IOWA CONSERVATION COMMISSION
FISHERIES SECTION

FEDERAL AID TO FISH RESTORATION

ANNUAL PERFORMANCE REPORT

RESERVOIR INVESTIGATIONS

PROJECT NO. F-94-R-4

Study Title: Assessment of the Relationships Between Nutrients, Blue-Green Algae, Zooplankton and Fish Planktivores

Job 1: Relationship between water quality, plankton density and species composition of plankton

Job 2: Crappie density, growth and plankton density

PERIOD COVERED:
1 JULY, 1983 - 30 JUNE, 1984

FEDERAL AID TO FISH RESTORATION

ANNUAL PERFORMANCE REPORT

RESERVOIR INVESTIGATIONS

PROJECT NO. F-94-R-4

Study Title: Assessment of the Relationships Between Nutrients, Blue-Green Algae, Zooplankton and Fish Planktivores

Job 1: Relationship between water quality, plankton density and species composition of plankton

Job 2: Crappie density, growth and plankton density

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE: Iowa

PROJECT NO.: F-94-R-4

STUDY NO.: 3

JOB NO.: 1

NAME: Assessment of the Relationships Between Nutrients, Blue-Green Algae, Zooplankton and Fish Planktivores

JOB TITLE: Relationship betweeen water quality, plankton density and species composition of plankton

Period Covered: 1 July 1983 through 30 June 1984

ABSTRACT: Relationships between blue-green algae at Green Valley Lake and water quality was investigated to identify factors and mechanisms which promoted growth of nuisance blooms. Then limnocorrals were employed to determine the potential effectiveness of using alum, ricinolic acid and ammonium nitrate in controlling nuisance blooms of blue-green algae. Water quality and plankton counts in the lake indicated blue-green blooms, primarily Aphanizomenon, were associated with high chlorophyll(a) and Phosphorous concentrations. Peak blooms were associated with chlorophyll(a) values of 146-530 mg/l. Green and yellow-green blooms occurred in the spring and sometimes in the autumn when inorganic Nitrogen concentrations were .20 mg/l or greater. Blue-green succession occurred primarily in July-August when inorganic forms of Nitrogen were lowest. Three experiments during the summer showed alum effectively decreased pH to < 7 and alkalinity to < 50 mg/l; to a lesser extent phosphates were decreased. The response was, however, short-lived and usually within three weeks limnocorral water quality was similar to lake controls. Ammonium nitrate treatments produced nitrate and ammonia concentrations of greater than 5 and 2 mg/l, respectively. Similar to alum treatments, the response was short-lived and within three weeks, treatment corrals were similar to controls. Ricinolic acid treatment produced no significant changes in water quality. Response of phyto- and zooplankton to changes in water quality was minimal. A confounding factor in the limnocorral experiments was establishment of a microhabitat within the corrals. For example, abundant growth of filamentous algae on corral walls provided added shading. Also, poor circulation at the air-water interface decreased dissolved oxygen in the water column substantially. Recommendations included expansion of experimental control of blue-green algae from limnocorrals to a blocked-off cove and reduce the treatments to alum.

Prepared by: Larry Mitzner
Fisheries Research Biologist

Date Prepared: August 1, 1984

Approved by: Don Bonneau
Fisheries Research Supervisor

TABLE OF CONTENTS

Page

JOB 1

JOB 2

LIST OF TABLES

LIST OF TABLES (continued)

Job 2

LIST OF FIGURES

Page

Job 1

Job 2

STUDY OBJECTIVE

To determine methods for contol of nuisance blue-green algae and provide strategies for management of fish populations at these lakes.

JOB 1 OBJECTIVE

To determine the influence of water quality on the phytoplankton and zooplankton community.

INTRODUCTION

Blue-green algae is a nuisance in many Iowa waters, particularly those lakes with high nutrient inflow from heavily fertilized, rowcropped land. Nuisance blooms are detrimental to swimming, water skiing and fishing. Blooms are esthetically unpleasant and may even produce a toxin harmful to fish (Ingram, 1954; Rose, 1953). Another and potentially serious problem caused by dense algal blooms is summer fish kills. High plankton respiration and decomposition on hot, quiet nights can reduce dissolved oxygen levels to critical levels and kill fish. Sport fishing is an important aspect of the recreational use of these lakes. Bachman (1980) clearly defined the problem in an investigation to classify 107 Iowa lakes. The primary problem was nutrient loading which resulted in high phytoplankton populations as evidenced by high turbidity and chlorophyll(a) concentations. Several lakes with histories of plant communities almost wholly dominated by blue-green algae are Black Hawk Lake, East Okoboji Lake and Green Valley Lake.

Previous investigations summarized by Dunst (1974), showed a multitude of remedial lake rehabilitation strategies. More recently, Environmental Protection Agency publications (Stauffer, 1981; Recklow, 1981; Peterson, 1981; and Welch, 1981) have outlined various methods for lake rehabilitation. In-lake rehabilitation techniques which show promise are nutrient inactivation (Cooke, 1981) and alteration of the Nitrogen and Phosphorous ratio. N:P ratios may be critical in establishing algal species composition (Barica, 1980). Investigation of these techniques is important in developing lake rehabilitation strategies. Basic information is needed to aid in understanding relationships between nutrient cycles, blue-green algae densities and the well-being of fish planktivores.

The investigational approach will include assessment of water quality parameters and plankton at Green Valley Lake, a lake undergoing rehabilitation through monies provided by the Rural Clean Water Act and State of Iowa, cooperating. Water quality was monitored by the Iowa Depatment of Water, Air and Waste Water Management in 1981-1983 and will continue in 1984 as part of the lake rehabilitation program. Additionally, zooplankton and phytoplankton communities were monitored in 1982 and 1983 to describe the relationship between water quality and plankton. Experimental use of alum and adjustment of N:P ratio in limnocorrals will occur in 1983 and 1984.

DESCRIPTION OF THE STUDY AREA

Green Valley Lake is a 428 ac man-made impoundment located near Creston in Union County (Table 1). The lake is located in Green Valley State Park, yet much of the watershed lies outside the park and is subject to intensive rowcroping. The lake is perched high in the watershed with little wind protection which results in ephemeral stratification during calm periods.

Table 1. Physical description of Green Valley Lake and watershed.

Area	428 ac	Shoreline development	4.27
Maximum depth	26 ft	Volume development	1.13
Mean depth	10 ft	Watershed/lake area	11.6/1

Watershed use:

Cropland 77%	Pasture 18%	Timbered 2%

The lake was renovated of scale-fish, primarily carp, in 1974 and restocked with largemouth bass, black crappie and bluegill. The fishery is now dominated by bluegill, crappie, channel catfish and bullhead. The crappie population is dominated by a single slow-growing year class.

METHODS AND PROCEDURES

Water samples were collected by the park officer and transferred to the State Hygienic Laboratory for analysis. Field observations included dissolved oxygen, air temperature, surface water temperature, wind speed-direction and Secchi disc depth. Laboratory analysis consisted of ph, turbidity, chlorophyll(a), organic Nitrogen, ammonia, nitrate-nitrite complex, filterable phosphate and total phosphate. Analysis was completed according to EPA methods and standards. Sampling commenced in early May and continued through mid-September on a bi-weekly regimen. Two sampling locations were established at the lake, designated as site 1 and site 2 (Figure 1). Sampling at site 1 was statified at 2, 4 and 6 meters and designated as 1A, 1C and 1E, respectively. The depth at site 2 was approximately 1 meter and one sample (2A) was taken at mid-depth.

Plankton sampling commenced on May 16, 1983 and continued through September 1. Three stations were sampled (Figure 1) with two hauls at each station, one at the surface and another at one meter below surface. Net orifice was 104 cm^2 with a cod of 45 cm. Mesh size was 80 microns. The tow was made over a known distance as determined by land marks established on the shoreline; thus, total sample volume could be determined. The sample was preserved in 5% buffered formalin for later processing. At station 1, one gallon of surface water was taken to estimate quantity of phytoplankton passing through the mesh.

Figure 1. Green Valley Lake showing locations of water quality and plankton tow stations.

Each sample was poured into a 100 cc graduated cylinder and allowed to settle 7 days, then the volume of phytoplankton and zooplankton in the cylinder was recorded; in addition, blue-green algae volume floating on the surface of the cylinder was recorded. Following the volumetric measurements, the sample was thouroughly mixed and one ml aliquot was introduced into a Palmer counting cell. Identification of the biota and enumeration was made at 45 magnification. Two replicate slides were prepared and three fields examined within each slide. Phytotaxa were identified to at least subclass.

One gallon of unfiltered water was allowed to settle for 7 days and concentrated to 200 ml by siphoning off the supernatant. One drop was placed on a slide and 10 fields were examined. Triplicate slides were prepared.

Limnocorrals were constructed of 2 x 12 inch frame lumber with styrofoam floatation. The unit contained eight experimental compartments as shown in Figure 2. Each corral was 4 x 4 ft with a depth of 6 ft. Six mil polyethylene sheeting, weighted with a .5 inch rod, was used to line and seal each corral. Three experiments were conducted in 1983 involving duplicate treatments of alum (aluminum sulfate), ammonium nitrate and ricinolic acid; two compartments were relegated as control limnocorrals. Compartments were randomly selected before each experiment for treatments and controls. In addition, two samples were taken in the lake near the limnocorrals and provided background readings. Table 2 shows treatment levels during the experiments. Water quality was measured immediately after application and weekly for two additional weeks. Likewise, plankton was examined from a single vertical tow (6 ft) taken from each corral. Samples were processed identical to routine lake tows.

FINDINGS

Water Quality

Phosphorous, in its combined forms with various organic and inorganic ions, is considered one of the primary factors in biological productivity of Iowa lakes (Bachmann, 1980). Total phosphate concentrations at Green Valley Lake ranged from .09 mg/l at station 1A on June 13, to 2.6 mg/l at station 2A on August 8 (Table 3). Concentrations of Phosphorous at other strata were, likewise, at a peak on August 8 averaging 1.2 mg/l at all depths for station 1. Lowest overall total phosphate concentrations were found on the first sample period (May 11) when the average was .20 mg/l. After the peak on August 8, total phosphate decreased until sampling ceased on September 15 when values averaged .56 mg/l.

Filterable phosphate, which is more readily available for plant uptake, had values approximately 2-5 times less than total phosphate. Concentrations at individual stations ranged from a low of .02 mg/l at station 1A on May 11 to a maximum of 1.2 mg/l at station 1E on August 8 (Table 4). Patterns of filterable phosphates were nearly identical to total phosphates with lowest values in spring (May 11) averaging .04 mg/l, increasing to a peak on August 8 where mean concentration was .75 mg/l. Thereafter, filterable phosphates decreased until September when concentrations averaged .31 mg/l.

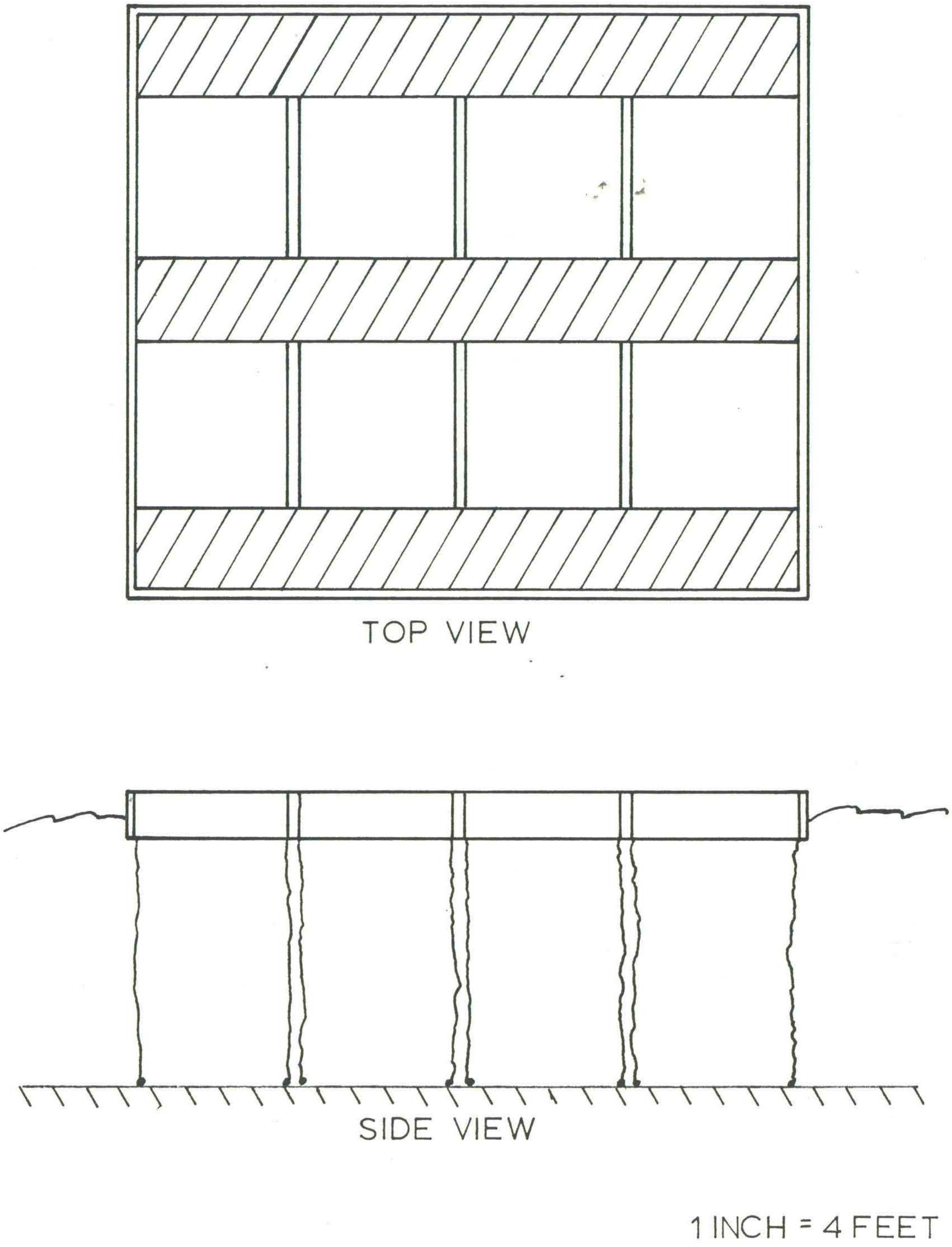

Figure 2. Diagram of limnocorral used at Green Valley to experimentally control blue-green algae.

Table 2. Treatments used to experimentally control blue-green algae in limnocorrals at Green Valley Lake.

Date	Ammonium Nitrate (mg/l)	Ricinolic Acid (mg/l)	Alum (g Al/l)
June 8	2	5	20
July 7	8	5	25
August 18	8	10 and 20	25

Table 3. Total phosphate concentrations (mg/l) at Green Valley Lake, 1983.

Date	Station			
	1A	1C	1E	2A
May 11	.17	.15	.18	.28
May 25	.22	.20	.21	.30
June 6	.12	.11	.10	.18
June 13	.09	.08	.09	.28
June 27	.14	.16	.37	.31
July 11	.20	.21	.23	.54
July 25	.25	.25	.30	1.40
August 8	.52	.90	2.10	2.60
August 22	.55	.56	.60	.92
September 6	.75	.77	.79	.96
September 15	.58	.55	.55	.56

Table 4. Filterable phosphate concentrations (mg/l) at Green Valley Lake, 1983.

Date	Station			
	1A	1C	1E	2A
May 11	.02	.02	.05	.05
May 25	.04	.04	.04	.04
June 6	.04	.05	.04	.05
June 13	.04	.03	.03	.06
June 27	.03	.10	.15	.10
July 11	.08	.11	.14	.13
July 25	.21	.22	.29	.65
August 8	.42	.71	1.20	.65
August 22	.45	.46	.49	.58
September 6	.45	.27	.31	.20
September 15	.44	.43	.43	.43

Nitrogen is also critical for plant production; however, it is not normally limiting, particularly when many forms of blue-green algae can utilize atmospheric Nitrogen which is readily dissolved into the water column. Organic Nitrogen concentration was consistently greater at station 2A where values were never less than 1.0 mg/l; maximum values approached 5 mg/l on August 8 (Table 5). By contrast, organic Nitrogen at station 1, regardless of depth, never exceeded 1.7 mg/l. Surface readings during the summer averaged 1.18 mg/l; those at mid-depth were nearly identical at 1.16 mg/l. Organic Nitrogen at the deep station (1C) was somewhat lower with a mean concentration of 1.02 mg/l. Seasonal distribution of organic Nitrogen showed a mode of high concentration on July 25 through August 8 when composite values averaged about 2 mg/l.

Table 5. Organic Nitrogen concentrations (mg/l) at Green Valley Lake, 1983.

Date	Station			
	1A	1C	1E	2A
May 11	1.1	.9	1.2	1.4
May 25	1.5	1.1	1.1	1.4
June 6	1.1	1.0	.9	1.5
June 13	1.0	.8	.8	2.4
June 27	1.0	.7	1.0	2.3
July 11	.6	.7	.7	1.0
July 25	.4	2.0	1.5	4.1
August 8	1.4	.9	.7	4.8
August 22	1.3	1.4	1.2	3.4
September 6	1.6	1.6	.3	3.1
September 15	2.0	1.7	1.8	1.7

Ammonia concentrations ranged from .01 mg/l on several dates to 4.1 mg/l at station 1C on August 8 (Table 6). Low values were attained on the first and last sample period with means .02 and .04 mg/l, respectively. Summer values were considerably higher; however, there were no consistent trends between stations as was evident for phosphates or organic Nitrogen.

Nitrate-nitrite complex is the most usable form of Nitrogen for plant uptake and assimilation. Concentrations of these ions showed high concentrations early in the season followed by a precipitous decrease in mid-summer. For example, the May 11 sample showed an average concentration of 2.6 mg/l (Table 7). Gradually the concentration decreased to about 1.2 mg/l a month later and by July 11 the average nitrate-nitrite concentrations were .2 mg/l. Two exceptionally high values were attained, both of which were at 1E. The first occurred on June 27 at 9.3 mg/l while the other was attained on September 6 at 4.8 mg/l.

Table 6. Ammonia concentrations (mg/l) at Green Valley Lake, 1983.

Date	Station 1A	 1C	 1E	 2A
May 11	.02	.02	.02	.03
May 25	.27	.30	.26	.46
June 6	.16	.15	1.50	.01
June 13	.15	.20	.17	.09
June 27	.27	.52	1.10	.13
July 11	.25	.47	.05	.03
July 25	.08	.07	.28	1.10
August 8	.10	4.10	2.20	.80
August 22	.11	.14	.22	.19
September 6	.01	.01	.79	.15
September 15	.10	.02	.01	.01

Table 7. Nitate-nitrite Nitrogen concentrations (mg/l) at Green Valley Lake, 1983.

Date	Station 1A	 1C	 1E	 2A
May 11	2.3	2.3	2.3	3.4
May 25	1.9	1.9	2.0	3.3
June 6	1.8	1.1	1.8	2.2
June 13	1.2	1.2	1.4	1.1
June 27	.8	.8	9.3	1.2
July 11	.2	.2	.2	.1
July 25	.1	.1	.1	.1
August 8	.1	.1	.1	.1
August 22	.1	.1	.1	.1
September 6	.1	.1	4.8	.1
September 15	.1	.1	.1	.1

Hydrogen ion concentration is indirectly influenced by carbon dioxide, a product of photosynthesis. High pH values were associated with high organic Nitrogen and phytoplankton counts; the reverse was true of lower pH values. Values were consistently over 7.5 (Table 8); in fact, 70% of the readings were ≥ 8. After July 11 pH averaged 8.5, while pH previous to that date had a mean of 7.8.

Table 8. Hydrogen ion concentration at Green Valley Lake, 1983.

Date	Station			
	1A	1C	1E	2A
May 11	8.1	8.1	8.1	8.5
May 25	7.7	7.7	7.4	7.6
June 6	8.2	8.0	8.0	8.0
June 13	7.7	7.4	7.4	8.2
June 27	7.7	7.8	7.3	7.5
July 11	8.5	8.4	7.6	8.5
July 25	8.5	8.5	8.5	7.9
August 8	8.5	8.5	8.5	8.6
August 22	8.5	8.5	8.5	8.7
September 6	8.5	8.5	8.5	8.9
September 15	8.5	8.5	8.5	8.8

Turbidity is a function of phytoplankton density, colloidal organic compounds, bacteria and suspended sediment. Turbidity at Green Valley was related to plankton concentrations in mid to late summer; however, early turbidity readings were undoubtedly a function of suspended sediment. For example, the high JTU values of 75, 60 and 75 at 2A for the August 8-September 6 sample period (Table 9) corresponded to peak chlorophyll(a) concentrations during the sample periods. Similar trends were shown for station 1A. Values at the more productive shallow station 2A were consistently greater than 1A where mean values for the respective areas were 34 JTU and 10 JTU. Similarly, silt turbidity at station 2A was more pronounced than 1A.

Chlorophyll(a) concentration is an indirect measure of phytoplankton density and provides a good approximation of primary productivity. At Green Valley Lake the major peak occurred on July 11, particularly at station 2A, where chlorophyll(a) concentration was measured at 277 mg/l (Table 10). The trend at station 1 was a gradual increase throughout the summer, averaging about 30 mg/l in the first three periods and attaining 60 mg/l by September 15. Production was evident at surface, mid-depth and deep stations where mean concentrations were 36, 33 and 28 mg/l, respectively. Average for station 2A was 106 mg/l

Table 9. Turbidity (JTU) at Green Valley Lake, 1983.

Date	Station 1A	 1C	 1E	 2A
May 11	4.7	4.7	6.5	13.0
May 25	11.0	12.0	12.0	25.0
June 6	6.3	4.1	6.4	8.4
June 13	3.3	3.0	2.9	12.0
June 27	4.2	2.7	30.0	25.0
July 11	3.9	3.2	3.5	30.0
July 25	9.7	15.0	7.5	29.0
August 8	10.0	4.7	28.0	75.0
August 22	13.0	12.0	16.9	60.0
September 6	19.0	19.0	23.0	75.0
September 15	22.0	22.0	23.0	22.0

Table 10. Chlorophyll(a) concentrations (mg/l) at Green Valley Lake, 1983.

Date	Station 1A	 1C	 1E	 2A
May 11	41	30	44	96
May 25	12	13	13	14
June 6	20	34	23	45
June 13	18	18	16	100
June 27	39	12	19	78
July 11	20	12	7.6	277
July 25	71	104	58	107
August 8	36	4	13	113
August 22	26	25	14	110
September 6	48	54	42	158
September 15	65	55	58	65

Interrelationships between these water quality parameters was assessed by multiple regression-correlation procedure. Chlorophyll(a) concentration was closely related to three variables including turbidity, organic Nitrogen and pH (Table 11). The relationship with turbidity provided the highest correlation coefficient of .577 with significance at the .01 level of probability. Regression coefficient of 1.70 was likewise significant ($p <$ .05); therefor, for each unit increase in chlorophyll(a) (one mg/l) there was an associated increase in turbidity of 1.70 JTU.

Table 11. Intraclass correlations of water quality parameters at Green Valley Lake, 1983.

	Chlorophyll(a)	pH	Turb	Org N	NH_3	NO_2-NO_3	Filtered P	Total P
Chlorophyll(a)	1	.415**	.577**	.502**	-.196	-.221	.078	.286
pH		1	.389*	.261	.042	-.491**	.540**	.444**
Turbidity			1	.760**	.063	-.062	.437**	.719**
Organic N				1	-.033	-.256	.353*	.605**
NH_3					1	.052	.544**	.453**
NO_2-NO_3						1	-.384*	-.249
Filtered P							1	.826**
Total P								1

*Significant at the .05 level.
**Significant at the .01 level.

Organic Nitrogen and chlorophyll(a) concentrations also showed a positive, significant ($p < .01$) relationship with a correlation coefficient of .502. The regression coefficient (6.58) was not significant ($p > .05$); however, and indicated low predictability of chlorophyll(a) based upon organic Nitrogen. Hydrogen ion concentration and chlorophyll(a) yielded a significant correlation coefficient of .415 and a regression coefficient 38.51. It, too, was significant ($p < .05$). The remaining correlations between chlorophyll(a) and ammonia, nitrate-nitrite Nitrogen, filterable phosphates, and total phosphates ranged from .286 to -.221; none were significant ($p > .05$).

Intraclass correlation and partial regression was computed with the highest degree of correlation ($r = .826$) between filterable phosphates and total phosphates. This might be expected since filterable phosphates make up a large part of total phosphates. Second largest correlation coefficient was between turbidity and organic Nitrogen at .760 ($p < .01$). Understandably as organic material, including phytoplankton and zooplankton, in the water column increased so organic Nitrogen increased. This same rationale and relationship was shown between turbidity and total phosphates where correlation coefficient was .719 ($p < .01$). Thereafter, intraclass correlation decreased to the .6 level. Total phosphates and organic Nitrogen yielded a significant correlation ($r = .605$). Significant ($p < .01$) negative correlation was evident only for pH and the nitrate-nitrite complex; correlation coefficient was -.491. As nitrate-nitrite concentration increased pH decreased.

Phytoplankton

Plankton tow samples showed blue-green algae was, by far, the most dominant. The blue-green segment was comprised chiefly of Aphanozomenon with occasional Microcystis colonies and Oscillatoria filaments. Peak bloom in 1982 occurred early August with mean values of 497,000 per liter (Figure 3). The bloom started to build in early June and by July had attained the 200,000 per liter level. During August the bloom collapsed with blue-greens almost non-existent by September. A secondary bloom occurred in September with values attaining the 60,000 per liter range.

In 1983 blue-green plankton was again dominated by Aphanizomenon; however, density was not nearly as great. Maximum abundance occurred at 76,000 per liter in mid-July (Figure 3). The population began to build in June, peaked in July and then declined. By mid-August blue-green algae had declined to level of about 700 per liter. Even though the peak in 1983 was not nearly as great as previous years the level attained was of nuisance proportions.

Green and yellow-green algae groups were combined. This assemblage consisted primarily of desmids, diatoms and some flagelated Chrysophytes. The 1982 population was almost completely supressed by blue-greens and never reached bloom proportions until September when concentrations averaged about 6,000 per liter (Figure 4). A slight pulse occurred at the end of July and early August but values were only in the 2,000 per liter range. The typical spring bloom was nearly non-existent.

The green/yellow-green complex in 1983 peaked in early July with a mean of 6,700 per liter (Figure 4). Values in May and June fluctuated around the 1,000 per liter level. By mid-July the bloom had collapsed. An autumn pulse never developed.

Plankton density was closely related to chlorophyll(a) concentrations. Examination of Table 10 and Figures 3 and 4 show chlorophyll(a) was, indeed, a close measure of phytoplankton density. Peak chlorophyll(a) occurred identical to peak plankton density. However, measures of chlorophyll(a) concentrations did not distinguish, however, between blue-greens and other, more beneficial plankton forms such as the desmids or flagellated Chrysophytes.

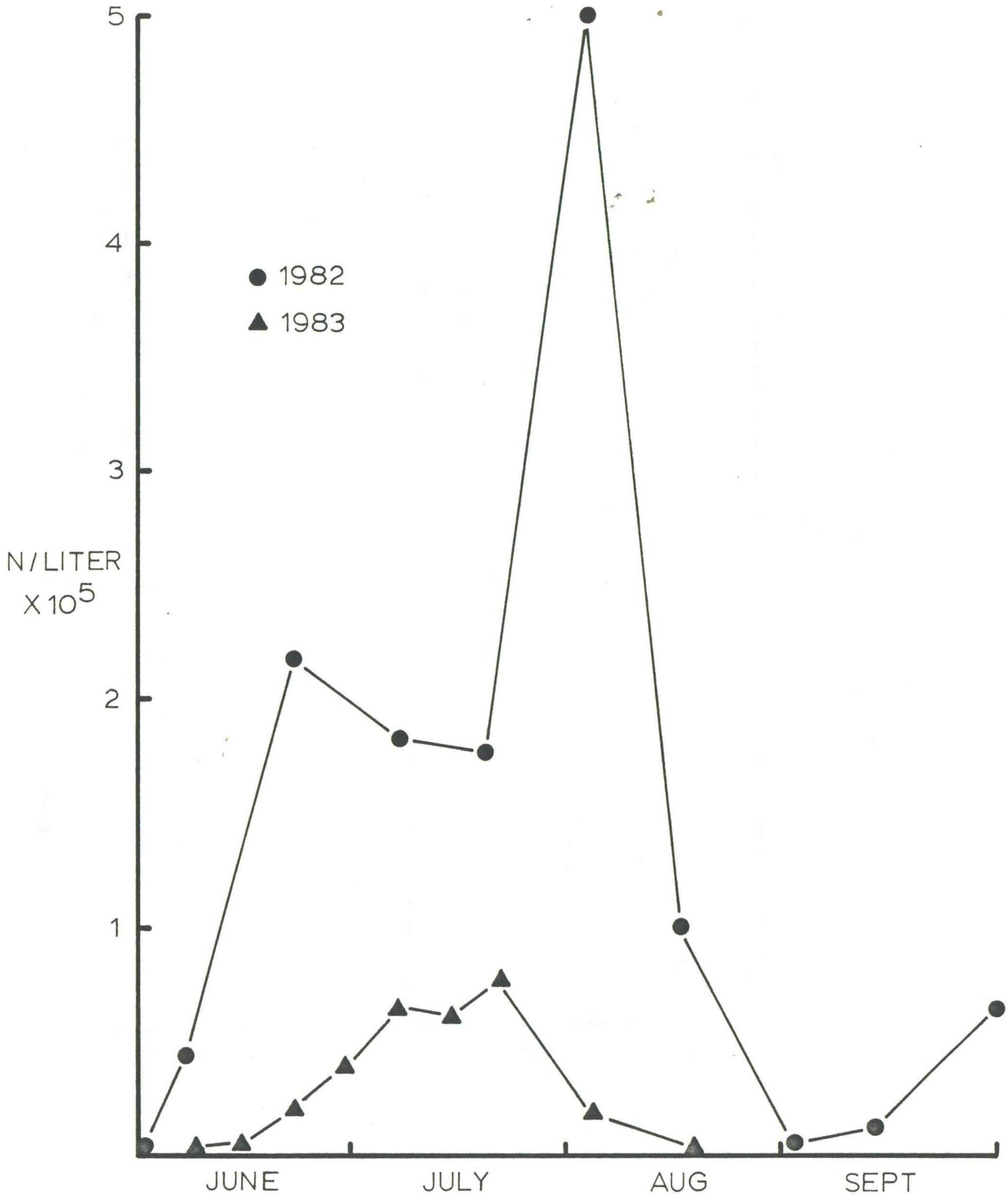

Figure 3. Average numerical abundance of blue-green algae in plankton tows at Green Valley Lake.

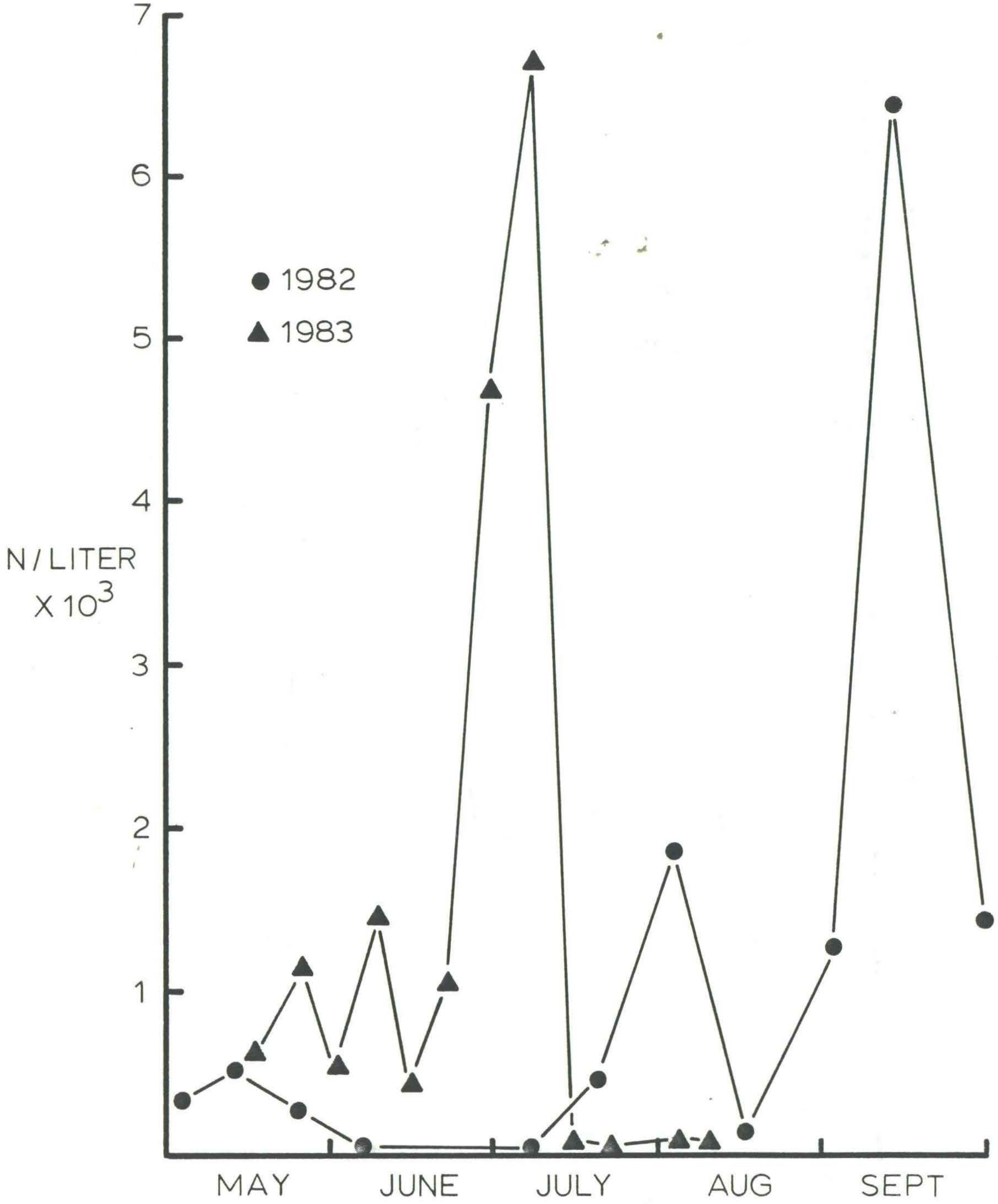

Figure 4. Average numerical abundance of green/yellow-green algae in plankton tows at Green Valley Lake.

Zooplankton

Enumeration of zooplankton, particularly those used by crappie as food, indicated cladocera were most important followed by copepods. The 1982 population produced a bi-modal frequency with greatest abundance in the spring with another, smaller pulse in August-September. Peak cladoceran density in May, 1982 was about 1,000 per liter, while values in August-September averaged about 500 per liter (Figure 5). Abundance of cladocera during July-August was never greater than 300 per liter. Counts in 1983 showed a much greater abundance in May compared to 1982. The peak concentration occurred in late May with a mean of 2,600 per liter. Density, thereafter, decreased rapidly and by July cladocera were rare. There was no autumn pulse.

Copepods showed a similar pattern. The spring peak in 1982 occurred in April at about 100 per liter (Figure 6). This was followed by a gradual decline through July and a resurgence in August and September and by the end of September populations averaged nearly 400 per liter. The copepod population in 1983 fluctuated greatly with greatest densities ocurring in mid-June; values at that time averaged 900 per liter. By July 1, copepods were extremely rare.

Limnocorral Experiments - Water Quality

Limnocorral experiments were designed to attempt a control of blue-green algae, on a limited basis, previous to a possible whole lake treatment. Water quality analysis provided a measure of treatment impact upon chemical constituents of the water which might inhibit blue-green algal growth.

Experiment One - The first experiment conducted June 8-22 occurred during the growth phase of the blue-green population. Blue-green algal densities in the lake ranged from an average of 225 on June 8 to 18,073 per liter on June 22. Water quality parameters for the first experiment are given in Table 12. Ammonium nitrate corral treatment immediately increased ammonia and nitrate concentrations; initial concentrations were 2.13 and 2.75 mg/l, respectively. Nitrite concentrations were increased initially from .17 mg/l on June 8 to .33 mg/l a week later. These readings were significantly ($p < .05$) different from control values (Table 13); however, by the third week ammonia, nitrate and nitrite concentrations were within the range of control readings. The remaining parameters including alkalinity, phosphates, pH and turbidity were not significantly different from controls.

Alum treatment corrals provided a much different chemical regimen. Most noticeably, alkalinity and pH decreased precipitously. When alum was applied alkalinity decreased to 35 mg/l while pH was reduced to 5.5 (Table 12). Other chemical parameters were not significantly different from control corrals. As the experiment progressed, however, pH and alkalinity were nearly identical to control corrals. In fact, within a week the affects of the alum treatment were not detected.

Ricinolic acid had no detectable affect on water quality. A floculant formed during application much as the reaction shown for alum; however, water quality values were similar to control corrals.

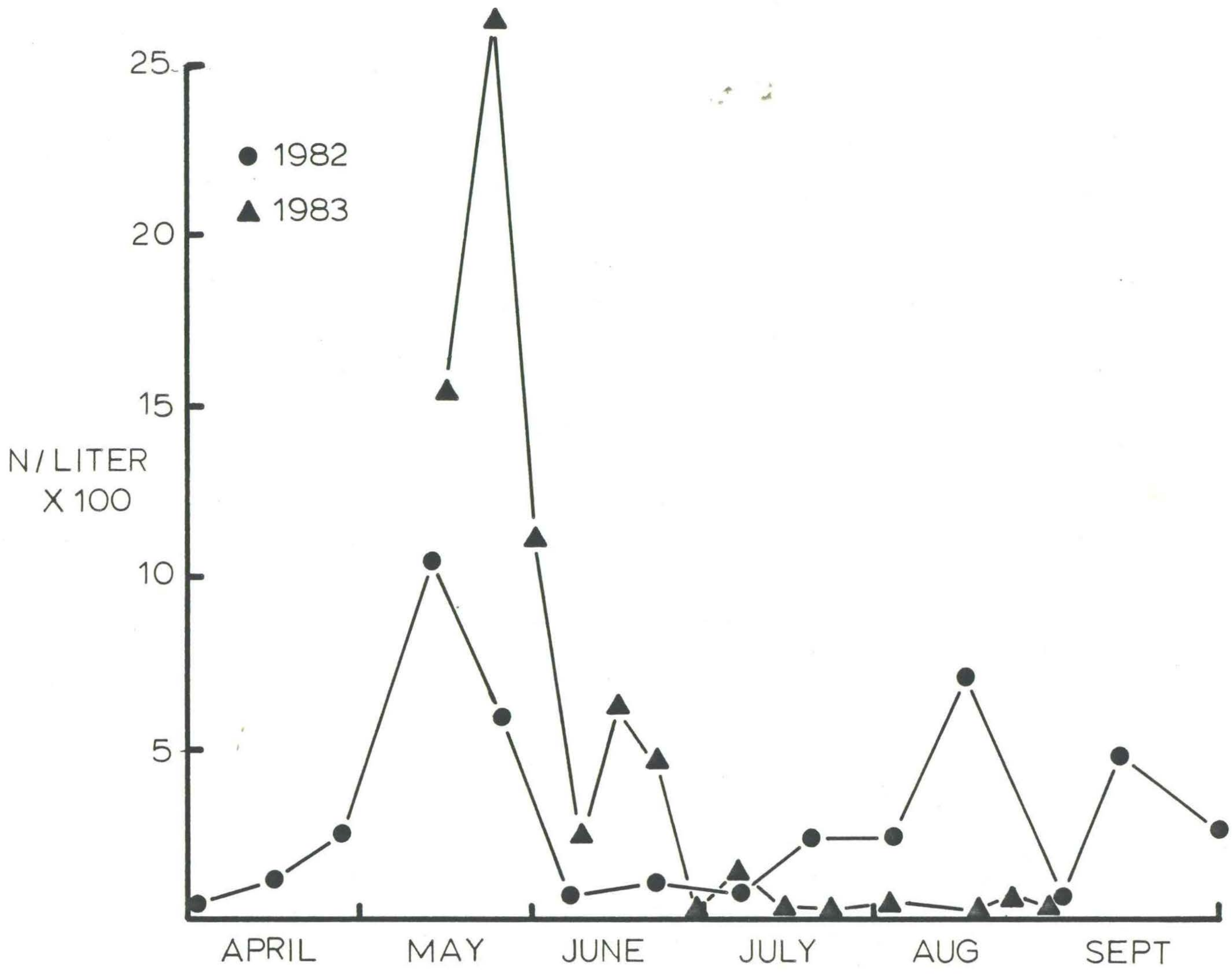

Figure 5. Density of cladocera at Green Valley Lake in 1982-1983.

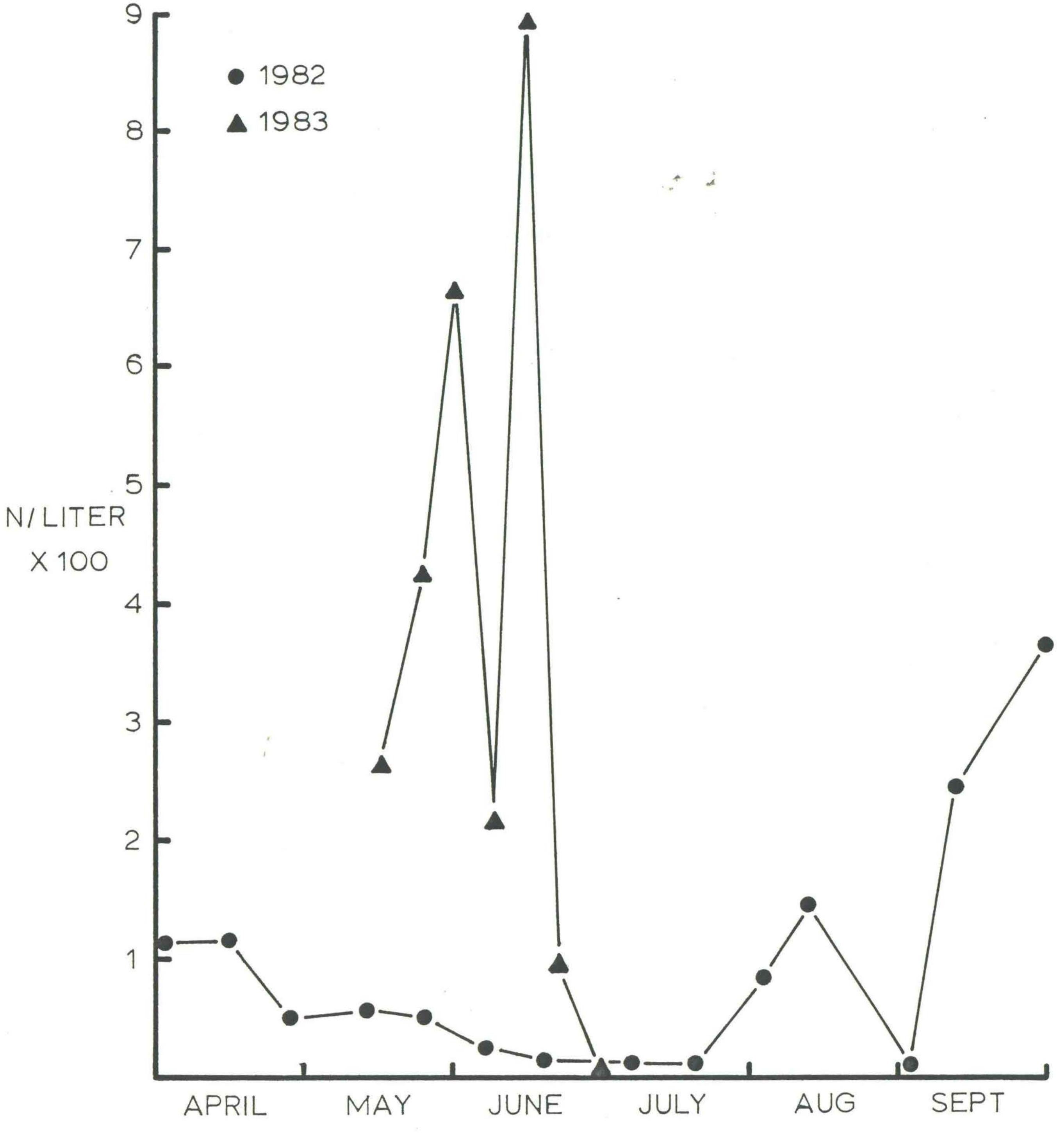

Figure 6. Density of copepods at Green Valley Lake in 1982-1983.

Table 12. Limnocorral experiment number one at Green Valley Lake, June 8-22, 1983. Values are averages of replicate samples and measured in mg/l unless indicated.

Parameter	Treatment Ammonium Nitrate	Aluminum Sulfate	Ricinolic Acid	Inside Control	Outside Control
Ammonia					
June 8	2.13	.23	.45	.33	.25
June 15	1.05	.91	.77	1.12	.82
June 22	.31	.33	.50	.40	.45
Nitrate					
June 8	2.75	2.00	1.55	1.35	2.50
June 15	1.35	1.60	1.75	.45	1.10
June 22	2.00	2.00	1.50	1.50	1.45
Nitrite					
June 8	.17	.12	.15	.16	.11
June 15	.33	.15	.17	.17	.13
June 22	.22	.20	.20	.16	.15
Alkalinity					
June 8	123	35	121	131	123
June 15	123	123	123	123	123
June 22	131	123	123	131	140
Ortho P					
June 8	.18	.13	.15	.15	.14
June 15	.09	.06	.07	.07	.05
June 22	.08	.04	.10	.16	.18
Inorganic P					
June 8	.22	.14	.22	.15	.16
June 15	.12	.06	.07	.09	.10
June 22	.18	.15	.16	.18	.24
Total P					
June 8	.39	.18	.35	.15	.17
June 15	.08	.08	.08	.08	.09
June 22	.18	.12	.22	.20	.22
pH					
June 8	8.10	5.50	7.70	7.50	8.45
June 15	8.00	8.15	8.15	8.05	8.05
June 22	8.05	8.45	8.35	8.35	8.40
Turbidity (JTU)					
June 8	11.4	9.6	6.8	49.8	7.7
June 15	77.0	47.0	45.5	49.5	58.5
June 22	6.2	5.8	6.0	8.5	8.0

Table 13. Results of water quality assessment between limnocorrals. ns = P > .05, * = p < .05 and ** = p < .01.

	NH_4	NO_2	NO_3	Alk	OrthoP	InorgP	TotalP	pH	JTU
Exp #1	ns	ns	*	ns	ns	ns	ns	ns	ns
Exp #2	**	*	ns	**	ns	*	*	**	ns
Exp #3	ns	ns	**	ns	ns	*	ns	ns	ns

Experiment Two - The second experiment was similar the first except ammonium nitrate teatment was increased from 2 to 8 mg/l and alum was increased from 20 to 25 mg/l. Lake plankton during this experiment were at peak abundance and dominated by blue-green algae.

Ammonium nitrate treatment corrals, as before, showed a vast increase in ammonia, and nitrate concentration. Values were 3.0 and 5.1 mg/l, respectively, on the first sample of July 7 (Table 14). These values were significantly ($p < .05$) different from control values (Table 13). Treatment reaction was similar to the first experiment, however, the elevated nitrate concentraton continued into the second week when mean levels were 3.7 mg/l compared to controls of .4 mg/l; however by the third week there were no differences between treatment and control. Other parameters were not changed appreciably by the treatment of ammonium nitrate.

Alum treatment showed the same reation as before. That is, pH and alkalinity were greatly reduced. In the first experiment pH and alkalinity increased during the three week period. However, during this experiment pH and alkalinity remained low with values of 44 mg/l for alkalinity and 6.5 for pH. Also, during this experiment inorganic phosphates were reduced significantly ($p < .05$) from control values. Final values for alum treatment and control on July 21 were .22 mg/l and 1.80 mg/l, respectively. Total phosphate followed the same trend where alum treatment and control values were .50 mg/l and 3.80 mg/l, respectively.

Ricinolic acid produced no treatment effects.

Experiment Three - The third experiment was identical to the second except ricinolic acid treatment level was increased to 10 mg/l in one corral and 20 mg/l in another. Phytoplankton density in the lake at this time was decreasing; in fact, by September 1 blue-green algae had decreased to an average count of 770 per liter.

Ammonium nitrate treatement, although the treatment level was increased by 4-fold, yielded the same results as experiment one. That is, a significant increase in ammonia and nitrate Nitrogen was detected initially. Values in this experiment were 3.0 and 9.25 mg/l, respectively. However, by the second sample week values were nearly identical to control levels (Table 15). As before, other parameters were not changed.

Table 14. Limnocorral experiment number two at Green Valley Lake, July 7-21, 1983. Values are averages of replicate samples and measured in mg/l unless indicated.

	Treatment				
Parameter	Ammonium Nitrate	Aluminum Sulfate	Ricinolic Acid	Inside Control	Outside Control
Ammonia					
July 7	3.00	.55	.37	.69	.40
July 14	3.00	3.00	.47	1.28	.67
July 21	3.00	3.00	1.49	2.80	.54
Nitrate					
July 7	5.10	.10	.10	.10	.10
July 14	3.70	.10	.65	.40	.90
July 21	.10	.10	.10	.10	.10
Nitrite					
July 7	.04	.03	.03	.03	.04
July 14	.30	.03	.01	0	.01
July 21	.01	.03	.02	.01	.01
Alkalinity					
July 7	131	18	123	123	131
July 14	140	18	140	140	123
July 21	131	44	140	140	131
Ortho P					
July 7	.08	.05	.07	.06	.10
July 14	.06	.02	1.20	1.45	.25
July 21	.95	.78	1.30	1.00	.55
Inorganic P					
July 7	.18	.12	.29	.06	.21
July 14	.17	.12	1.45	1.75	.75
July 21	1.05	.22	1.80	1.80	.65
Total P					
July 7	.19	.11	.45	.09	.15
July 14	.30	.12	1.80	2.00	1.20
July 21	1.55	.50	2.35	3.80	.80
pH					
July 7	8.30	6.70	8.60	8.35	8.50
July 14	7.55	5.85	7.45	7.40	8.50
July 21	7.10	6.55	7.20	7.05	8.50
Turbidity (JTU)					
July 7	8.0	3.9	8.5	9.3	9.8
July 14	13.5	4.4	16.0	17.5	11.5
July 21	5.0	4.1	5.5	17.2	7.2

Table 15. Limnocorral experiment number three at Green Valley Lake, August 18-September 1, 1983. Values are averages of replicate samples and measured in mg/l unless indicated.

	Treatment				
Parameter	Ammonium Nitrate	Aluminum Sulfate	Ricinolic Acid	Inside Control	Outside Control
Ammonia					
August 18	3.00	.30	.60	.50	.40
August 25	.55	.25	.25	.40	.40
September 1	.50	.45	.45	.45	.45
Nitrate					
August 18	9.25	.15	.30	.1	.1
August 25	.10	.10	.10	.1	.1
September 1	.10	.10	.10	.1	.1
Nitrite					
August 18	.04	.01	.02	.01	.01
August 25	.03	.01	.01	.01	.01
September 1	.02	.01	.01	.01	.01
Alkalinity					
August 18	123	105	140	131	123
August 25	140	140	140	131	131
September 1	140	131	140	140	140
Ortho P					
August 18	1.60	.65	1.45	1.40	1.50
August 25	2.10	2.00	2.00	2.45	2.25
September 1	1.70	1.50	1.50	1.70	1.70
Inorganic P					
August 18	1.90	1.00	1.65	2.05	2.05
August 25	2.25	2.10	2.00	2.45	2.25
September 1	2.05	1.90	1.75	2.25	2.10
Total P					
August 18	2.45	1.25	3.60	2.50	2.50
August 25	2.70	2.85	3.40	3.25	2.90
September 1	2.55	2.50	2.60	2.85	2.55
pH					
August 18	8.50	7.55	7.75	8.55	8.35
August 25	8.15	8.35	8.25	8.40	8.25
September 1	8.45	8.40	8.50	8.50	8.30
Turbidity (JTU)					
August 18	49.5	28.5	70.5	47.0	45.0
August 25	27.0	59.5	30.5	34.0	37.0
September 1	27.0	27.0	28.0	26.0	22.0

Alum, likewise, produced an initial decrease in alkalinity (105 mg/l) and pH (7.55). Unlike previous experiments these were not significantly different from control readings. And, as before, all values were nearly identical to control values by the third week.

Ricinolic acid treatment level was increased but produced no significant change in any water quality parameters.

Limnocorral Experiments - Plankton

Plankton algae and zooplankton density within the corrals during the three experiments showed wide variation, both between experiments and within corral treatments. Generally, however, the densities followed those obtained in lake tows. First, blue-green algae were low followed by a vast increase in the second experiment and then a collapse in numbers by the third experiment.

Experiment One - Blue-green algae concentrations varied from zero in 6 of the 10 corrals on July 8 to 4×10^5 per liter in the alum treatment corrals three weeks later (Table 16). Green/yellow-green algae populations were less variable. Initially they were found in a densities of 12,000-25,000 per liter. Interestingly the greatest decrease in green algae occurred within the corral controls and in controls just outside the corrals where concentrations averaged 5,000 per liter at week three. Ricinolic acid corrals averaged 23,000 per liter at the third week, while ammonium nitrate and alum corrals had densities of 12,000 and 17,000 per liter, respectively.

Zooplankton was dominated by nauplii ranging initially from 192 per liter in alum corrals to 1,144 per liter in the control corrals on the third week. Copepods and cladocerans ranged from 0 to 763 per liter.

Assessment of plankton density was particularly difficult due to large sample variation. One fact, however, was certain — bluegreen algae increased in all of the treatment corrals. In fact, blue-green density was greater in treatment corrals (> 100 per liter) than control corrals (80 per liter).

Table 16. Mean plankton counts in limnocorral experiment number one; June 8-22, 1983. Phytoplankton values in N/liter (x 1,000); zooplankton in N/liter.

	Treatment				
Parameter	Ammonium Nitrate	Aluminum Sulfate	Ricinolic Acid	Inside Control	Outside Control
Blue-green					
Initial	0	0	2	0	4
Final	142	401	134	82	233
Green/yellow-green					
Initial	16	12	14	25	25
Final	12	17	23	4	6
Cladocera					
Initial	0	0	0	0	0
Final	572	763	191	191	382
Copepoda					
Initial	191	191	382	0	0
Final	0	382	191	572	763
Nauplii					
Initial	1,526	192	1,907	572	2,479
Final	572	763	763	1,144	381

Experiment Two - Both phytoplankton and zooplankton were low or decreasing during this segment. For example, blue-green algae averaged about 1.5 x 10^6 per liter initially but had decreased to about .3 x 10^6 per liter on the third week (Table 17). The decrease didn't appear to be more rapid in conrol corrals than in treatment corrals. Green and yellow-green algae were nonexistent by the third week, as were cladocera; copepods were rare. Nauplii continued fairly abundant, but averaged somewhat less than 1,000 per liter. Again, there was no evidence of any treatment effect.

Table 17. Mean plankton counts in limnocorral experiment number two; July 7-21, 1983. Phytoplankton values in N/liter (x 1,000); zooplankton values in N/liter.

	Treatment				
Parameter	Ammonium Nitrate	Aluminum Sulfate	Ricinolic Acid	Inside Control	Outside Control
Blue-green					
Initial	1,574	524	1,503	1,662	1,834
Final	173	185	294	306	635
Green/yellow-green					
Initial	12	0	23	12	4
Final	0	0	0	0	0
Cladocera					
Initial	191	0	191	0	0
Final	0	0	0	0	0
Copepoda					
Initial	0	0	0	0	191
Final	0	0	0	191	0
Nauplii					
Initial	954	954	381	381	192
Final	192	0	954	0	0

Experiment Three - Blue-green algae continued to decline from August 18-September 1; values ranged from 41,000-187,000 per liter (Table 18). In all cases -- both control and treatment -- blue-green algae decreased. Green algae were nearly nonexistent, as were copepods and nauplii. Cladocera had shown an increase from the previous experiment and ranged up to 1,716 per liter. Assessment, as before, showed treatment, regardless of type or level, had no appreciable affect upon plankton.

Table 18. Mean plankton counts in limnocorral experiment number three; August 18-September 1, 1983. Phytoplankton values in N/liter (x 1,000); zooplankton values in N/liter.

	Treatment				
Parameter	Ammonium Nitrate	Aluminum Sulfate	Ricinolic Acid	Inside Control	Outside Control
Blue-green					
Initial	84	70	74	78	93
Final	53	62	62	72	41
Green/yellow-green					
Initial	2	0	0	2	0
Final	0	0	0	0	0
Cladocera					
Initial	191	763	572	1,716	763
Final	191	0	382	382	0
Copepoda					
Initial	0	191	0	0	0
Final	191	0	0	191	0
Nauplii					
Initial	191	0	0	191	0
Final	0	0	0	0	0

DISCUSSION

The primary intent of this investigation was to identify factors and mechanisms which promoted the growth of blue-green algae and develop management strategies to control nuisance algal blooms.

Chlorophyll(a) provided a good index of phytoplankton biomass; however, this procedure did not adequately define the blue-green compliment of the algal community. Qualitative analysis of phytoplankton was obtained through identification and enumeration of the major taxa of algae obained in plankton tows. Quantitative counts obtained from these samples agreed well with chlorophyll(a) concentrations. The taxonomic analysis showed the dominance of blue-greens to the phytoplankton community. The cause, however, of blue-green algal dominance was complex and difficult to explain. Previous investigations (Bachman, 1980) showed Phosphorous is the primary nutrient responsible for major blooms. Conversely, the depletion of Phosphorous results in blooms of lesser and lesser intensity. This was, likewise, demonstrated in this investigation. For example, correlation coefficients between chlorophyll(a) and total phosphate concentrations were positive during each of the three years (1981-1983).

Examination of the inorganic forms of Nitrogen (ammonia and nitrate-nitrite) in combination with chlorophyll(a) provided an insight into the community dynamics of blue-greens with particular reference to the nutrient budget. The highest chlorophyll(a) concentrations in 1981-1983 (530, 460, 277, 250, 212 and 146 mg/l) all occurred after mid-July and were primarily due to Aphanizomenon densities. Green and yellow-green blooms always preceeded the mid-July blue-green blooms. High algae biomass was, likewise, associated with low inorganic Nitrogen. Conversely, green algae blooms were associated with higher ammonia, nitrate and nitrite concentrations.

The prerequisite for nuisance blue-green blooms, at least at Green Valley Lake, appeared to be a Phosphorous concentration of about .20 mg/l or greater coupled with a decrease in inorganic Nitrogen. Nitrate-nitrite concentrations had decreased to about .20 mg/l or lower by the time Aphanezomenon started to appear in large concentrations. Experimental control of blue-greens in the limnocorrals, therefore, was designed to decrease phosphate concentrations with ricinolic acid and alum in four corrals while increasing inorganic Nitrogen with ammonium nitrate in two corrals.

Findings showed ricinolic acid had the least affect on water quality. Ammonium nitrate did, indeed, increase inorganic Nitrogen, particularly ammonia and nitrate concentrations. The effect was short-lived, however, and usually within two weeks the concentrations were within rates found in control corrals. Likewise, alum treatment was fairly ephemeral where pH and alkalinity decreased significantly at first, but gradually increased to normal levels. During the second experiment, however, alum significantly reduced pH, alkalinity and phosphate concentrations throughout the experiment.

Response of blue-green algae to chemical treatment was minimal. Population abundance in the corrals followed the same trend as control corrals. Even in the second experiment where alum effectively controlled phosphate concentrations, blue-green algae density was not significantly different from blue-greens in control corrals. Zooplankton and other phytoplankton were, likewise, not affected by any of the treatments.

Comparison of controls outside the limnocorral to controls in the limnocorral showed a microhabitat developed within the plastic inserts. Filamentous algae grew on the plastic walling and within three weeks had formed a thick mat. Shading and light extinction could easily have influenced planktonic growth forms, as well as water quality parameters.

RECOMMENDATIONS

Experimental limnocorral treatments provided some degree of influence upon water quality but not the biota within the corrals. The investigation should be continued an aditional year with treatment expanded to a cove, blocked off with plastic. This should help negate the microhabitat encountered using limnocorrals. Alum appeared to be the most effective control and should be used as an experimental treatment for blue-green algae.

LITERATURE CITED

Bachmann, R. W., M. R. Johnson, M. V. Moor and T. A. Noonan. 1980. Clean lakes classification study of Iowa's lakes for restoration. Comp. Rpt., Iowa State Univ., Ames. 715pp.

Barica, J., H. Kling and J. Gibson. 1980. Experimental manipulation of algal bloom composition by nitrogen addition. Canadian J. Fish. and Aquatic Sci. 33(7):1175-1183.

Cooke, G. D. 1981. Precipitation and inactivation of phosphorous at a lake restoration technique. EPA-600/3-81-012. U.S. Environ. Protect. Agency. Corvallis, OR.

Dunst, R. C., S. Born, P. Ultormark, S. Smith, S. Nichols, J. Peterson, D. Knauer, S. Serns, D. Winter and T. Wirth. 1974. Survey of lake rehabilitation techniques and experiences. Tech. Bull. No. 75. Dept. Nat. Resour. Madison, WI.

Ingram, W. M and G. W. Prescott. 1954. Toxic freshwater algae. Am. Midl. Natur. 52(1):75-87.

Peterson, S. A. 1981. sediment removal as a lake restoration technique. EPA-60/3-81-013. U.S. Environ. Protect. Agency. Corvallis, OR.

Rose, E. T. 1953. Toxic algae in Iowa lakes. Iowa Acad. Sci. 60:738-745.

Stauffer, R. E. 1981. Sampling strategies for estimating the magnitude and importance of internal phosphorous supplies in lakes. EPA-600/3-81-015. U.S. Environ. Protect. Agency. Corvallis, OR.

Welch, E. B. 1981. The dilution/flushing technique in lake restoration. EPA-600/3-81-016. U.S. Environ. Protect. Agency. Corvallis, OR.

ANNUAL PERFORMANCE REPORT

RESEARCH PROJECT SEGMENT

STATE:	Iowa	NAME:	Assessment of the Relationships Between Nutrients, Blue-Green Algae, Zooplankton and Fish Planktivores
PROJECT NO.:	F-94-R-4		
STUDY NO.:	3		
JOB NO.:	2		
		JOB TITLE:	Crappie density, growth and plankton density

Period Covered: 1 July 1983 through 30 June 1984

ABSTRACT: Removal of 85,000 black crappie at Green Valley Lake by management netting crews in May, 1982 accounted for biomass reduction of about 20%. This investigation assessed the response of the removal program upon growth, age structure and body condition of the remaining population. Growth increased gradually since 1980 when growth rate was 15% below normal. In 1983 it was 2% below normal. Mean length increased from 7.2 inches in May, 1982 to about 8 inches by September, 1983. PSD values, likewise, increased with values of 25 at removal to 42 after two growing seasons. Relative weight (W_r) increased significantly from 84 to 96 during the same time period. Angling effort and harvest has increased substantially at the lake and population dynamics are now influenced by mortality due to harvest. Recruitment has been low.

Prepared by: Larry Mitzner
Fisheries Research Biologist

Date Prepared: August 1, 1984

Approved by: Don Bonneau
Fisheries Research Supervisor

STUDY OBJECTIVE

To determine methods for control of nuisance blue-green algae and provide strategies for management of fish populations at these lakes.

JOB 2 OBJECTIVE

Determine the impact of removing at least 50% of the crappie population < 7 inches on zooplankton and the remaining fish population.

INTRODUCTION

Blue-green algae blooms play an important role in fish community dynamics. Arnold (1971) showed blue-green algae are rarely used as food by zooplankton or fish planktivores. Blue-green algae thus transfer primary production to the fish population first through decomposers and then to benthic invertebrates and bottom feeders. Shunting of energy away from the zooplankton community would be expected to have a detrimental effect upon juvenile fish and planktivores. This situation is aggrevated at some lakes, such as Green Valley, by a dominant year class of slow growing crappie.

Investigation of biological rehabilitation techniques is important in developing lake management strategies. Basic information, particularly the relationship between planktivorous fish and blue-green algae is needed to aid in understanding the cause-effect relationships between nutrient cycles, zooplankton, phytoplankton and the well-being of fish planktivores.

Dense planktivorous fish populations have an adverse impact upon large-sized zooplankters which, in turn, have a greater tendency to control blue-green algae (David Wright, personal communication). Biological rehabilitation has been accomplished by population reduction to decrease abundance of dominant species. An extensive literature survey by Rutledge (1972) showed removal of stunted crappie was successful; however, success is directly related to intensity of removal.

METHODS AND PROCEDURES

The benefit of a large biomass removal of crappie (goal 50%) would be determined by comparing growth and body condition of crappie before and after removal. Crappie removal occurred from May 4, 1982 through May 14, 1982. Fyke nets were set along the shoreline and located around the lake. Nets were run daily except on the weekend (May 8 and 9) and on May 6 when strong wind curtailed netting activity. Twenty nets were fished the first day; thereafter, 80 nets were fished. Total effort during the 10-day spawning peak was 820 net-days involving a crew of 5-7 people. A total of 85,000 crappie weighing 21,400 lbs were removed (Mitzner, 1983).

Population characteristics of crappie were determined in September 1982 with cove rotenone sampling; two coves totalling 2.72 acres were sampled. Standard expansion methods were used to estimate biomass, species composition and size structure. During 1982 and again in 1983 length-weight and scale samples were collected. Standard age-growth methods were used to estimate growth, age structure and body condition factors.

FINDINGS

Growth estimates of black crappie in 1983 were based upon 51 scale readings with results shown in Table 1. Maximum average length was attained for the 1978 year class at age 5 with a mean length of 196 mm (7.7 in). Grand average calculated lengths using weighed means showed growth of 83 mm (3.3 in) during the first year of life; thereafter, values were 129 mm (5.1 in), 161 mm (6.3 in), 184 mm (7.2 in), 193 mm (7.6 in) and 184 mm (7.2 in). Growth of crappie at Green Valley were found to be far below crappie growth in the Midwest region (Figure 1).

Table 1. Back calculated growth (mm) of black crappie at Green Valley Lake computed from 51 scales collected in 1983. Values in parenthesis are inches.

Year Class	N	Age 1	2	3	4	5	6
1980	8	80	127	152			
1979	36	84	130	163	184		
1978	6	78	131	164	185	196	
1977	1	80	110	140	161	172	184
Weighted Mean		83 (3.3)	129 (5.1)	161 (6.3)	184 (7.2)	193 (7.6)	184 (7.2)

Goodness and poorness of growth based upon the total collection of scales since 1982 showed 1975 and 1977 were, by far, the best years of growth with values of 35% and 18% above normal growth, respectively (Figure 2). The single poorest year of growth was 1978 with an index value of -22%. Growth in 1979 was -9% which corresponded to the abundant 1979 year class. Since then growth rate has gradually increased until 1983 when it was about 2% below normal growth.

Length-frequency of crappie and scale samples taken in 1983 showed the 1979 year class was dominant. Since removal of crappie in May 1982, this year class has gradually increased in mean length. For example, during removal operations in 1982 PSD was 25 followed by an increase to 36 in September (Figure 3). Then by September 1983 PSD had increased to 42.

Body condition of crappie sampled in 1983 expressed as relative weight (W_r) averaged 96 with a range of 86-112. Values for May, 1982 and July, 1982 were 86 and 84, respectively. Student's t-test showed crappie in 1983 had significantly better body condition than those prior to or shortly after removal.

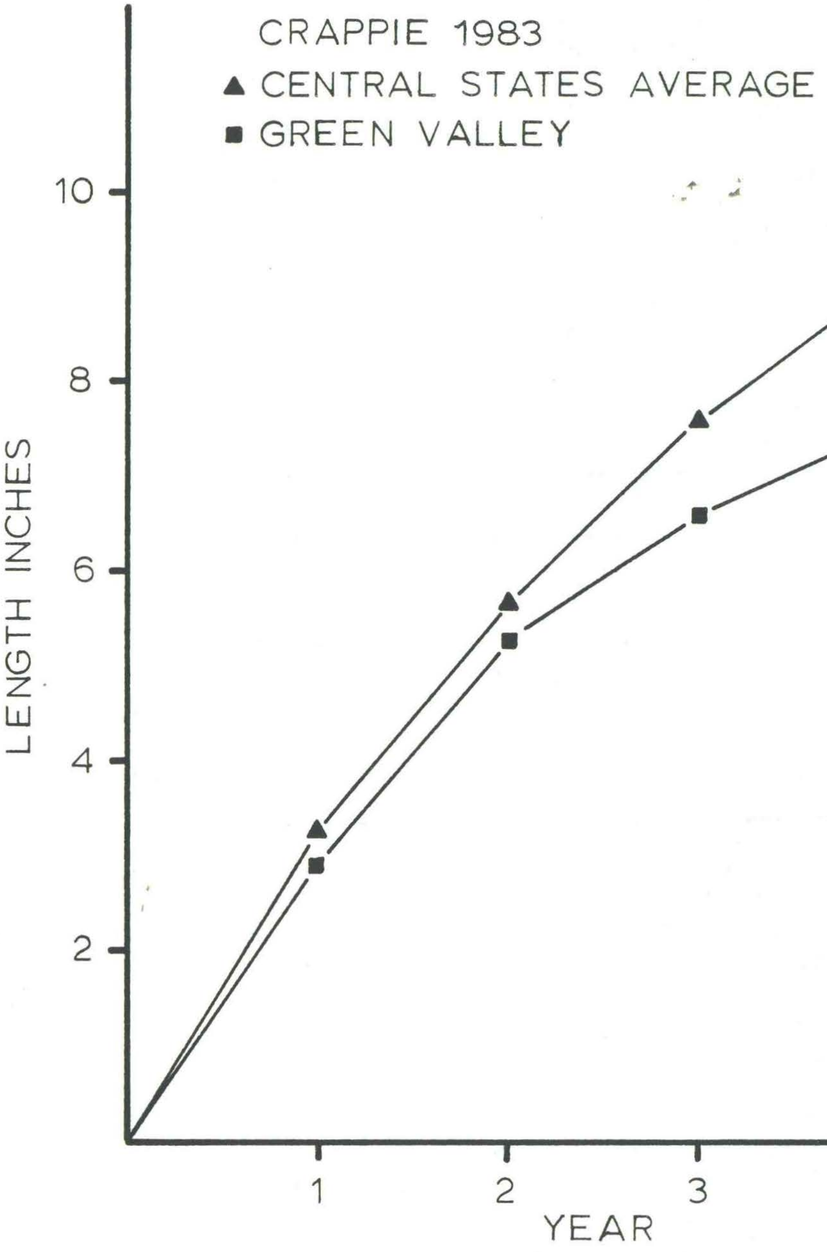

Figure 1. Average back calculated length of crappie at Green Valley Lake and central states average.

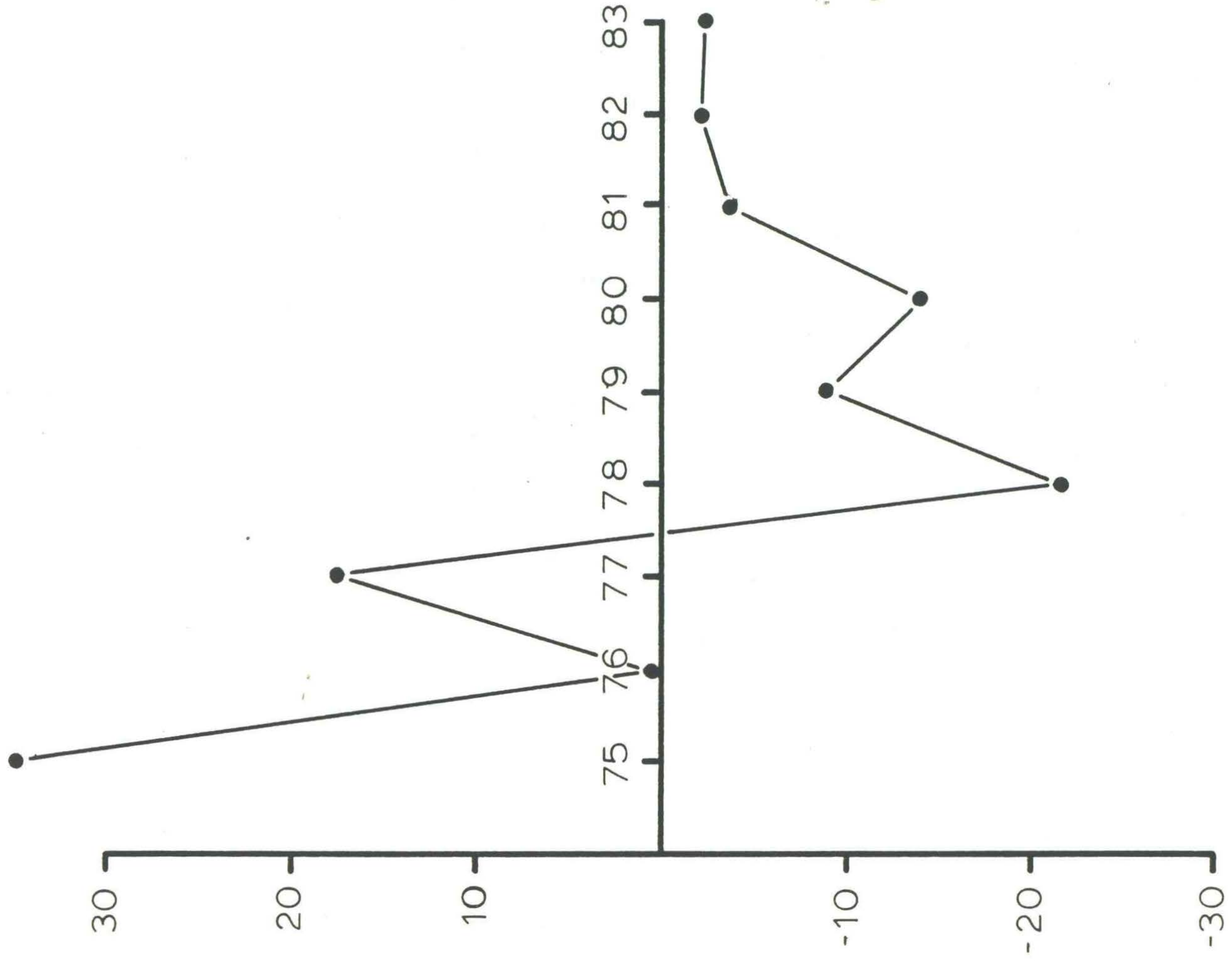

Figure 2. Goodness and poorness of growth index at Green Valley Lake, 1975-1983.

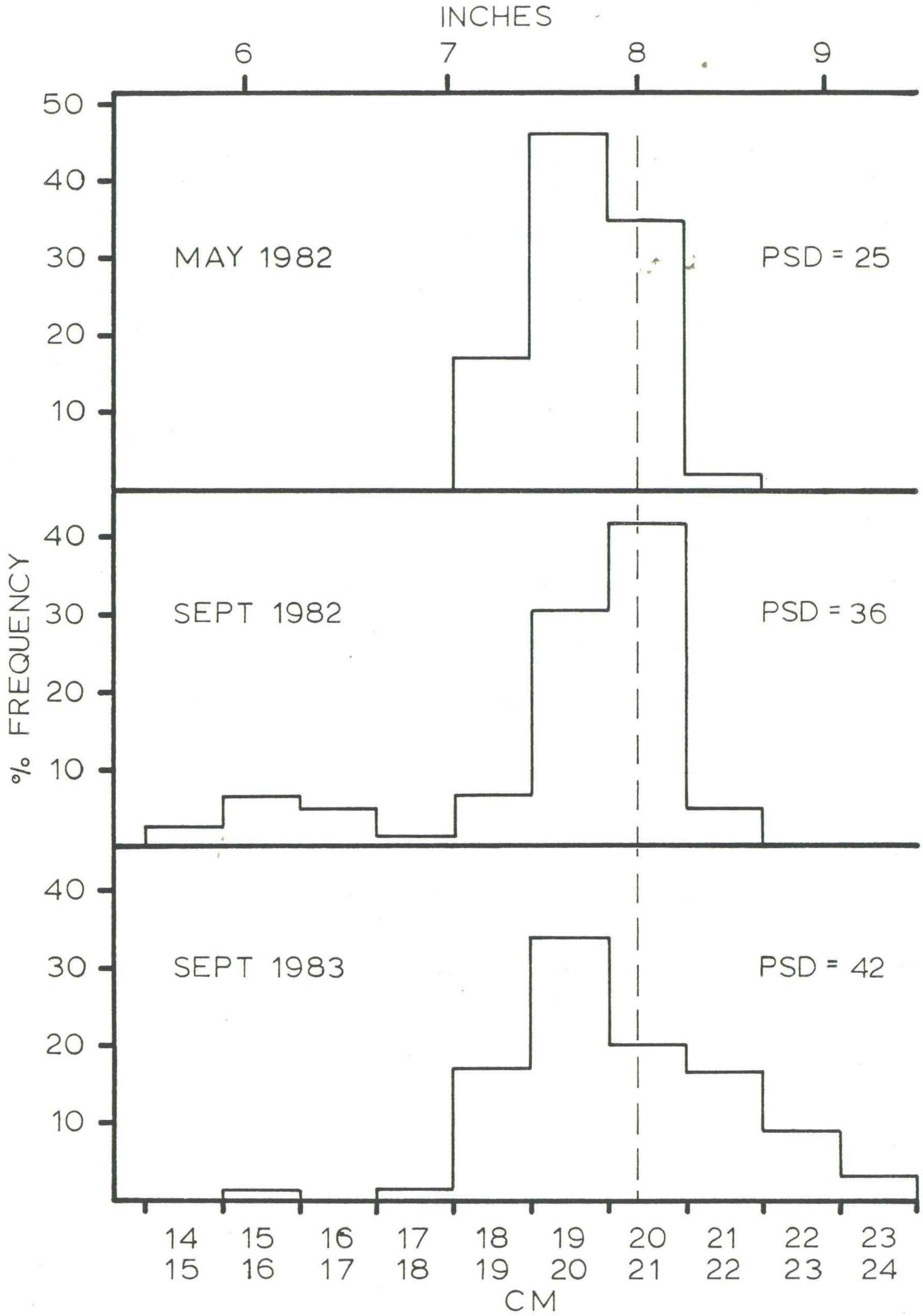

Figure 3. Length-frequency distribution of black-crappie at Green Valley Lake, 1982-1983.

DISCUSSION

Growth and body condition of black crappie at Green Valley Lake improved substantially following removal of about 20-25% of the biomass in 1982. Mean length at that time was about 7.1-7.3 inches. Fish sampled in 1983 averaged approximately 8 inches with over 40% greater than 8 inches. It is entirely speculative whether the removal program alone had a large influence on growth, particularly in comparison to other removal experiments (Rutledge, 1972). Plankton may have also been an important factor. Zooplankton populations were about 2-4 times higher in 1983 compared to 1982.

Undoubtedly a major factor in accelerated growth was continued removal of crappie by angling. During 1982-1983, public relations effort keyed-in on Green Valley Lake and, during the 1982 winter fishery and 1983 spring fishery, extensive angling effort was expended at the lake and resulted in a large harvest of black crappie. Angling pressure at Iowa lakes can easily approach 200 hours per acre. This effort would be a conservative estimate for Green Valley. If a catch rate of 2 fish per hour (again, a conservative estimate) were attained then an estimated 170,000 fish would have been harvested. Removal of fish at this magnitude would double that attained by netting.

Regardless of the biological mechanisms involved in the increased growth increment -- it occurred. Public awarness of this population will become increasingly important. Nets were able to remove about 20% of the biomass. Now that crappie are much more acceptable, anglers should be able to remove at least that amount, if not more.

RECOMMENDATIONS

Public relations effort should continue at Green Valley Lake to promote black crappie harvest. Fishing pressure within the next few years will undoubtedly have more impact on the population than traditional management efforts. As the crappie population is depleted fish survey efforts should continue with emphasis on reproduction. Extremely abundant year classes of crappie, bullhead or bluegill may appear and the cycle could be repeated. In such an event the predator population should be maintained at high levels.

LITERATURE CITED

Arnold, D. E. 1971. Injestion, assimilation, survival and reproduction by *Daphnia pulex* feed seven species of blue-green algae. Limno. Oceanogr. 16:906-920.

Mitzner, L. R. 1983. Assessment of the relationship between nutrients, blue-green algae, zooplankton and fish planktivores. Fed. Aid Fish. Restoration Annual Rpt. F-94-R-3. Iowa Cons. Comm., Des Moines, IA.

Rutledge, W. P. and J. C. Barron. 1972. The effects of removal of stunted white crappie on the remaining crappie population of Meridian State Park Lake, Bosque, Texas. Tech. Series No. 12. Texas Parks and Wildl. Dept.