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FINAL REPORT

DETERMINATION OF THE EFFICACY OF FERTILIZATION PRACTICES ON BOB KIDD LAKE

For the:

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DETERMINATION OF THE EFFICACY OF FERTILIZATION PRACTICES ON BOB KIDD LAKE

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Introduction

Fertilization strategies have been used as a standard practice on Bob Kidd and other lakes and reservoirs to enhance the availability of phytoplankton and zooplankton as food sources for developing fish. The nominal practice is to use a fixed application rate and a constant ratio of nitrogen and phosphorus fertilizer per acre of lake surface. The application technique varies as does the timing. Application techniques vary from spillage and bulk deposition of fertilizer at selected sites to broadcasting of pellets or a pre-mixed slurry via boat and/or airplane. Timing is usually in the spring under appropriate weather conditions.

The standardized application of a fixed formula at a constant rate at a convenient time precludes tailoring for optimal efficacy. Maximum efficiency can be obtained by determining the limiting nutrient for the water body; the timing of the deficiency, abundance of the non-limiting nutrient, and location and aerial size of the fish growth zone. Formulation, nutrient addition rate, application technique, and time of application can then be determined to optimize the quality and quantity of phytoplankton/zooplankton production. Also, correct fertilization practices can minimize potential for undesirable eutrophication, weed growth, or other management problems.

Based upon the considerations of trophic status of the test lake and the goal of achieving maximum desirable phytoplankton and zooplankton production pulses for optimal utilization, a field demonstration was jointly developed by the Fisheries Division

of the Arkansas Game & Fish Commission (AG&FC) and the Arkansas Water Resources Center (AWRC). A test protocol was jointly developed to determine the effectiveness of the present practice of applying four tons of 18-46-0 NPK fertilizer at selected sites to produce a desirable response of increased green algae standing crop and subsequent increase in zooplankton production. Bob Kidd Lake was chosen as the test site because of its previous management history (AG&FC) and phytoplankton research study (AWRC). In November, 1990 0.2 mg/l rotenone was applied to the lake. This application resulted in a reduction of the gizzard shad population from 92 to 35 kilogram per hectare. From August, 1990 through March, 1991, the lake was lowered ca. two meters to allow the growth of vegetation along the shoreline. In January 1, 1991, a protective slot of 33-40.5 cm (13-16") of bass was instituted. During the spring of 1991 the lake was not fertilized as it had been in previous years (Allen Carter, 1991, personal communication). In addition, annual data of chemical, physical, and biological parameters indicated that Bob Kidd Lake was nitrogen and not phosphorus limited (Meyer, 1992).

Site Description

Bob Kidd Lake was constructed in 1975 in west-central Washington County about two miles west of Prairie Grove (Fig. 1). The 81 ha (200 acre) lake has an average depth of 4 m (13') with a maximum depth of 9 m (30'). The major sport fish are bluegill, channel catfish, crappie, largemouth bass and redear sunfish. Other fish include the blue catfish, grass carp, green sunfish and warmouth. Marginal vegetation and dead trees are visible along the northern and western margins. A berm extending out from the dam at ca. 2 m depth is present along its entire length (AG&FC, 1989).

Protocol and Methods

Six sampling stations were established with triplicates within and outside of the zone of fertilization. Sampling was coordinated with AG&FC field managers so that the samples were collected 14 days, 9 days and immediately before fertilization. Samples were collected approximately four (4) hours after fertilization and then daily for five (5) consecutive days and then at 1, 2, and 3 week intervals. Field parameters and plankton samples were collected between 8:00 and 10:00 a.m.; except for the immediate post-fertilization samples.

The fertilized sampling sites were located along the central north shore and at the northern and the central site on the dam berm. The reference sampling sites included a north shore station beyond the zone of fertilization, the southern berm site and a mid-lake deeper water station near the overflow. The overflow site was the location for more extensive sampling from March, 1991 through February, 1993 (Meyer, 1992).

Field activities included measurement of temperature and oxygen profiles at each meter depth. Water samples were collected with a one meter long, liter TPFE baler at one and three meters. These samples included: 200 ml sample for chlorophyll analysis, 20 ml sample for nitrate-n (NO_3), soluble reactive phosphate-p (SRP-P) analysis, and a 20 ml phytoplankton sample. Zooplankton were collected with a 3-0 meter Wisconsin Net haul. The phyto- and zooplankton were preserved with M_3 (A.P.H. A, 1992). Temperature and oxygen were determined with a YSI Model 54 dissolved oxygen meter. Nitrogen and phosphorus concentration were determined with a Dionex 3000 ion chromatograph and the chlorophyll with a Hitachi dual-beam spectrophotometer. Phytoplankton were enumerated with a Palmer-Maloney cell and Zeiss Photomicroscope while the zooplankton were enumerated with a Sedgwick-Rafter cell with a Leitz stereomicroscope at 100x magnification. All data are stored on magnetic media using Microsoft Excel v. 4.0 software. This software has been used to

produce the included graphs. All field and laboratory procedures follow approved standard methods with appropriate quality assurance and quality control procedures.

Results and Interpretation

Based upon the prior research by Meyer and Trost (Meyer, 1992) Bob Kidd Lake is a dimitic lake with a well established period of thermal stratification from early April through early October. The epilimnion extends to four meters with a two meter thick metalimnion. Oxygen stratification closely follows the thermocline during thermal stratification. The oxygen maximum occurs during the isothermal period when temperatures are at the minimum (January-February). Surface photosynthetically active radiation (PAR) quickly diminishes to 30-50% at one meter and to 5-15% at the second meter. Photosynthesis is limited to the upper four to five meters. Their data strongly indicates that the lake is nitrogen limited. Ammonia-N is only present as a decomposition product in the hypolimnion or following plankton die-off. SRP-P concentrations vary but phosphorus seems to be available and not restricting the growth of the phytoplankton. Analysis of chlorophyll's reflect the seasonal changes in phytoplankton quantity and quality. A detailed analysis of these long-term studies will be available as a subsequent AWRC publication.

Four tons of 18-46-0 NPK fertilizer was applied from sacks via spillage and bulk deposition along the north shore and dam berm. All of the applications were in the epilimnion, therefore, adequate light, as well as similar temperatures and oxygen concentrations were present for phytoplankton assimilation of nutrients, growth and population expansion. Data from the combined fertilized sites are compared with the long-term midlake and shoreline reference sites. (Note: The data from the other unfertilized sites were identical or nearly identical to the midlake values.)

Temperature in the epilimnion (down to 4 meters) were isothermal throughout the lake and at each sampling station. The temperatures were limited to a range of 24-

27°C. The thermocline remained constant throughout the test period. No storm event was of great enough energy to tilt the thermocline and induce circulation. Similarly oxygen concentrations were always greater than 6 mg/l with undetectable variation between sites. Photosynthetically active radiation (PAR) was measured as a percent of the surface input to determine if the fertilizer was deposited below the photic zone (1% PAR). As shown by the difference at days 14-, 9- and 0- there is some nominal variation but near agreement between sites (Fig. 2). Post-fertilization three meter values are in near agreement except for an increase at day 2+. This increase is the result of temporary reduced plankton populations at the south dam and mid-lake sites. Throughout the sampling series the photic zone extended beyond the berm or shore depth at which fertilizer was applied. In summary, the fertilizer was applied under conditions in which the water was warm and well mixed, adequate oxygen and light were available for active growth of the phyto- and zooplankton.

Figure 3 depicts the long-term NO_3-N trends at the midlake unfertilized site. The time period includes one annual cycle when the lake was not fertilized (1991) and a cycle with fertilization. These data clearly demonstrate a rapid utilization of nitrate in the spring to undetectable concentrations. This nutrient begins to accumulate in the fall and increases to a maximum during the winter. It is inferred that nitrate diminishes with increasing insolation in the spring and accumulates in the fall when light becomes limiting. Greater detail of this pattern of decline was reflected in the prefertilization data at all sampling sites (Fig. 4). Following fertilization a temporary minimal increase in NO_3-N was observed but there was little difference between fertilized and unfertilized sites.

The long-term concentration of SRP-P show a general cycling of phosphorus through the successional phytoplankton assemblages (Fig. 5). Maximum concentrations are present during the light limited winter period but phosphorus is generally available throughout the growing season. The addition of fertilizer appears to

have no immediate impact but may disperse and result in an observed increase on 15 July 1992. This increase reflects an unutilized phosphorus resource and limitation by another parameter. The addition of fertilizer results in a dramatic increase in SRP-P at the fertilized sites vs. the reference sites (Fig. 6). This increase remains through the first week post fertilization but returns to a nominal level by the second and third weeks. Concentrations at the fertilized sites remain at 1.5 to 6 times the reference concentration during the first week. This suggests that the phosphorus concentration was in surplus with minimal assimilation by the phytoplankton. The reduction to nominal levels by the second and third weeks may be the result of dispersal and dilution enhanced by storm events.

The incorporation of nitrogen and phosphorus nutrients by the phytoplankton result in increased biomass and may produce a change in the standing crop assemblage. Changes in biomass would be reflected in increase turbidity and concentration of chlorophyll-a. Assemblage structure is expressed in chlorophylls-b and -c concentrations since certain phytoplankters contain only one additional chlorophyll. The derived effect of fertilization would be an increase in chlorophyll-b. A comparison of the fertilized and reference sites should reflect changes in turbidity and chlorophylls if the formulation and concentration were correct to produce expansion and changes in the phytoplanton assemblage.

The mean turbidity data show that there is no important difference between the fertilized and reference sites and that there is little perceptible change with time (Fig. 7).

Figure 8 compares the chlorophyll-a data from the combined fertilized and reference sites. These data indicate that there was no difference between these sites. Similarly there was no discernible difference between chlorophyll-b and -c at the fertilized vs. reference sites (Figs. 9 & 10, respectively).

Another measure of the response of the phytoplankton to fertilization is by direct microscopic enumeration. The data depicted in the Figures 11-15 are based upon careful microscopic identification and enumeration. The desired response to fertilization would be an increase in Chlorophyta (green algae) with minimal or no increase in the Cyanophyta (blue-green algae). The latter would be an indicator of enhanced eutrophication and can produce earthy tastes and odors. Increased growth in the Cryptophyta (cryptomonads) and Pyrrhophyta (dinoflagellates) would be considered beneficial. Increases in Bacillariophyta (diatoms) can result in oily taste and odor problems.

The algal assemblage during the test period is dominated by the Chlorophyta and Cyanophyta with Cryptophyta and Bacillariophyta of lesser importance. The Pyrrhophyta and other phytoplankters were insignificant. The figures comparing the fertilized vs. reference sites for each of these taxa clearly show that the abundance's of the algae were nearly identical. The total abundance of phytoplankton, as shown in Figure 11, describes a close agreement between the values at the fertilized and reference sites. Figures 12 (Chlorophyta) and 13 (Cyanophyta) show that the organisms increased and decreased in unison at both sets of sites. The lesser important Cryptophyta (Fig. 14) was slightly less synchronous while the Bacillariophyta (Fig. 15) illustrates almost complete congruency. (Note the change of scale in Figures 14 & 15.)

These data indicate that all changes in phytoplankton abundance was a whole lake response and was disassociated with addition of fertilizer. Also, the assemblage composition was not influenced by the nutrient addition. These data, when considered with the nutrient data, are consistent. Although phosphorus was added to the system, no discernible response was measured. The chemical data (Fig. 3) indicates that nitrate was limiting and that the minimal addition of nitrate was not adequate to produced a measurable change in the algal population. Also, these data suggest that

phosphorus was present in adequate concentration and that the addition of phosphorus produced no detectable increase.

Without an increase or change in the phytoplankton assemblage, little expansion or modification of the zooplankton community occurred. The zooplankton were enumerated and divided into major taxonomic units of rotifers, copepods, and cladocerans. Nauplii were enumerated to estimate the population growth potential of the cladocerans. The total number of zooplankters at the fertilized and reference sites were nearly equal throughout the test period except for the initial collection at Day 14- (Fig. 16). Also, there was no major change in abundance over time. The Day 14- spike was the result of the presence of nearly 100,000 rotifers per liter along the northern stations of the dam (Fig. 17). The abundance of these rotifers also influenced the slight deviations in total zooplankters. At all other sites the rotifers and total zooplankters were essentially equal. Predominance of rotifers may be associated with selective predation. Copepods were lesser in abundance than other zooplankters; however, their abundances were approximately equal at both fertilized and reference sites (Fig. 18). Adult cladocera numbers gradually diminished during the test period at both the fertilized and reference sites (Fig. 19). Naupli were present in greater abundance and tended to increase in numbers by day 21+ at all sites (Fig. 20).

Without an increase in the phytoplankton biomass or change in abundance, an increase in zooplankton would not be forecasted. The anticipated sequence of events, following fertilization, would include an initial increase in nutrients, followed by a change in the quantity and quality of phytoplankters and, later, an increase in zooplankters with possible shift in assemblage composition. The absence of this sequence of events would suggest that at least one parameter was limiting. The experimental protocol was designed to minimize or eliminate as many variables as possible; therefore, the fertilizer deposition was restricted to sites included within the epilimnion. Each of the sites was equivalent in temperature, oxygen concentrations

were near saturation, and the PAR photic zone extended beyond the epilimnion into the upper metalimnion; therefore, nutrients of NO_3-N and SRP-P become the primary controlling parameters.

The data clearly show that nitrogen is normally limiting in the Bob Kidd Lake ecosystem. Phosphorus varies in concentration as one algal population succeeds another. But phosphorus was present in adequate quantity to support existing as well as a greater biomass. The absence of detectable nitrate strongly indicates that it is the limiting nutrient. Limitation by this essential nutrient prevents the full potential of the other parameters to be realized.

These data also provide a mechanism by which limiting nutrients can be identified. Measurement of the nutrient concentrations when light is the primary factor limiting phytoplankton growth, i.e., winter, provides a reference point. Nutrient concentrations during late spring or early summer, when light is no longer limiting, should be compared with the winter values. As shown by this project, the differences in SRP-P in the winter vs. spring/summer is unremarkable (Fig. 5). In contrast, nitrate concentrations are at their maximum during the winter and dramatically crash to zero with increasing light availability (Fig. 3). This parameter remains at its minimum until total insolation decreases (decreasing day length & increasing sun angle) in autumn.

The results of this project indicate that the proper protocol was developed to measure the impact of fertilization. The derived data permitted the determination of the influence of the nutrients, as well as the response of the two primary food sources. The protocol carefully selected application sites that were in the epilimnion where temperature, oxygen, and light were optimal and unimportant variables. The analytical procedure produced data which provided insight into the influence of the nutrient addition on the dynamics of the phyto- and zooplankton assemblages. The availability of winter nutrient concentrations proved to be invaluable in understanding the system and identification of the primary limiting factor.

Conclusions

1) The cooperative approach to developing a protocol for determining the influence of nutrient additions was highly successful.

2) The protocol directly described the system prior to fertilization and the influence of added nutrients to water quality as well as quality and quantity of the phytoplankton and zooplankton assemblages.

3) The selection of Bob Kidd Lake permitted the inclusion of valuable data from an ongoing project to assist in the interpretation of the results.

4) The water was at the appropriate temperature for rapid phytoplankton growth with nutrient addition.

5) The photic zone extended beyond the epilimnion into the metalimnion.

6) Oxygen concentrations exceed the requirements for rapid zooplankton assemblage expansion.

7) The data strongly indicate that the lake is nitrate-N limited.

8) SRP-P varies in concentration through the year in association with phytoplankton succession.

9) Nitrate-N was similar at the fertilized and reference sites.

10) SRP-P was detected within a few hours after application and remained at elevated level for at least one week.

11) Turbidity, as a measure of phytoplankton abundance, did not change after fertilization.

12) Chlorophylls-a, -b and -c were essentially equivalent at the fertilized and reference sites; indicating no change in phytoplankton abundance and composition.

13) Phytoplankton analysis demonstrated no difference in either abundance or composition between the fertilized and reference sites.

14) The lack of response of phytoplankton to enhanced phosphorus indicates that phosphorus was not the limiting nutrient.

15) The lack of changes in zooplankton abundance and composition is expected based upon the absence of increase in the phytoplankton standing crop.

16) The chemical data suggest that granular fertilizer applied with the spillage and bulk deposition technique was an effective procedure for Bob Kidd Lake.

Recommendations

1) Lakes subjected to fertilization should include collection of nutrient data at monthly intervals to determine nominal annual nutrient cycles.

2) Information derived from monthly collections should be used to determine nominal N:P concentrations and ratios.

3) The resultant information should be used to identify the time at which one of the nutrients became limiting.

4) Phytoplankton samples should be collected and analyzed in concert with the nutrient data to determine the nominal succession and dominant organisms.

5) Phytoplankton data should be used to anticipate and measure their response to fertilization.

6) Surface temperature measurements should be taken to establish the annual changes in this parameter in the epilimnion.

7) Secchi disc measurements should be included with the phytoplankton samples to provide an indirect measure of plankton abundance and as an estimate of light penetration.

8) The combined data be used to confirm or modify the fertilization formulation, rate and/or time of application.

9) Consideration should be given the form of the fertilizer, the zone of application, and the application method.

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Figures

Figure 1. Lake Bob Kidd Map

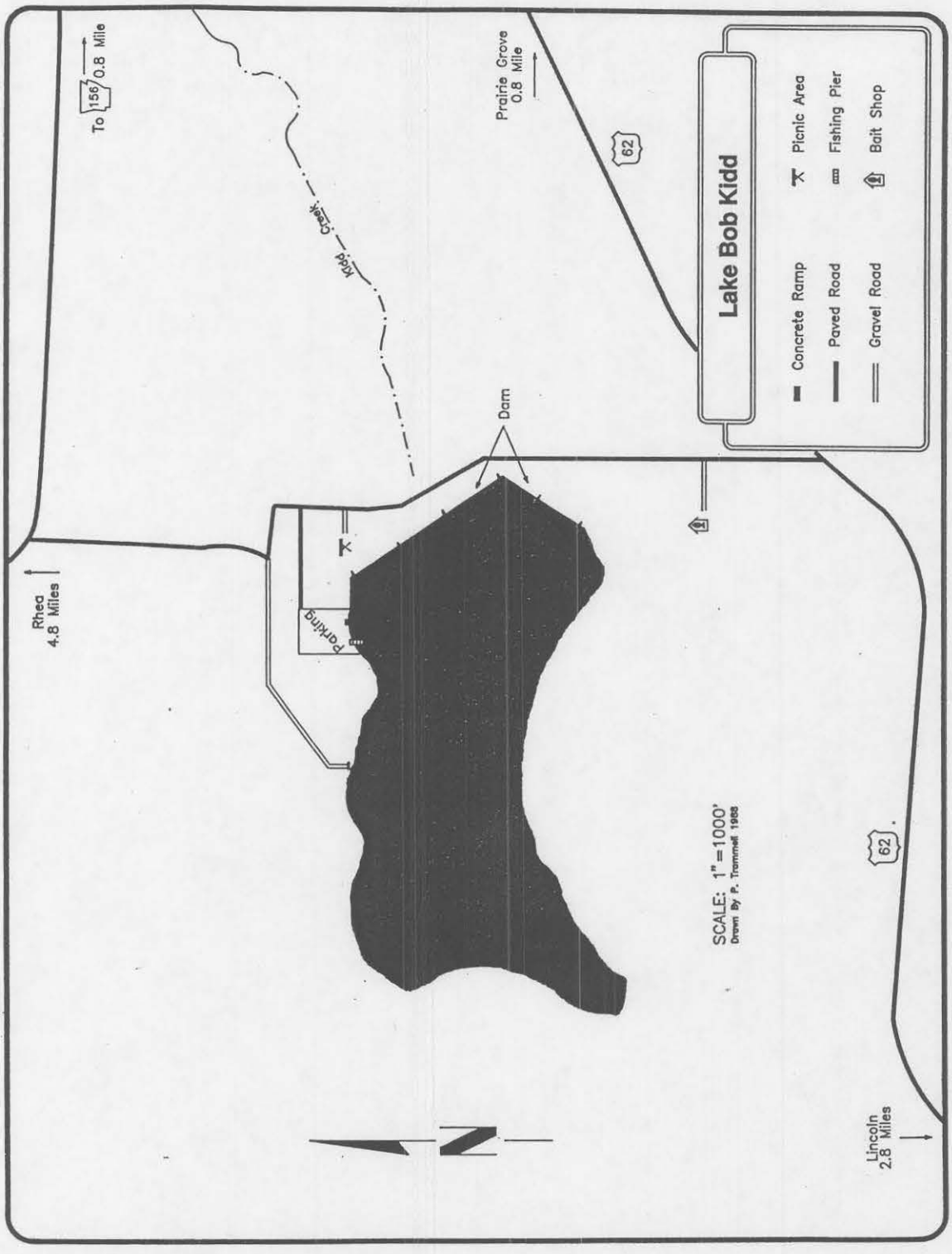
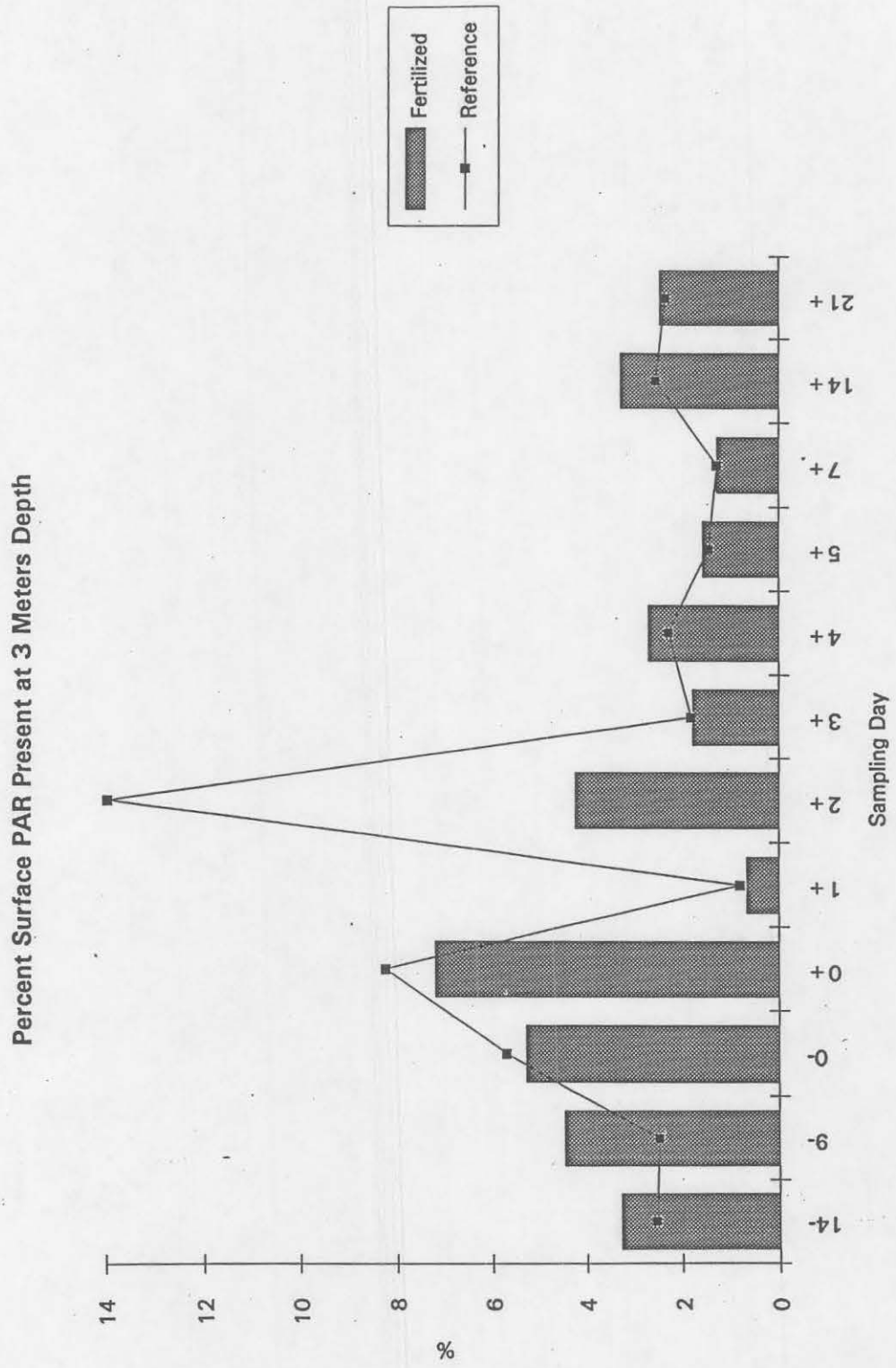


Figure 2. Mean Percent Surface PAR Present at 3 Meters Depth



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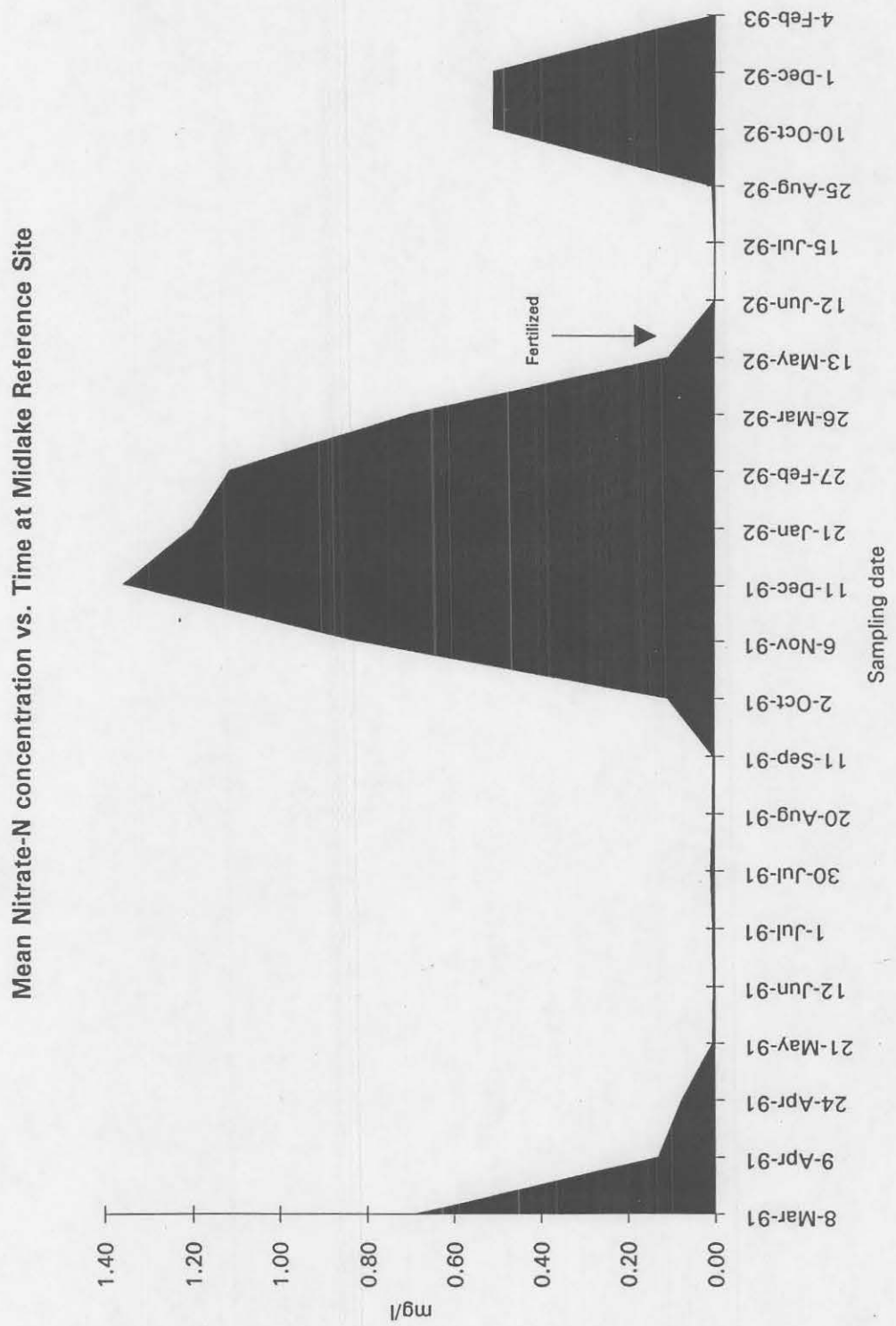


Figure 4. Mean Concentration of Nitrate-N

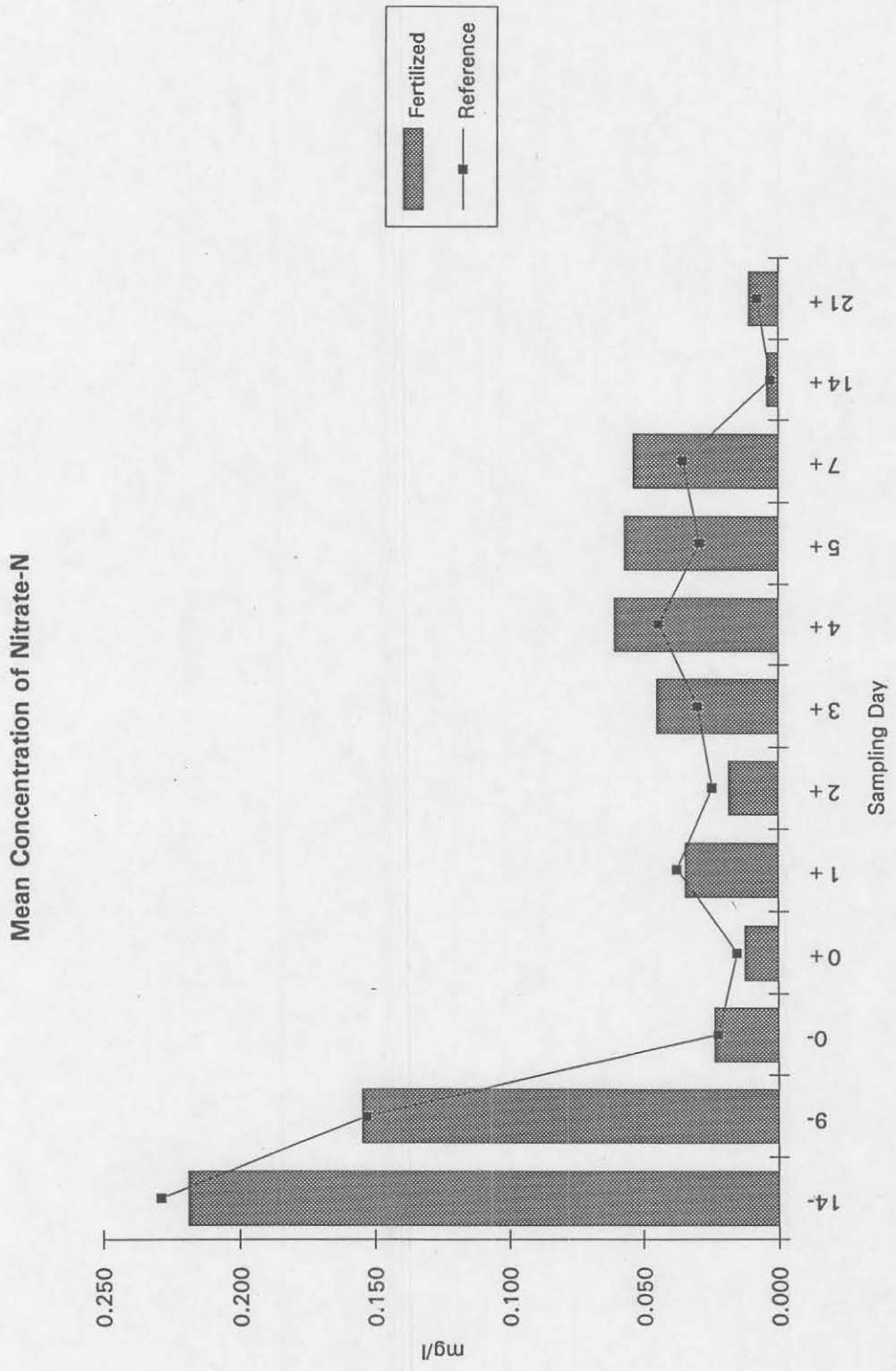
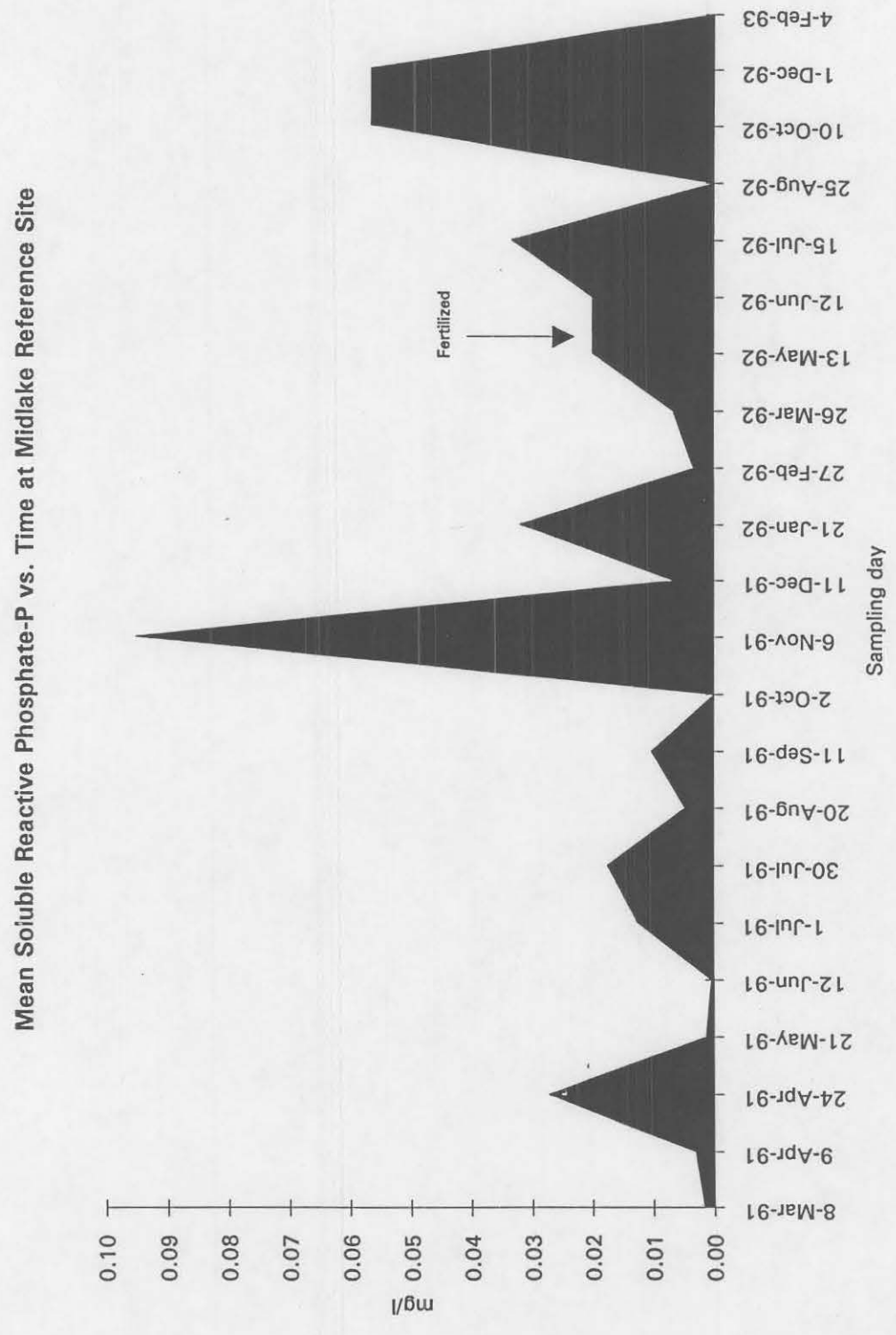


Figure 5. Mean Soluble reactive Phosphate-P vs. Time at Midlake Reference Site



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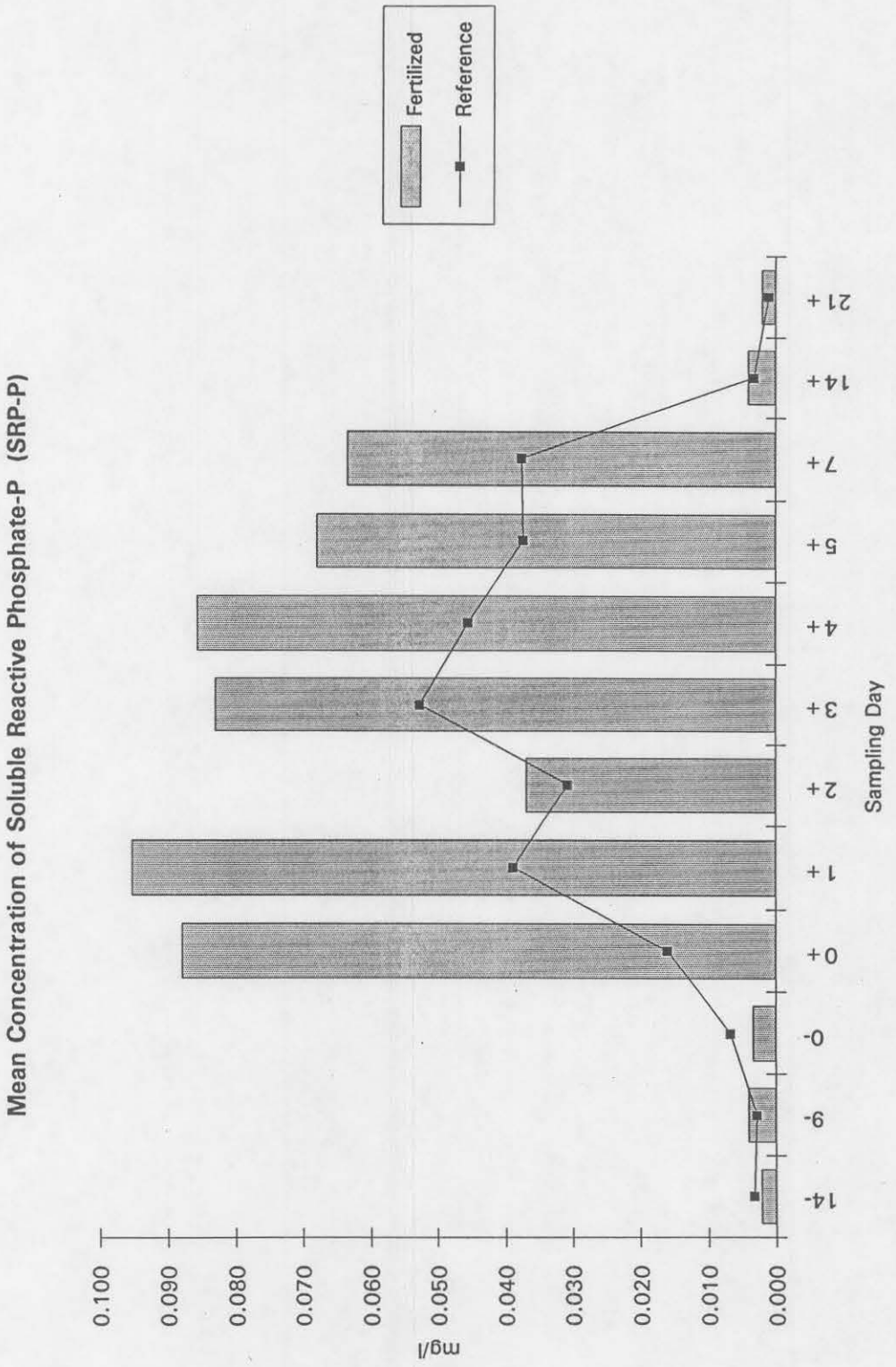

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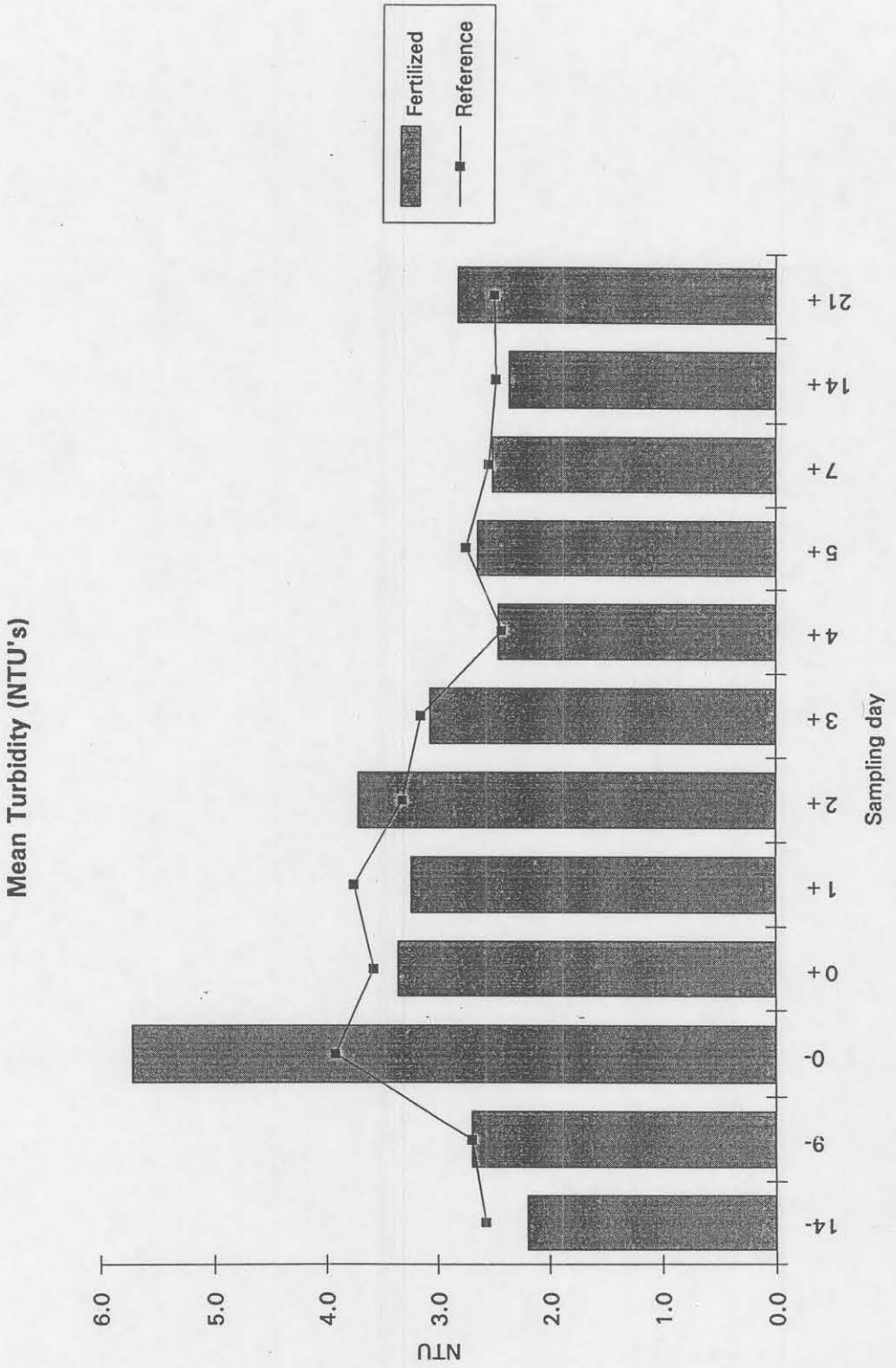


Figure 8. Mean Chlorophyll-a in ug/l

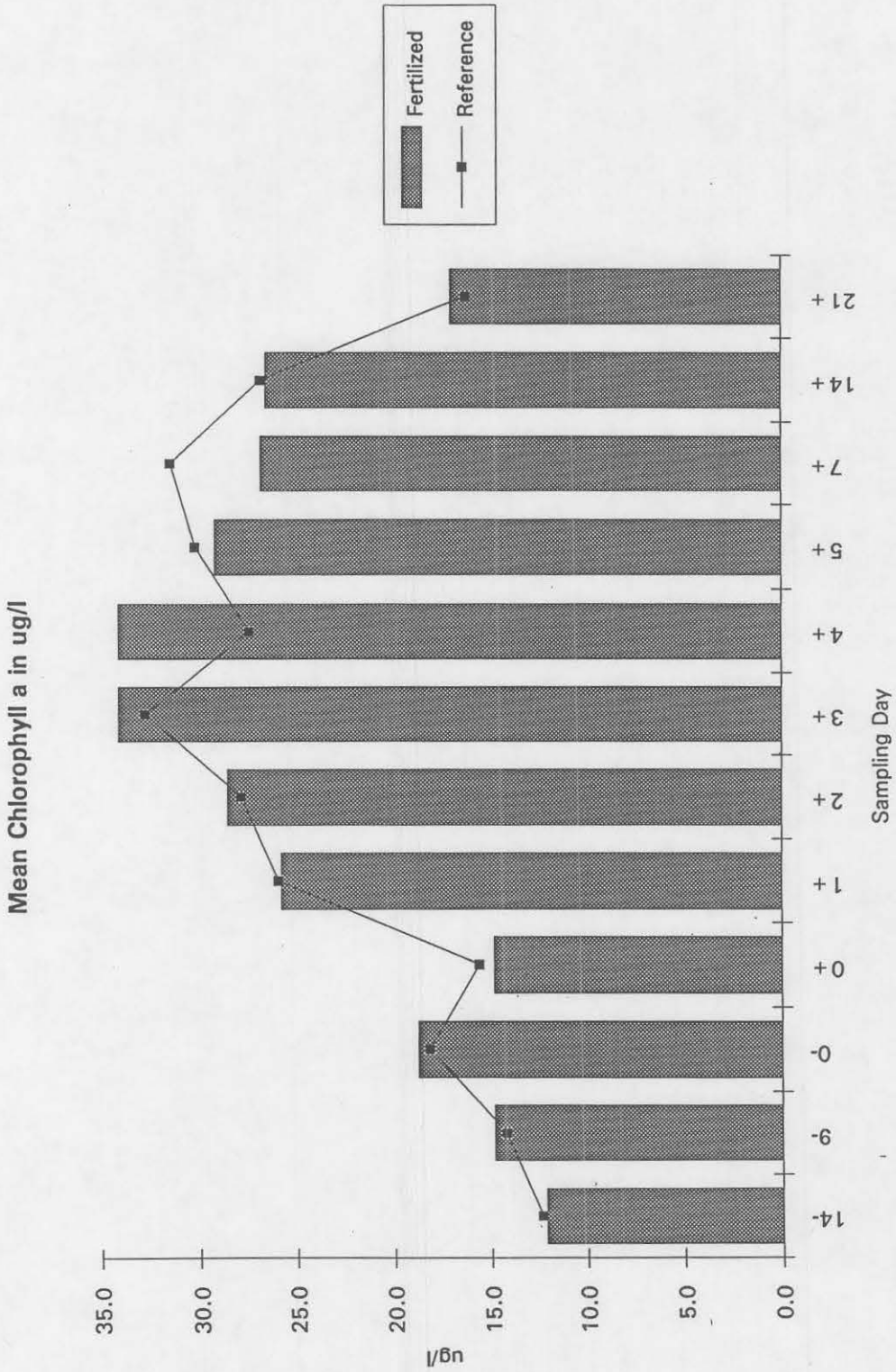


Figure 9. Mean Chlorophyll-b in ug/l

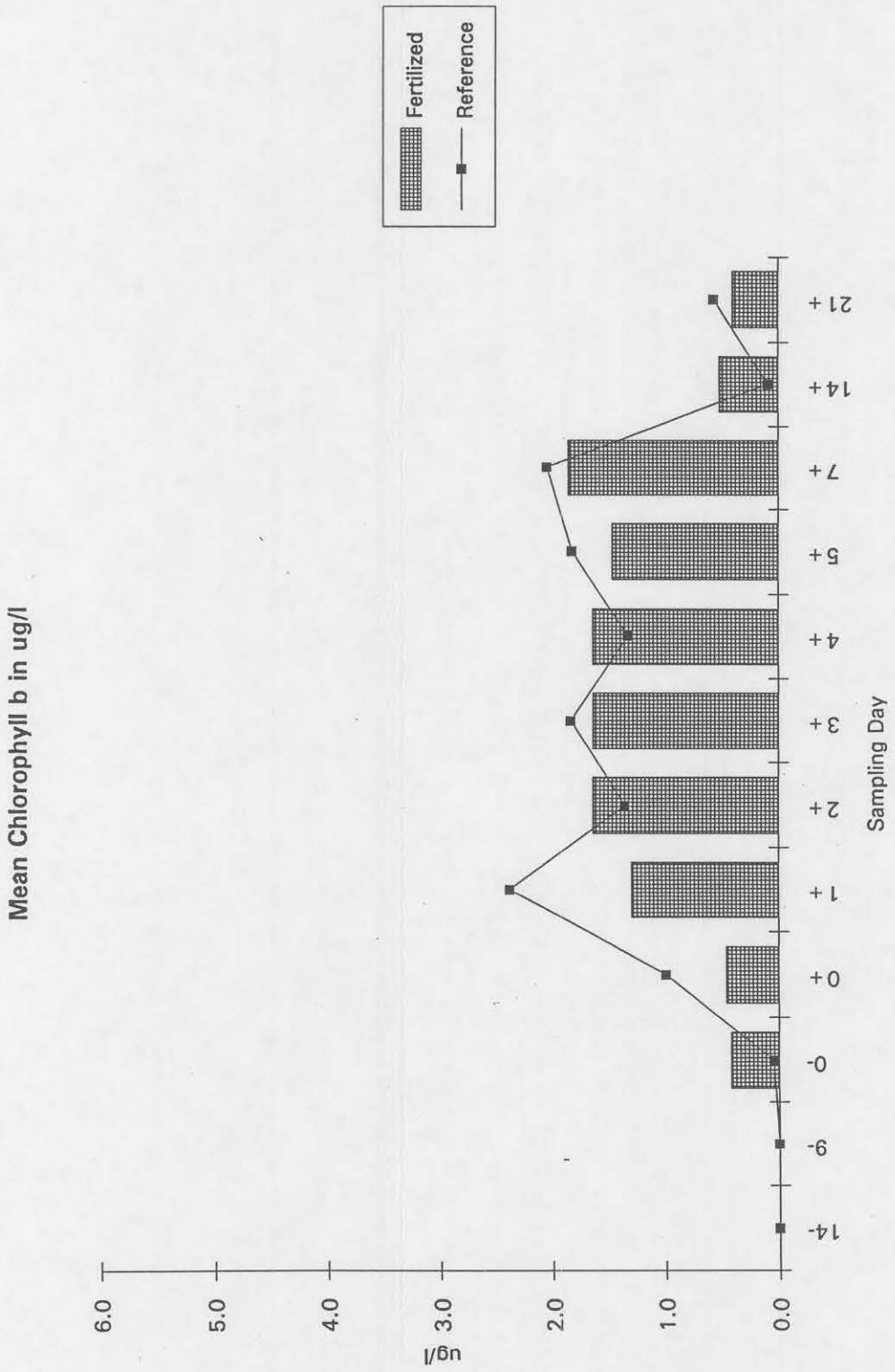


Figure 10. Mean Chlorophyll-c in ug/l

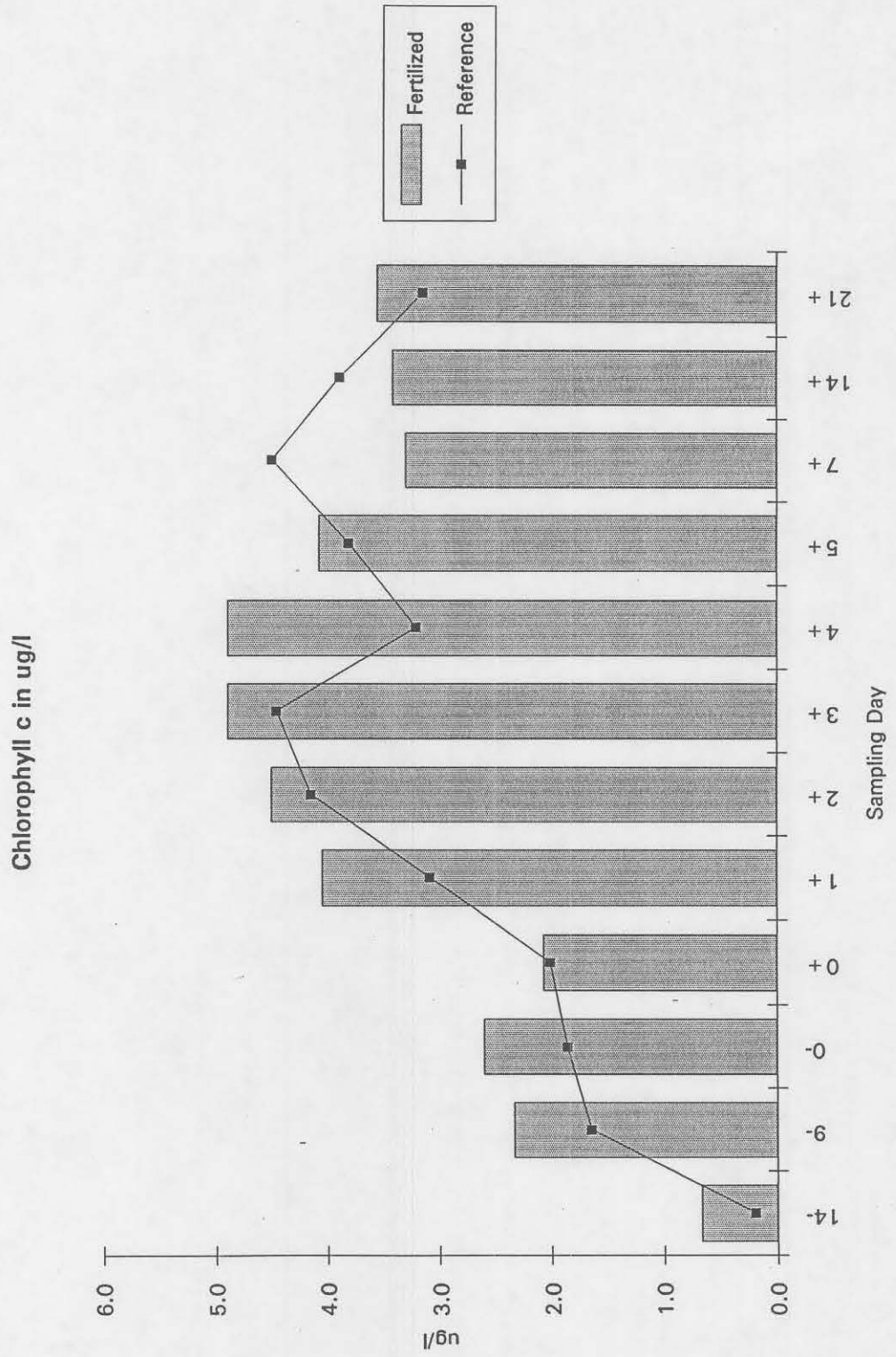
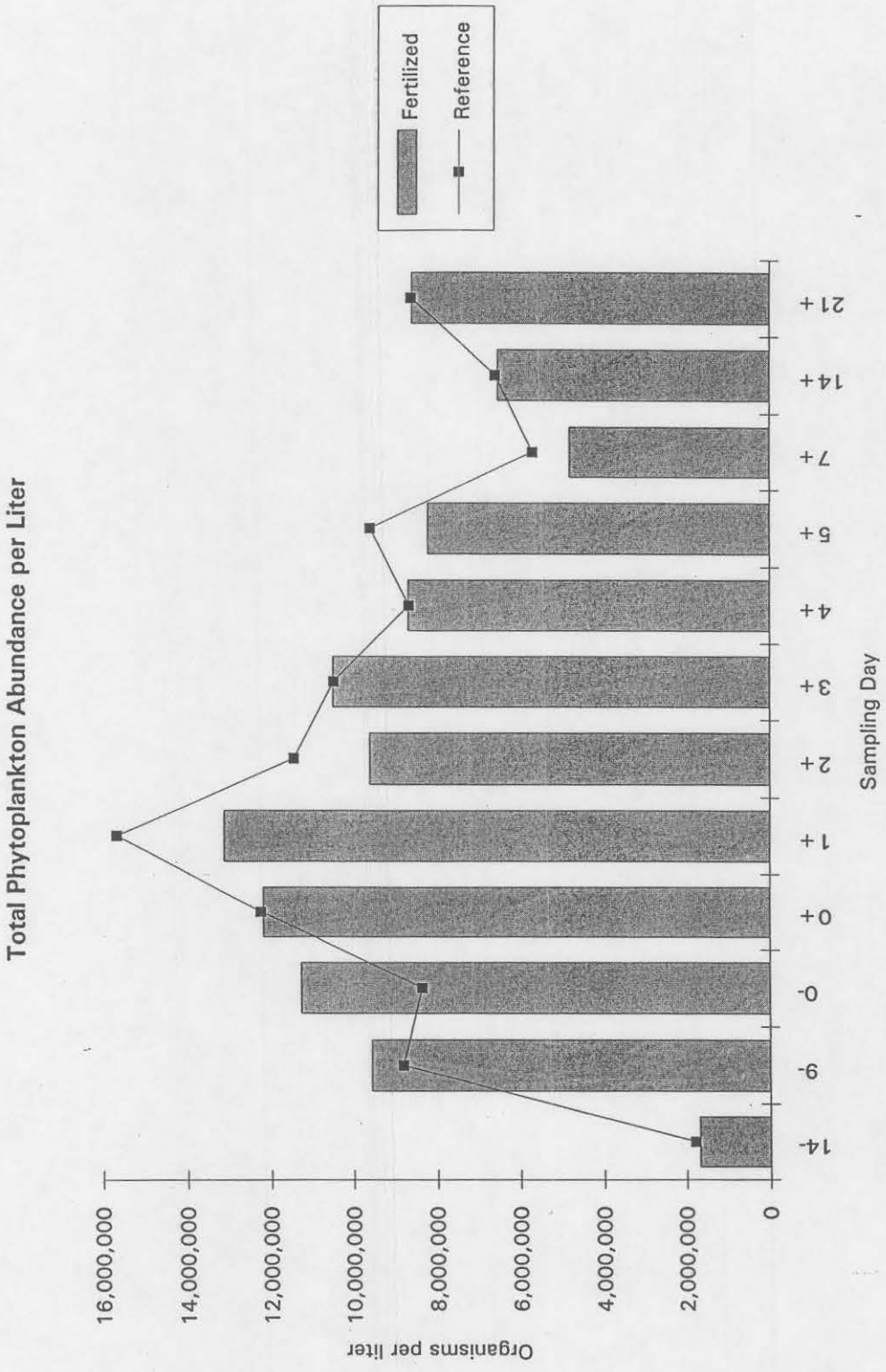


Figure 11. Mean Total Phytoplankton Abundance per liter



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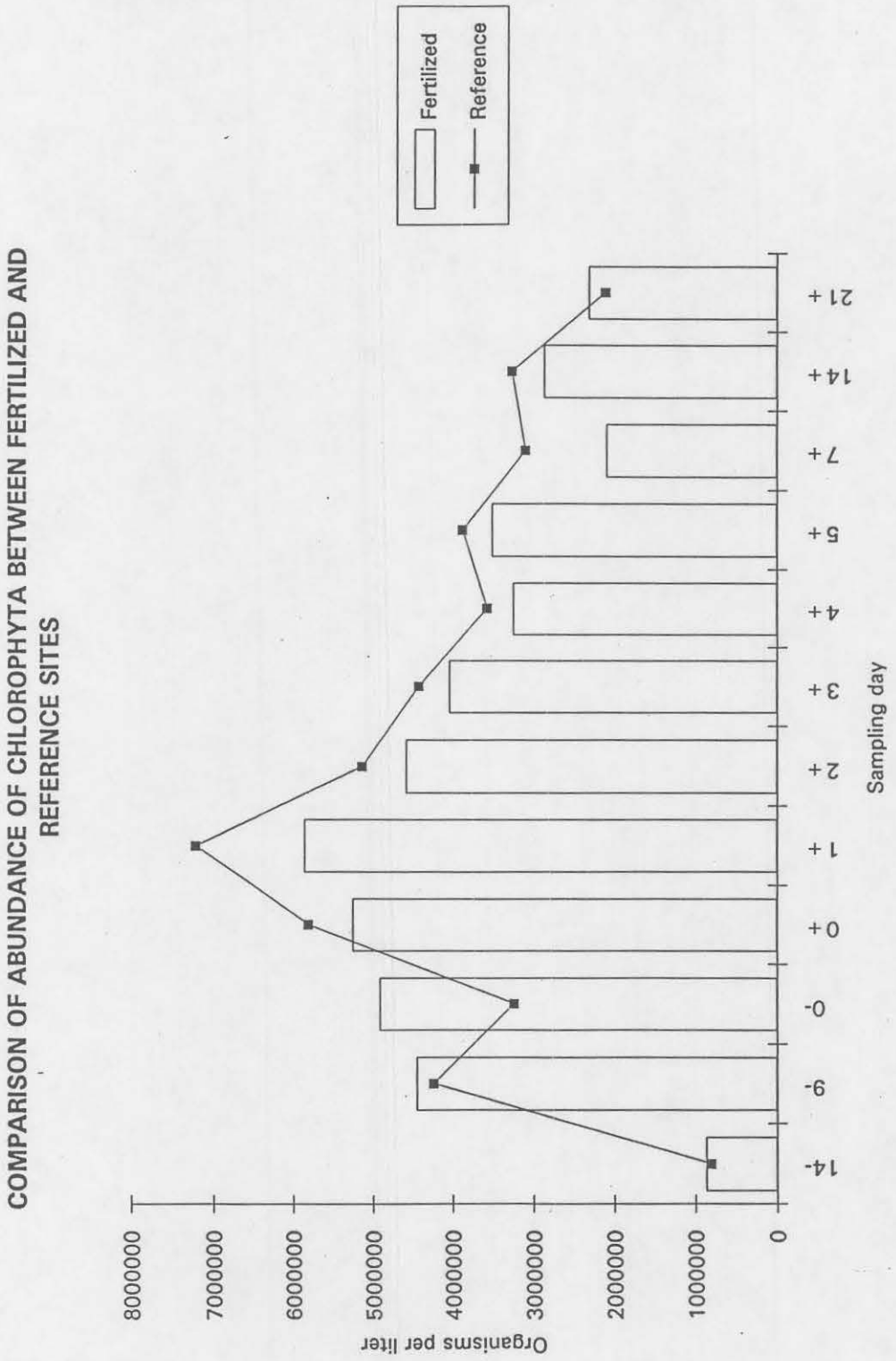

Figure 13. Comparison of Mean Abundance of Cyanophyta between Fertilized and Reference Sites

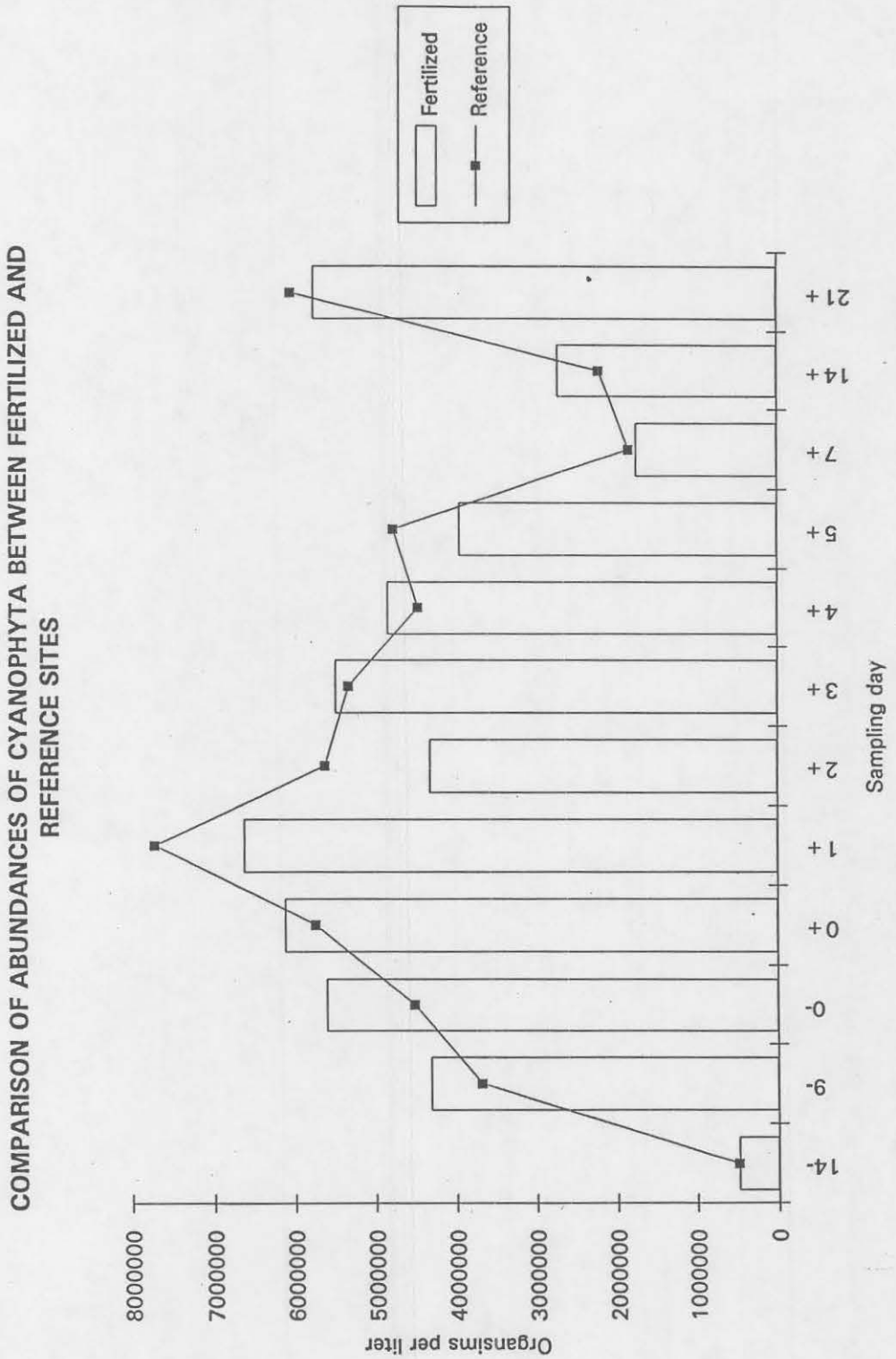

Figure 14. Comparison of Mean Abundance of Cryptophyta between Fertilized and Reference Sites

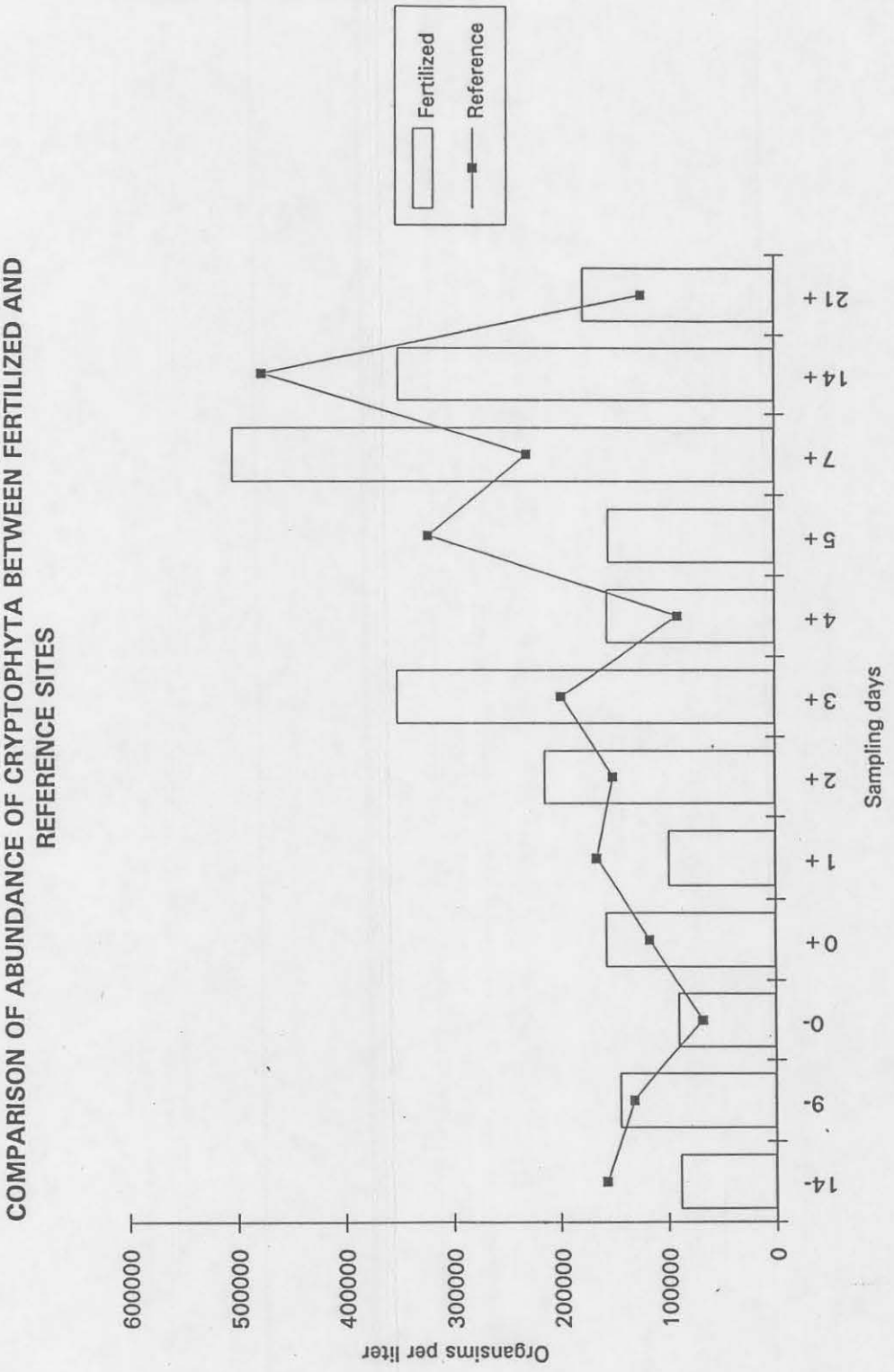

Figure 15. Comparison of Mean Abundance of Bacillariophyta between Fertilized and Reference Sites

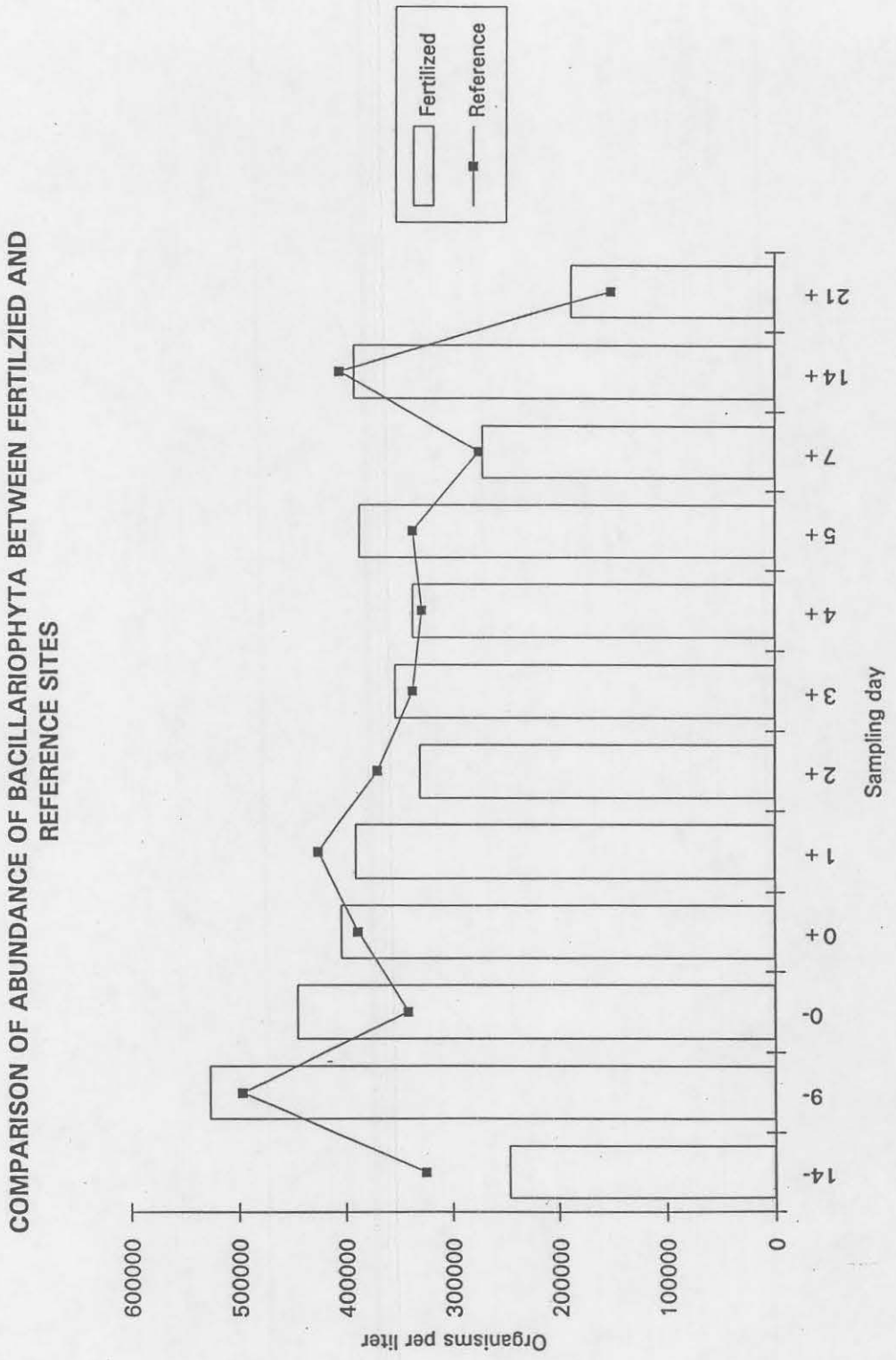

Figure 16. Mean Total Number of Zooplankters per liter

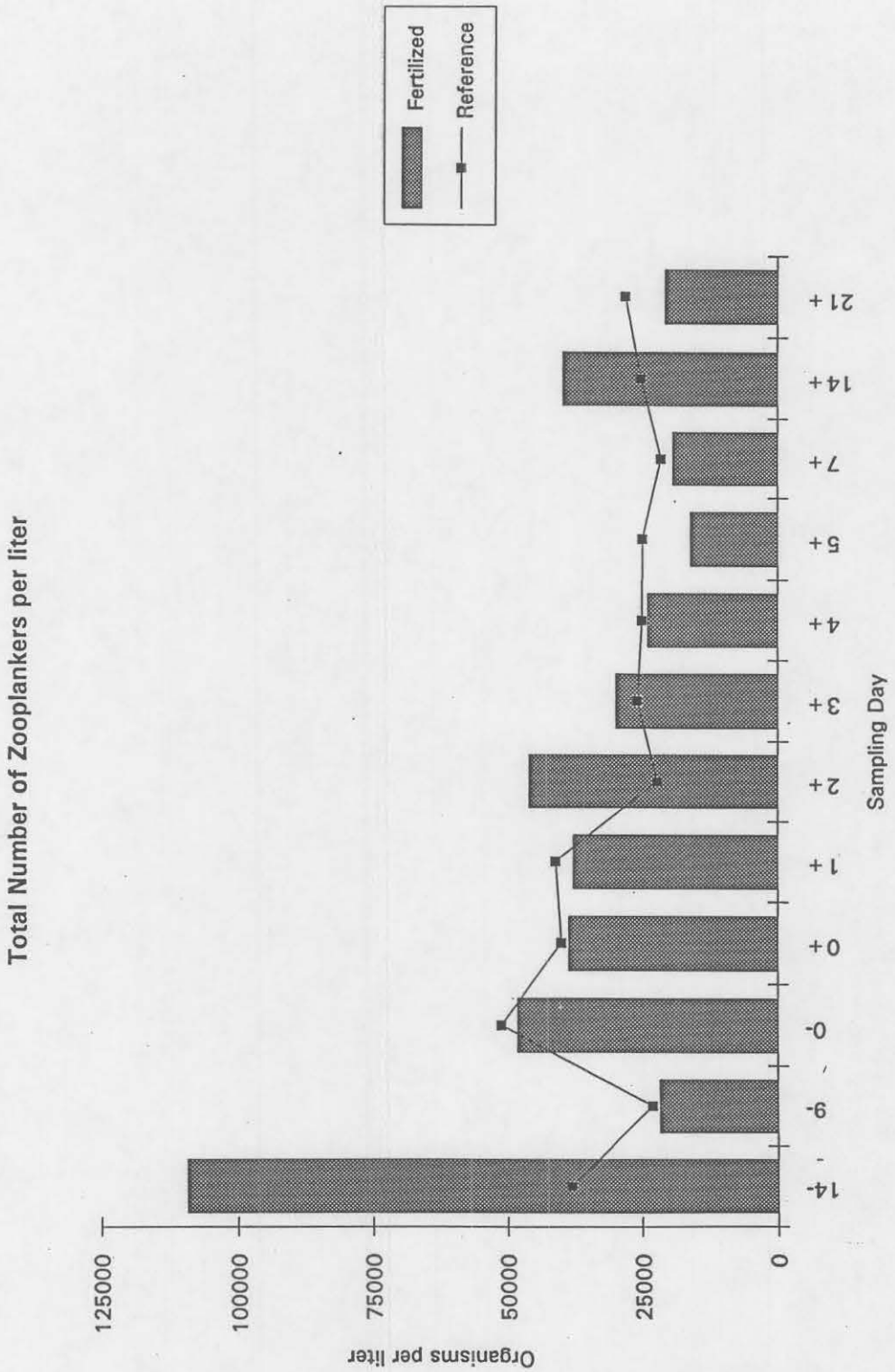

Figure 17. Mean Number of Rotifers per liter

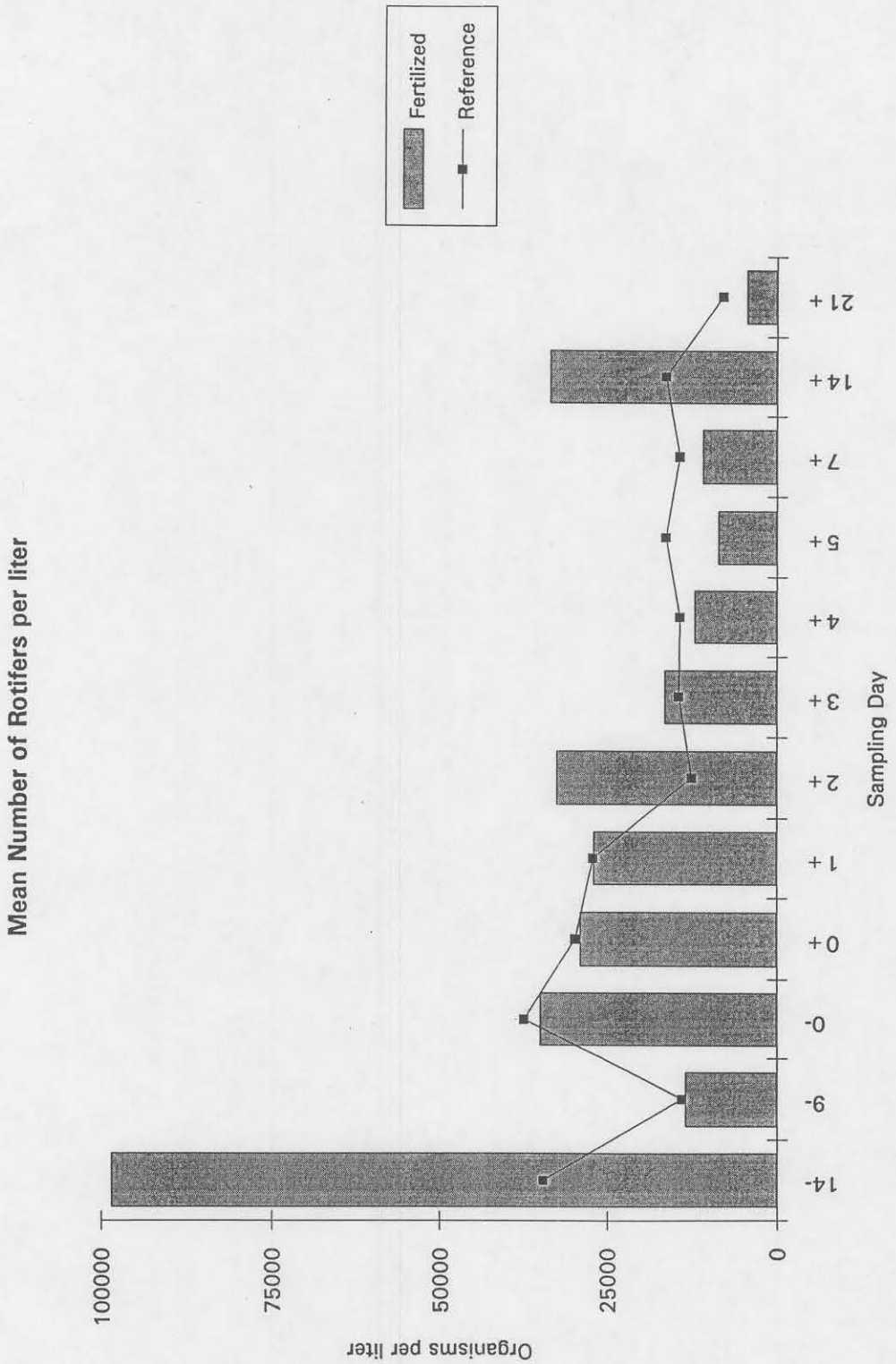

Figure 18. Mean Number of Copepods per liter

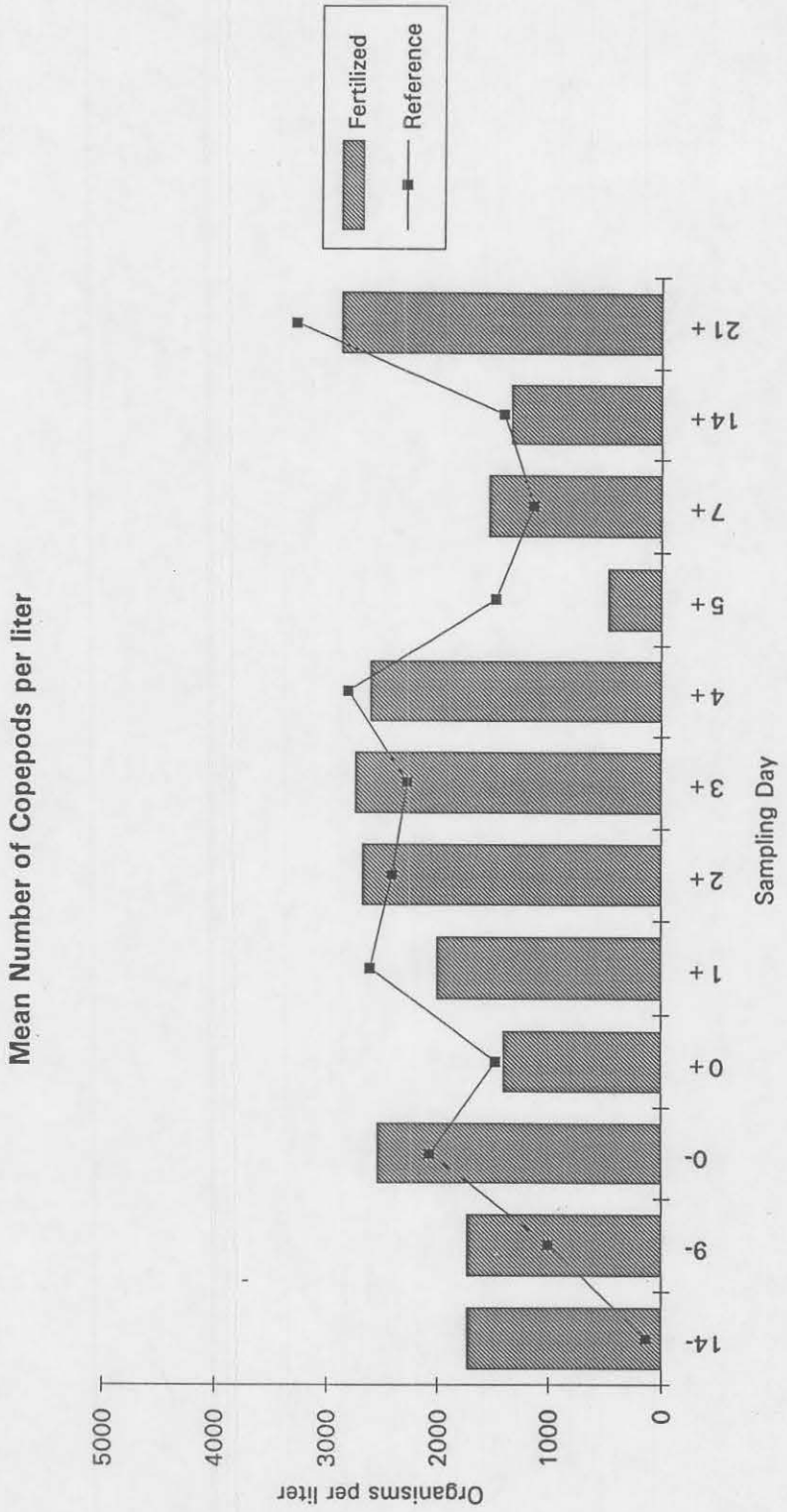

Figure 19. Mean Number of Cladocera per liter

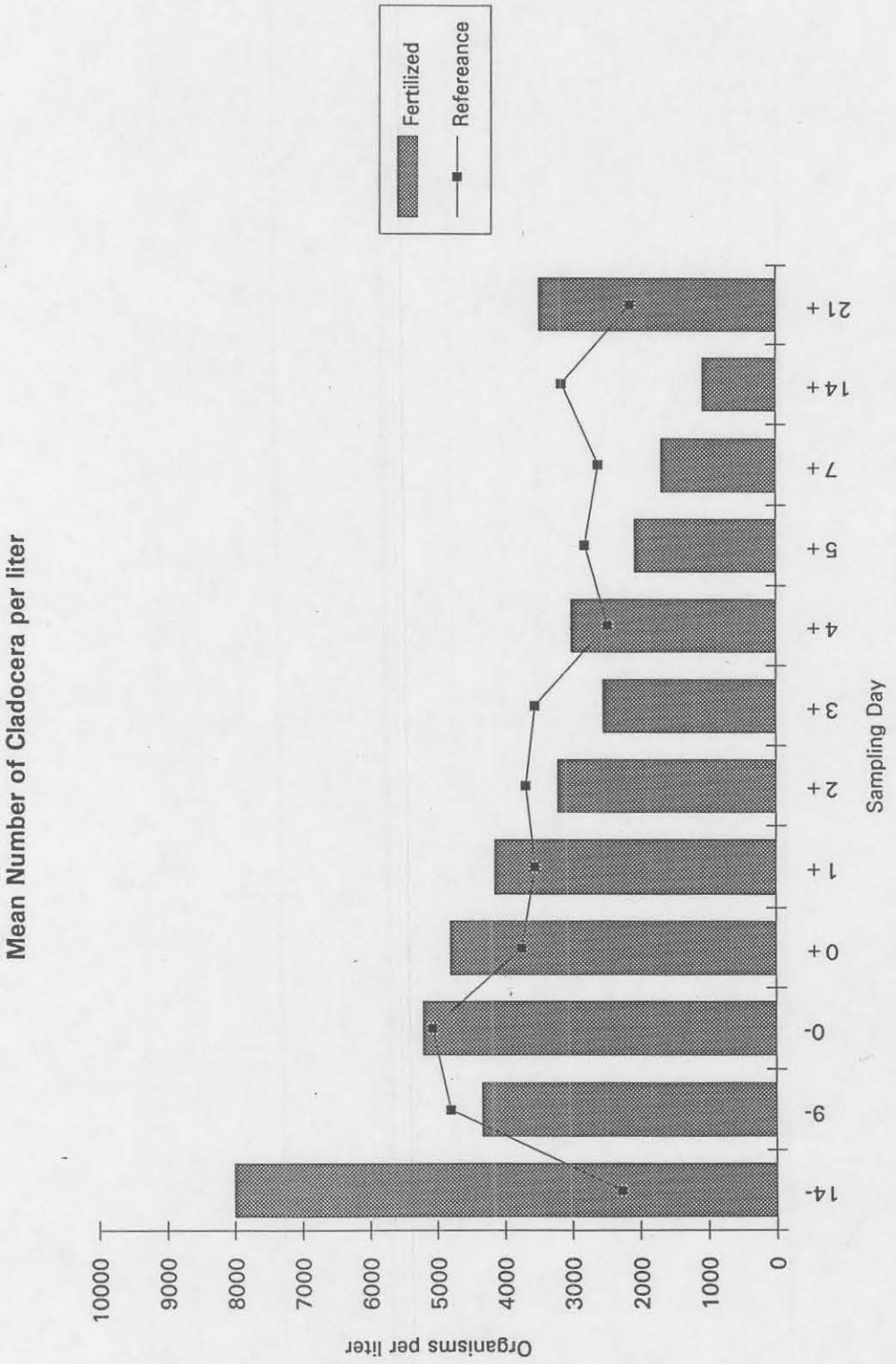

Figure 20. Mean Number of Naupli per liter