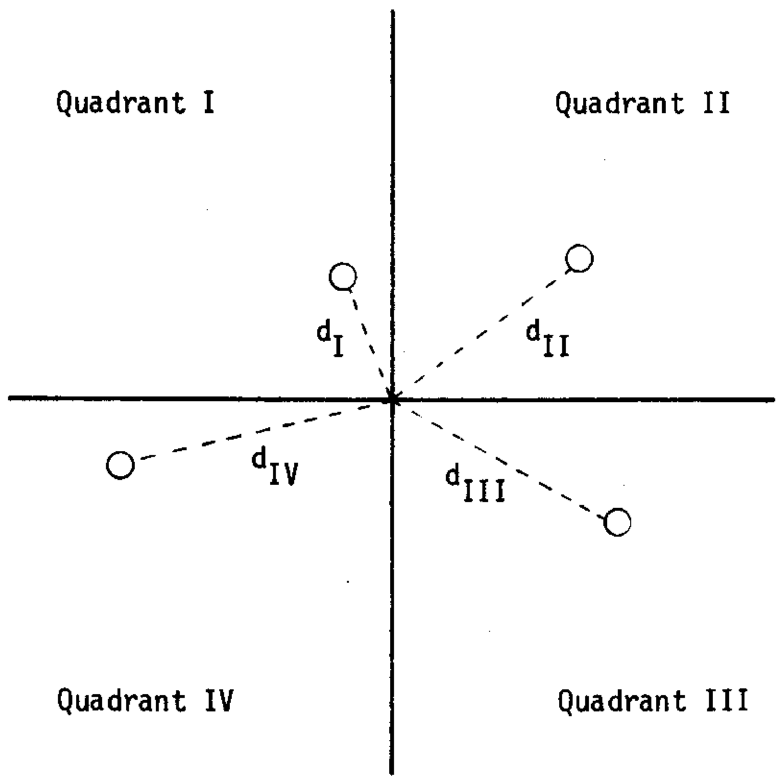

Figure 54: Sample Station for Determining Vegetation Density

1) $$\text{Total density of all species} = \frac{\text{unit area}}{(\text{mean point-to-plant distance})^2}$$

2) $$\text{Relative density} = \frac{\text{individuals of a species}}{\text{total individuals of all species}} \times 100$$

3) $$\text{Density} = \frac{\text{relative density of a species}}{100} \times \text{total density of all species}$$

4) $$\text{Average dominance} = \frac{\text{total basal area of a species}}{\text{total basal area of all species}}$$

5) Dominance = density of species x average dominance value for species

6) $$\text{Relative dominance} = \frac{\text{dominance for a species}}{\text{total dominance for all species}} \times 100$$

7) $$\text{Frequency} = \frac{\text{number of points at which species occurs}}{\text{total number of points sampled}}$$

8) $$\text{Relative frequency} = \frac{\text{frequency value for a species}}{\text{total of frequency values for all species}} \times 100$$

9) Importance value = relative density + relative dominance + relative frequency

Cover Species

As seen in Table 13 for cover species, thicket and transition zones differ greatly in the amount of plant material present for the more common species. Cedar Elm, Black Hickory and Texas Ash contribute more plant material to the thicket zone than to the transition zone. Live Oak, Post Oak and Huisache make their major contribution to the biomass of the transition zone. The importance values for these species show the same trends as were shown by the dominance values.

Understory Species

The trends shown by the dominance values for the understory do not correlate to those shown by the corresponding importance values. However, the relative values show trends which agree with the importance values. This indicates that the differences in basal areas of the species is responsible for the discrepancy. The major species of the thicket and transition zones are the same, but appear in different proportions. The only notable exception is that Huisache is quite common in the transition zone, but is absent in the thicket.

Bush Species

Dominance values for the bushes are based on the aerial coverage per acre of the species, which differs from the basis of the dominance values of cover and understory. Therefore, there is a closer correlation between the dominance values and importance values for the more common species. Unfortunately, the less common species such as Sugarberry and Dewberry do not agree very well, because they are based on fewer measurements. Still, the three most important bush species in all respects are the Dwarf Palmetto, the Hawthorn Rose Hedge, and the Yaupon plant.

Grasses

Observations made in the field sampling program explain the reason why the greatest dry weight of grassy plants occurs in the thicket zone where there is less light available for ground plants. The thicket zone showed a predominance of herbaceous ground vegetation which is heavier than the pasture grass and which is also only lightly grazed with respect to the pasture grasses; whereas the lightweight pasture grasses are heavily grazed by cattle.

Conclusions

The units of lbs/acre in Table 16 which have been calculated for the grasses can be directly applied to leaching rates to get a value of lbs nutrients/acre. This, however, is not the case for the units of square feet basal area per acre and square feet aerial coverage per acre which have been used in the dominance tables for cover, understory, and bushes. Another study is necessary to make it possible for this relationship to be computed. The average sized tree of each of the major species should be stripped of its soft parts. These should be weighed and multiplied by the density of that species. The resulting value would be the weight of leachable material per acre that is contributed by that species. When this is applied to the leaching rate, the result is the weight of nutrients per acre that is contributed by that species. The summation of this last value for all major species will give a reasonable estimate of the amount of leachable nutrients in the reservoir site.