Evaluation of Fertilizers to Increase Plankton Abundance in Reservoir Coves

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Abstract: A study was conducted in Lake Benbrook and Squaw Creek reservoirs, Texas, to determine whether naturally occurring phytoplankton and crustacean zooplankton abundance in selected coves could be increased by fertilization. In each reservoir, 1 cove was fertilized once a week for 4 weeks using inorganic fertilizer (liquid 10–34–0, N-P- K, applied at 1 mg/liter P_2O_5), 1 cove was fertilized with the same inorganic fertilizer plus organic fertilizer (cottonseed meal applied at 225 kg/ha), and 1 cove received no fertilizer as a control. Nutrient and plankton levels in the coves were monitored before, during, and after fertilizer application. Nutrient levels increased imediately after application of fertilizer, but returned to pre-treatment levels within 1 week. Fertilized coves did not have higher phytoplankton or zooplankton densities than non-fertilized coves. Dilution resulting from high water exchange rates between coves and the main reservoir was suspected as the cause for lack of fertilization effects.

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Artificial fertilization in hatchery and farm ponds is an effective method of increasing zooplankton density, and subsequent fish productivity (Swingle and Smith 1939, Geiger 1983). While artificial fertilization of large impoundments is not usually considered to be economically practical, such programs when applied to areas of a reservoir may be. Research on the effects of artificial fertilization within reservoirs has yielded conflicting results (Raymont 1946, Wood and Sheddan 1968, Smith 1969).

Fertilization efforts in Texas reservoirs have been limited and also have produced mixed results (J. E. Kraai, Texas Parks and Wildl. Dep., pers. commun.). In recognition, however, that increasing primary and secondary production could lead to increased survival of stocked sport fishes, I conducted an investigation to determine if phytoplankton and crustacean zooplankton abundance in selected coves of Texas reservoirs could be increased by artificial fertilization.

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Methods

The study was conducted in 2 north central Texas reservoirs, Lake Benbrook and Squaw Creek Reservoir. Three coves in each reservoir were chosen to meet the following criteria defined by Wood and Sheddan (1968): coves were similar in surface area and volume, at right angles to prevailing winds, sufficiently separated to maximize independence, but close enough to have similar drainage characteristics.

Lake Benbrook is a 1,525-ha reservoir located on the Clear Fork of the Trinity River in Tarrant County, Texas, and was impounded in 1952. It has a mean depth of 7 m, an approximate turbidity of 50 JTU and a total alkalinity of 150 mg/liter.

Squaw Creek Reservoir, located in Hood and Somervell counties, was impounded in 1977 and covers 1,325 ha. It has a mean depth of 4 m, approximate turbidity of 5 JTU and a total alkalinity of 100 mg/liter which suggests low fertility (Sellers 1984).

Three coves having mean surface areas of 0.40 (range 0.31–0.47) and 0.43 (range 0.39–0.50) ha were chosen as experimental coves on Lake Benbrook and Squaw Creek reservoirs, respectively (Table 1). Fertilization treatments were randomly assigned to coves in both reservoirs. One cove in each reservoir received no fertilizer (control), 1 cove received inorganic fertilizer (liquid 10–34–0, N-P-K) and 1 cove received both inorganic and organic (cottonseed meal) fertilizer. Inorganic fertilizer was applied at a rate of 1 mg/liter P_2O_5 by diluting the liquid and broadcasting it over the surface of the cove. Organic fertilizer was applied by broadcasting at a rate of 225 kg/ha. Fertilizer was applied at these rates once each week for a 4-week period beginning 18 April 1985. These fertilizers and rates have been effective in hatchery ponds (Geiger 1983). Since inorganic fertilizer was applied on the basis of volume and organic fertilizer was applied on the basis on surface area, no comparisons between reservoirs were intended.

Four permanent sampling stations were established for each of the 6 coves as follows: station A - located in the back of the cove; station B - located midway between the back of the cove and the mouth; station C - located at the mouth of the cove; and station D - located approximately 50 m outside the mouth of the cove.

Sampling began 1 week before fertilization and continued for 8 weeks. Oxygen-temperature profiles were measured weekly in each cove at station B using a YSI Model 51 oxygen-temperature meter. Measurements were made in the water column at 0.5-m intervals between 0900 and 1500 hours. Chlorophyll *a* concentrations were measured weekly at all stations using methods described in American Public Health Association (1971). Additionally, nutrients (total and ortho phosphorus, ammonia, and nitrate nitrogen) were measured 3 days before the first application of fertilizer, midway through the fertilization program, and 3 weeks after the last fertilizer application. Water samples for nutrient analysis and chlorophyll *a* were taken by pumping an integrated sample from the entire water column at mid-

Table 1. Physical and chemical parameters of coves used for fertilization experiment, Lake Benbrook and Squaw Creek Reservoir, Texas. Water samples were taken from the entire water column at mid-cove.

Cove	Treatment	Surface area (hectares)	Volume (m^3)	Date	Total phosphorus (mg/liter)	Ortho-phosphorus (mg/liter)	Ammonia nitrogen (mg/liter)	Nitrate nigrogen (mg/liter)
				Lake Benbrook				
1	No fertilizer	0.31	6,980	4-15-85[a]	0.09	0.03	0.10	0.79
				5-9-85[b]	0.06	0.01	0.07	0.14
				6-5-85[c]	0.04	0.01	0.56	0.04
2	Inorganic fertilizer[d]	0.42	5,921	4-15-85[a]	0.11	0.01	0.10	0.19
				6-5-85[c]	0.07	0.01	0.36	0.04
3	Inorganic[d] and organic[e] fertilizer	0.47	3,948	4-15-85[a]	0.05	0.01	0.10	0.19
				5-9-85[b]	0.03	0.01	0.09	0.19
				5-9-85[f]	0.31	0.10	0.24	0.19
				6-5-85[c]	0.08	0.01	0.20	0.09
				Squaw Creek Reservoir				
1	No fertilizer	0.50	7,032	4-15-85[a]	0.03	0.01	0.04	0.02
				5-8-85[b]	0.10	0.03	0.24	0.02
				6-5-85[c]	0.01	0.01	0.02	0.02
2	Inorganic[d] fertilizer	0.40	7,895	4-15-85[a]	0.02	0.01	0.03	0.02
				6-5-85[c]	0.01	0.01	0.10	0.02
3	Inorganic[d] and organic[e] fertilizer	0.39	8,142	4-15-85[a]	0.04	0.02	0.03	0.02
				5-8-85[b]	0.06	0.01	0.09	0.02
				5-8-85[f]	0.46	0.45	0.39	1.95
				6-5-85[c]	0.02	0.01	0.22	0.02

[a]3 days prior to first fertilizer application.
[b]1 hour prior to third fertilizer application.
[c]3 weeks after final fertilizer application.
[d]Liquid 10-34-0, N-P-K, applied at 1 mg/liter P_2O_5 weekly for 4 weeks.
[e]Cottonseed meal applied at 225 kg/ha weekly for 4 weeks.
[f]1 hour after third fertilizer treatment.

cove and were analyzed using standard methods (Am. Public Health Assoc. 1971). Nutrient concentrations were also measured 1 hour before and after the third fertilizer application in coves receiving both organic and inorganic fertilizer to assess the immediate effects of fertilization.

Crustacean zooplankton densities in each cove were estimated from weekly samples taken at all sample stations during the entire 8 week study. Zooplankton samples consisted of 50 liters of water taken between 0900 and 1500 hours with a portable gasoline powered pump while moving the intake slowly from the surface to the bottom. The sample was concentrated through an 80-micron net and preserved in 5% buffered formalin. Mean crustacean zooplankton were determined from counts of 3 separate, 1-ml aliquots from each sample after dilution to 100–200 organisms/ml. Counts were made in a Sedgewick-Rafter cell using a variable-power binocular dissecting scope.

After the fertilization program was completed, fluorescent dye was added to 1 cove in Squaw Creek Reservoir, and visual observations were made to determine the time the dye remained in the cove.

A split-plot analysis of variance (ANOVA) was conducted for each reservoir. The hypothesis of no difference in mean chlorophyll *a* or mean density of total crustacean zooplankton ($P < 0.05$) was tested among whole plots (fertilizer treatments) and subplots (stations) with weeks as blocks. Such ANOVA models assume that measurement errors among stations and among times are independently and identically normally distributed. Because treatment replications were bases on repeated sampling of spatially-ordered stations, the independence assumption was suspect. Lack of independence among errors can result in distorted significance tests (Cochran 1947, Box 1954, Millard et al. 1985). Independence among stations and weeks was examined by testing for non-zero correlations ($P < 0.05$) among errors from all pairwise combinations of weeks with respect to weekly means across stations and treatments, and stations with respect to station means across weeks, respectively. Dependent variables were transformed [$\log_e(x+1)$] to approximate the assumptions of equal variances and normality. All analyses were performed with SAS (SAS 1982).

Results and Discussion

Nutrient concentrations were higher in samples collected immediately after fertilizer application than those collected before; however, the effects were apparently short term (Table 1). One hour prior to the third fertilizer application, nutrient measurements showed no increase over pre-treatment values, even though fertilizer had been applied both 1 week and 2 weeks before. One hour after the third application of fertilizer the levels of phosphorus and nitrogen were elevated in samples from both reservoirs (Table 1). Dissolved oxygen concentrations were similar in all samples within each reservoir and remained high (> 6.0 mg/liter) on all dates sampled.

Differences in chlorophyll *a* concentrations (Fig. 1) were not significant among

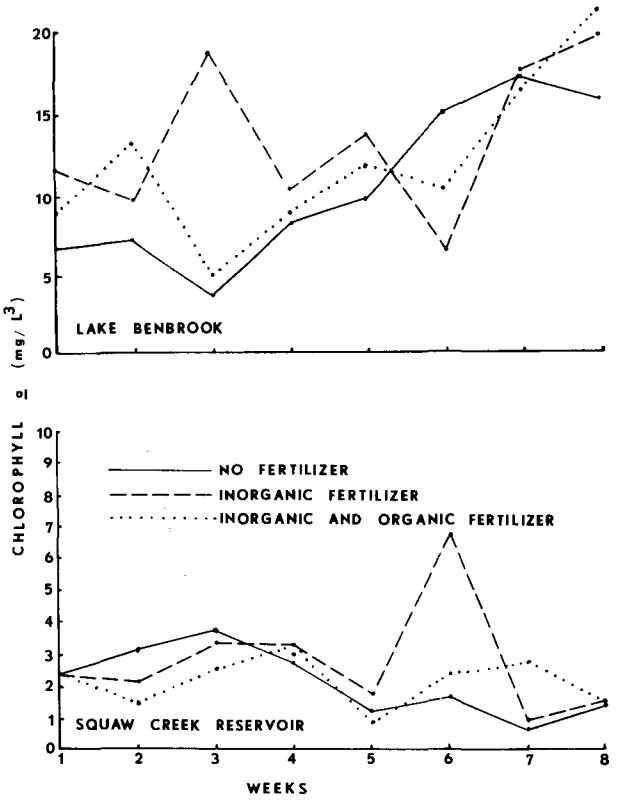

Figure 1. Mean weekly chlorophyll *a* concentrations in experimental coves, Lake Benbrook and Squaw Creek Reservoirs, Texas, April–June 1985. In each reservoir, 1 cove was treated with inorganic fertilizer (liquid 10–34–0, N-P-K, applied at 1 mg/liter P_2O_5 weekly for 4 weeks), 1 with the same inorganic and organic fertilizer (cottonseed meal applied at 225 kg/ha weekly for 4 weeks), and 1 with no fertilizer. Fertilizer applications were made once each week during weeks 2–5.

treatments in either reservoir. There were also no significant differences in chlorophyll *a* concentrations among stations. Less than 20 percent of the error correlations were significantly different than zero for stations and weeks in both reservoirs. Therefore, distortion of *P*-values from the ANOVA model should be minimal.

There were no significant differences in total crustacean zooplankton densities among coves or among stations in either reservoir with the exception of a significant treatment difference in Squaw Creek Reservoir. This difference may, however, be an artifact of correlated errors for stations and weeks. Less than 20 percent of the correlations among errors for both stations and weeks were significantly different than zero for Lake Benbrook. However, 42% and 29% of the correlations among stations and weeks, respectively, were significantly different than zero for Squaw Creek Res-

ervoir. Further, weekly sample means (Fig. 2) do not suggest treatment differences were biologically significant.

Fertilization treatments appeared ineffective in increasing plankton in the coves of these reservoirs. This may have been due to water exchange between the relatively small fertilized areas and the total reservoir. This phenomenon is supported by the observation that fluorescent dye was diluted from a Squaw Creek Reservoir cove within 3 hours after application. Similarly, nutrient concentrations were higher in samples taken 1 hour after fertilization than those recorded before fertilization, but had returned to pre-treatment levels within 1 week. Wood and Sheddan (1968) found similar results in Norris Reservoir, Tennessee. They felt much of the fertilizer used in their study may have been sluiced out of the coves by wind or reservoir currents. They did note an increase in zooplankton but the increase coincided with

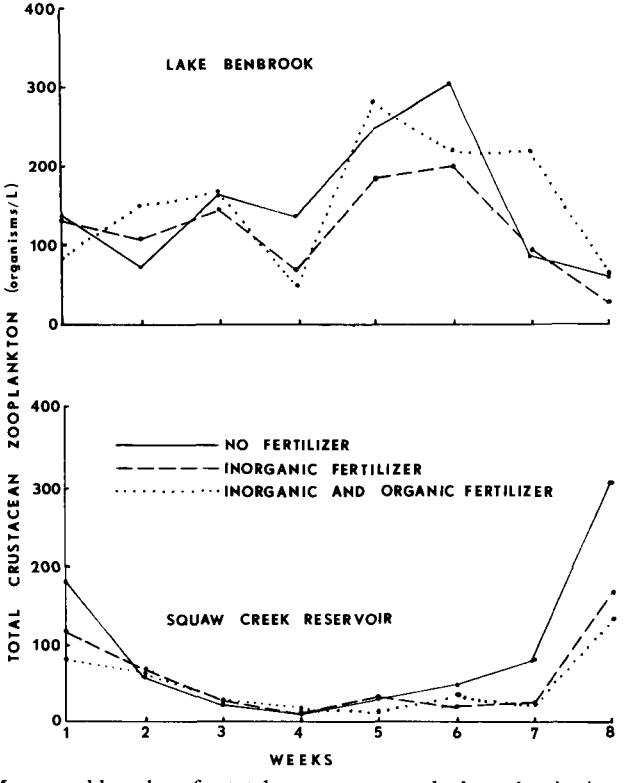

Figure 2. Mean weekly values for total crustacean zooplankton density in experimental coves, Lake Benbrook and Squaw Creek Reservoirs, Texas, April–June 1985. In each reservoir, 1 cove was treated with inorganic fertilizer (liquid 10–34–0, N-P-K, applied at 1 mg/liter P_2O_5 weekly for 4 weeks), 1 with the same inorganic and organic fertilizer (cottonseed meal applied at 225 kg/ha weekly for 4 weeks), and 1 with no fertilizer. Fertilizer applications were made once each week during weeks 2–5.

increasing water temperatures and heavy rainfall. They concluded that there was no measurable benefit from their fertilization efforts. In the present study, the fact that crustacean zooplankton numbers and chlorophyll *a* concentrations did not increase in fertilized coves suggests that there is no practical benefit from a cove fertilization program as it was conducted during this study.

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