IOWA CONSERVATION COMMISSION

FISHERIES SECTION

FEDERAL AID TO FISH RESTORATION

ANNUAL PERFORMANCE REPORT

GRASS CARP INVESTIGATIONS

PROJECT NO. F-92-R-2

Study No. 504.6 - Biological Control of Nuisance Aquatic Vegetation by Grass Carp

Job No. 1: Aquatic macrophyte standing crop, primary productivity and water quality at Red Haw Lake

PERIOD COVERED: 1 JULY, 1978 - 30 JUNE, 1979

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RESEARCH PROJECT SEGMENT

STATE:	Iowa	NAME:	Biological Control of Nuisance Aquatic Vegetation by Grass Carp
PROJECT NO.:	F-92-R-2		
STUDY NO.:	504.6		
JOB NO.:	1	TITLE:	Aquatic macrophyte standing crop, primary productivity and water quality at Red Haw Lake

Period Covered: 1 July, 1978 through 30 June, 1979

ABSTRACT: Aquatic vegetation abundance, water quality and primary productivity were measured at Red Haw Lake during the study segment and related to intensity of vegetation control by grass carp. The plant community was dominated by Elodea *and* Najas. *Maximum weight in the quadrant samples for* Elodea *occurred in May at 219 g/m². Najas attained maximum biomass in August at 290 g/m². Biomass estimates for* Potamogeton *and* Ceratophyllum *were < 100 g/m². Coverage of the plant total community ranged from 2.23 ha (5.5 ac) in May to 4.76 ha (11.8 ac) in July. Maximum standing crop was attained in August at 8.1 metric ton (8.9 ton). Vegetation control was approximately 90% when compared to plant biomass levels before grass carp were stocked. Water quality was determined by measuring 11 parameters. Those parameters showing significant changes since 1973 were nitrate and nitrite nitrogen, turbidity pH and alkalinity. Nitrates and nitrites showed an inverse relationship with vegetation control; as vegetation was controlled at a higher rate nitrate and nitrite concentrations decreased. Hydrogen ion concentration decreased significantly from 7.65 to 6.35 during 1974-1976. Thereafter, a reverse trend occurred and pH again increased to 7.30 by 1978. Alkalinity showed the opposite trend of pH. Turbidity was significantly greater in 1978 and was caused mainly by silt run-off within the watershed. Primary productivity of phytoplankton decreased from 2.04 g of carbon/m²/day in 1975 to 1.05 g carbon/m²/day in 1978. Water quality during the investigation has not deteriorated nor has phytoplankton become a nuisance.*

Prepared by: Larry Mitzner
Fishery Research Biologist

Date prepared: June, 1979

Approved by: Don Bonneau
Fishery Research Supervisor

STUDY OBJECTIVE

To assess the long-term impact of biological vegetation control by grass carp on water quality and primary production of phytoplankton and measure the effect of reduced shoreline vegetation of fishing in Red Haw Lake.

JOB 1 OBJECTIVE

To measure the biomass of aquatic macrophytes, primary production of phytoplankton and water quality at Red Haw Lake.

INTRODUCTION

Grass carp introductions at Red Haw Lake continue to be monitored, as before, to determine their potential in a statewide aquatic vegetation control program. The investigation which commenced in 1973 emphasized the long-term effects of vegetation control on water quality, and the impact that biocontrol would have upon the sport fishery.

The first years of the investigation showed grass carp effectively controlled vegetation. Several facets of grass carp life history including growth and behavior were investigated. As vegetation control was maintained at the 80-90% level of pretreatment water quality assessment became more important. This segment of the investigation emphasized the relationship of biocontrol upon water quality and primary productivity of algae during 1974-1978.

STUDY BACKGROUND

Initial introductions of grass carp at 18 fish/ha (7.4/ac) with mean weight of 380 g (.84 lbs) were made at Red Haw Lake in 1973. The following year 8.6 fish/ha (3.5/ac) of the same size were stocked to augment the initial plant. Aquatic vegetation biomass when grass carp were introduced was 2,438 g/m^2 and was dominated by Potamogeton, Najas, Elodea and Ceratophyllum. Najas and Potamogeton were, by far, the most abundant. Three years later mean standing crop of these plants was reduced to 211 g/m^2. Plant coverage of the vegetation remained about the same, ranging from 3-6 ha (8-14 ac). Density of vegetation was much reduced and at many areas of the lake, however, small stands of vegetation, particularly Ceretophyllum, remained nearly untouched by grass carp. Najas the first to be controlled by grass carp was nearly eliminated in 1974. Yet, Najas was first to recover. Plant biomass began to increase rapidly in 1977 as grass carp numbers decreased. The rapid increase in macrophytes was primarily caused by Najas.

Grass carp consumed vast quantities of vegetation and grew rapidly. An estimated 76 metric ton (MT) (84 ton) of vegetation was consumed during 1973 followed by 69 MT (76 ton) in 1974. Mean length and weight of grass carp by October, 1976 was 824 mm (32.4 in) and 6,847 g (15.1 lbs). Greatest biomass in the grass carp population was attained in 1975 at 1,767 kg (3,892 lbs) or 61 kg/ha (54 lbs/ac); thereafter, the population sustained a steady decrease in density until an estimated low of 6 fish/ha (2.4/ac) was attained in 1977. All plant groups were consumed; however, Najas and Potamogeton were selected over Ceratophyllum and Elodea.

Great quantities of vegetation were being consumed during 1975 and 1976 resulting in tons of excreta being released into the water column and unto the mud-water interface. It was expected such a great change in the biotic community could effect an equally large change in the nutrient budget; however, there was no overall adverse effect upon water quality. Analysis showed organic phosphorous, inorganic phosphorous, turbidity, BOD and temperature were not significantly different between sample years 1976-1977. Nitrites and nitrates decreased as vegetation control by grass carp increased. Alkalinity increased significantly ($p < .01$) from 115 mg/ℓ in 1974 to 134 mg/ℓ in 1977.

Vegetation control at the 90% level along the shoreline had a major influence upon the sport fishery. Shoreline anglers fished 2,974 hours in 1974 compared to 7,181 hours in 1976; boat fishing remained nearly constant at 8-9,000 hours. Catch effort for shore fishermen ranged from .70-1.47 fish/hour, while boat anglers caught 1.02-1.97 fish/hour.

METHODS AND PROCEDURES

Plant community dynamics were measured in 1978 using identical procedures as before (Completion Report, Project F-88-R, Study No. 504). Water quality and primary productivity procedures and sampling methods also remained unchanged.

FINDINGS

MACROPHYTES

Mean plant biomass at Red Haw during 1978 was 178 g/m^2 and ranged from 52 g/m^2 in June to 302 g/m^2 in August. The maximum sample biomass was 1,920 g/m^2 which occurred at station 5 in August (Table 1). Mean sample biomass in May and September were nearly identical at 224 and 220 g/m^2, respectively. Thirteen quadrant samples contained no measureable vegetation. These occurred at stations 2, 3, 4, 6, 9 and 10. Mean biomass at stations 5, 8, 9 and 10 was greater than 200 g/m^2; however, two stations were greatly influenced by extraordinarily high samples at station 5, in August and station 10 in May.

Table 1. Estimated weight in g/m^2 of aquatic vegetation in quadrant samples at Red Haw Lake during 1978.

Station	May	June	July	August	September	Mean
1	56	1	8	1	8	15
2	36	296	0	0	0	66
3	24	128	356	0	0	102
4	0	0	184	52	4	48
5	12	20	36	1920	120	422
6	0	4	64	92	88	50
7	16	36	4	96	292	89
8	796	40	180	116	852	397
9	0	0	72	748	752	314
10	1304	0	0	0	80	277
Mean	224	52	90	302	220	178

Major plant groups included Potamogeton, Elodea, Ceratophyllum and Najas. None of the above were considered a nuisance during 1978. Maximum biomass of Najas occurred in August when 290 g/m^2 was attained (Table 2). Najas was not observed in the samples prior to August. Elodea was the second most abundant plant with an estimated biomass in May of 219 g/m^2; thereafter, standing crop decreased and by August had attained a low of 5 g/m^2. Elodea increased in density during September to 59 g/m^2.

Table 2. Estimated weight in g/m^2 of four major plant groups at Red Haw Lake, 1978.

	Potamogeton	*Elodea*	*Ceratophyllum*	*Najas*
May	3	219	3	0
June	3	50	< 1	0
July	74	17	0	0
August	8	5	0	290
September	21	59	1	138

Potamogeton attained highest biomass in July at 74 g/m^2. Ceratophyllum was fairly abundant at station 3 during the May sample; thereafter, Ceratophyllum was nearly non-existent.

Total biomass of the macrophyte community was estimated as the product of areal growth and mean standing crop in the sample quadrants. Greatest mean depth to the outer perimeter of weed growth was 1.59 m (5.2 ft) and occurred during June. High water clarity was maintained during July when mean depth of plant growth was 1.43 m (4.7 ft) (Table 3). During the remainder of the year depth was < 1 m (3 ft).

Table 3. Average depth of plant growth, area covered by the plant community, biomass and total weight of the plant community, 1978.

	Depth		Area		Biomass		Total Weight	
	m	ft	ha	ac	g/m^2	lbs/ft^2	MT	T
May	.58	1.9	2.23	5.50	224	.04	5.0	5.5
June	1.59	5.2	5.24	12.94	52	.01	2.7	3.0
July	1.43	4.7	4.76	11.76	90	.01	4.3	4.7
August	.73	2.4	2.69	6.65	302	.06	8.1	8.9
September	.76	2.5	2.78	6.87	220	.04	6.1	6.7

Area of coverage by the plant community ranged from 2.23 ha (5.50 ac) in May to 5.24 ha (12.94 ac) in June. Coverage in terms of percent of the lake area therefore ranged from 8% to 18%. Areal growth was least during May, greatest during June. Thereafter percent coverage decreased gradually from July-September. Expanded quadrant biomass samples showed greatest total weight of plants in the lake was during August at 8.1 metric ton (MT) (8.9 tons). Lowest plant weight occurred in June at 2.7 MT (3.0 tons) which was due mainly to low quadrant weight; areal distribution was greatest in June.

WATER QUALITY

Mean organic phosphates in 1978 ranged from .27 mg/ℓ at 4 m to .75 mg/ℓ at 8 m. Concentration was intermediate at the surface with a mean of .33 mg/ℓ (Table 4). Organic phosphates were lowest at the surface station in June, July and August attaining no more than .12 mg/ℓ; highest values were attained below the thermocline at the 8 m level where concentrations in the summer rose to .50 mg/ℓ. Inorganic phosphates followed the same trend with values ranging from .36 mg/ℓ at 4 m to 1.14 mg/ℓ at 8 m. Surface concentration was .41 mg/ℓ. Seasonal variation of inorganic phosphates also followed the same pattern as organic phosphates. High values occurred at 8 m in the summer, while low values occurred at the surface during the same period.

Table 4. Mean water quality values at Red Haw Lake March, 1978, through February, 1979.

	Surface	4 m	8 m
Organic P (mg/ℓ)	.33	.27	.75
Inorganic P (mg/ℓ)	.41	.36	1.14
Nitrate N (mg/ℓ)	1.38	1.38	1.16
Nitrite N (mg/ℓ)	.033	.030	.018
Alkalinity (mg/ℓ)	118	120	141
pH	7.64	7.33	7.12
BOD (mg/ℓ)	2.66	3.88	10.34
Turbidity (FTU)	19.8	14.2	15.7
Dissolved oxygen (mg/ℓ)	9.8	5.2	2.8
Temperature (°C)	12.8	11.7	8.6

Nitrate nitrogen was lowest at 8 m with a mean concentration of 1.16 mg/ℓ. Values at 0 and 8 m were identical at 1.38 mg/ℓ. Again, the trend was the same for nitrite nitrogen except the values were much lower. For example, surface and 4 m average concentrations were about .03 mg/ℓ, while the mean at 8 m was .02 mg/ℓ. Fluctuations in nitrate and nitrite concentrations showed no particular trend during the sample season.

Alkalinity increased progressively with depth where maximum concentration was attained at 8 m with a mean of 141 mg/ℓ. Surface and 4 m averages were 118 mg/ℓ and 120 mg/ℓ, respectively. Seasonal fluctuation in alkalinity at the surface was low, ranging from 102 mg/ℓ in April to 137 mg/ℓ in January. Fluctuations were identical at 4 m; however, the values at 8 m ranged from 103 mg/ℓ in April to 171 mg/ℓ in August and September.

Hydrogen ion concentration was greatest at 8 m with a pH value of 7.12 followed by 7.33 at 4 m and 7.64 at the surface. Low pH values were quite prevalent below the thermocline during July-October; all pH values were < 6.00.

Biochemical oxygen demand was greatest at 8 m where the mean annual concentration was 10.34 mg/ℓ. BOD values decreased to 3.88 mg/ℓ at 4 m, and 2.66 mg/ℓ at the surface. Greatest BOD occurred below the thermocline during July through October when values were always greater than 10 mg/ℓ; values were < 5 mg/ℓ during the remainder of the year. Values increased during June through November at 4 m and ranged from 6-10 mg/ℓ. BOD values at the surface were consistently less than 7 mg/ℓ regardless of when the sample was taken.

Turbidity ranged from an average 14.2 FTU (Formazin turbidity units) at 4 m to 19.8 FTU at the surface. The high value at the surface was influenced by a single high reading in November of 118 FTU. Turbidity measurements taken during the remainder of the year were < 20 FTU. Likewise, the readings at 4 m were high in November where mean FTU was 75. High values recorded in November were the result of run-off of a heavy rain.

Dissolved oxygen was directly related to the thermocline where the mean values at the surface were 9.8 mg/ℓ decreasing to 5.2 mg/ℓ at 4 m and 2.8 mg/ℓ at 8. In May-September complete oxygen depletion was noted at 8 m; the same depletion occurred at 4 m in July-September. Surface oxygen was never less than 6 mg/ℓ during the sample period. Temperature followed the same trend as dissolved oxygen where mean values at 0, 4 and 8 m were 12.8, 11.7 and 8.6 °C, respectively. The highest temperature at 8 m was 13 °C. Highest temperatures attained at 4 m and surface were 22.6 °C and 27.0 °C, respectively. These values occurred in August.

PRIMARY PRODUCTION

Primary production of phytoplankton was measured as before by the light-dark bottle technique. Estimated production during the study segment was 1.05 g carbon/m^2/day (gC). Lowest production occurred late October through Decmeber when production estimates were < .2 gC (Figure 1). Maximum primary production occurred in June through mid-August when values were consistently greater than 2 gC. Maximum production of 3.13 gC was attained on 3 July 1978, while minimum production of .03 gC occurred in December.

Production was greatest within the first meter with a mean of .44 gC; thereafter, gradual decreases occurred. For example, at 2 m production was .24 gC which decreased to .19 gC at 3 m. Average production was .13 gC and .05 gC, respectively at 4 m and 5 m.

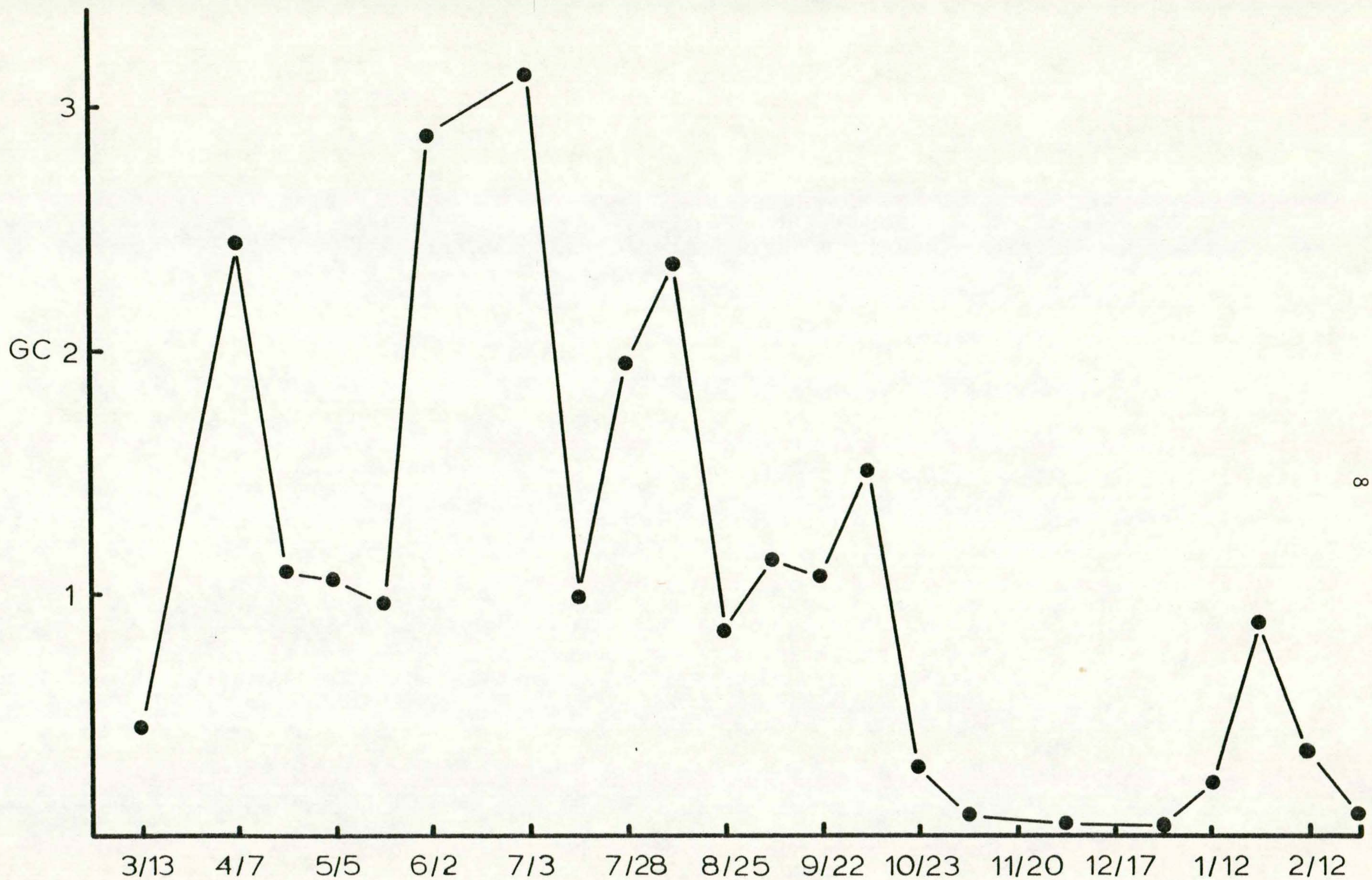

Figure 1. Primary production of phytoplankton at Red Haw Lake in March, 1978-February, 1979. Values are in grams of carbon/m^2/day (GC).

DISCUSSION OF FINDINGS

Relationships between biotic control of vegetation by grass carp, primary productivity and water quality remained similar to that found in previous years. Aquatic vegetation was maintained at 180 g/m^2 during 1978, a 13-fold decrease from weed levels attained prior to introduction of grass carp. The control level attained in 1978 was nearly identical to the 1976 level when mean vegetation biomass during the year was about 200 g/m^2. By late summer, 1977 aquatic vegetation increased to about 2,000 g/m^2. Resurgence of vegetative growth prompted restocking of 550 grass carp in 1978. The new fish combined with the remnant stocks of 1973 and 1974 were enough to effectively control vegetation in 1978 at the 90% level.

Analysis of variance procedure was used to test differences in mean biomass of vegetation between sample years. The analysis showed a significant difference and further analysis by multiple range testing showed means in 1973 and 1974 were similar ($p > .05$); however, were significantly greater than the remaining years, 1975-1978. Mean sample weights in 1975 and 1977 were similar, but were greater ($p < .05$) than 1976 and 1978. Finally, vegetation means in 1978 were significantly lower than any previous sample year.

Consumption of vegetation by grass carp ranged between 76 metric ton (MT) (84 ton) in 1973 and 69 MT (76 ton) in 1974. Consumption in 1977 and 1978 was not estimated, but was probably equal to, or higher than, 1973 and 1974. Most of the nutrients contained in the consumed vegetation were returned to the system in the form of egesta. Normal conversion rate of grass carp is 1:25-1:40; therefore, grass carp were shunting nutrients within the plants directly back to the water column and mud-water interface. Nutrient recycling of this nature could be expected to cause a vast change in the nutrient budget of the lake and, indirectly, a change in primary productivity within the phytoplankton population.

Analysis of variance for the 11 water quality measurements during the five year investigation showed a significant change in five of the parameters including nitrate nitrogen, nitrite nitrogen, turbidity, pH and alkalinity. Nitrite nitrogen showed an inverse relationship with intensity of vegetation control. Years of lowest vegetation control in 1974 and 1977 showed highest concentrations of nitrites. During these years mean nitrite concentrations were .021 mg/ℓ and .036 mg/ℓ, respectively. Conversely, when vegetation control was most intense in 1975, 1976 and 1978 mean nitrites were .009 mg/ℓ, .006 mg/ℓ and .027 mg/ℓ, respectively. Water quality, in terms of nitrites, improved as intensity of vegetation control increased. Nitrate nitrogen values followed the same trend as nitrite values except in 1978.

Hydrogen ion concentration showed a significant decrease in 1974-1976 as vegetation was heavily cropped by grass carp. Mean pH decreased from 7.65 to 6.35 during this period; however, a reverse trend occurred between 1976-1978 when pH increased to 7.30. The difference in mean pH between 1974 and 1978 was not significant ($p > .05$).

Alkalinity showed the opposite trend; lowest values were attained in 1974 when the mean was 115 mg/ℓ. Mean alkalinity increased to 134 mg/ℓ by 1977 and was significantly greater than the 1974-1975 sample years. The decrease in alkalinity in 1978 to 127 mg/ℓ was not significantly different from any years except 1974. Alkalinity showed no particular trend with regard to the intensity of plant cropping.

Turbidity in 1978 was significantly greater ($p < .05$) than previous years. A low of 7 FTU was attained in 1977 followed by a high of 17 FTU in 1978. The increased turbidity in 1978 was caused mainly by silt because phytoplankton populations were lower in 1978 than previous sample years.

Water quality parameters including organic phosphates, metaphosphates, orthophosphates, biological oxygen demand, dissolved oxygen and temperature were not significantly different ($p > .05$) between years. Therefore, water quality samples taken at Red Haw Lake since 1974 indicate no degradation in water quality; in fact, there was a decrease in levels of nitrate and nitrite nitrogen.

Primary production decreased steadily since 1975 when a high of 2.04 gC was attained. Sampling in 1974 showed production was nearly as great with a mean of 1.90 gC. Primary production decreased to 1.28 gC followed by further reductions in 1977 and 1978 to 1.24 gC and 1.05 gC, respectively. Phytoplankton production and its relationship to nutrients, light and temperature is extremely complex. The relationships become even more complex when control of aquatic macrophytes is considered. However, two important facts remain: since sampling commenced in 1974 water quality has not deteriorated and phytoplankton populations have not become a nuisance.

RECOMMENDATIONS

The investigation should continue for an additional year with emphasis on the sport fishery at Red Haw Lake. Aquatic vegetation is being controlled at the 90% level. An expandable creel census identical to those in 1971, 1974 and 1976 will be conducted. Investigations in water quality and primary productivity will continue an additional year.