Zooplankton Production and Pond Fertilization for Largemouth Bass Fingerling Production

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Abstract: Inorganic fertilizers were tested in combination with organic fertilization to study enhancement of zooplankton communities in largemouth bass (*Micropterus salmoides*) rearing ponds in southeast Colorado. Under study conditions, additions of triple superphosphate produced the greatest number of zooplankton/liter, a combination of liquid ammonium nitrate and phosphoric acid produced the greatest growth, and the highest yields were found in ponds treated with phosphoric acid alone. Triple superphosphate was as effective as liquid inorganic fertilizers in maintaining sufficient numbers of zooplankton and was easier to apply. Fish were returned at the desired length of 50 mm, which was longer than in previous years in spite of an increased stocking rate. Although total zooplankton/liter was lower than in previous years at the hatchery, cladoceran populations were maintained with no significant declines.

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One of the limiting factors under current production strategies of fingerling largemouth bass (*Micropterus salmoides*) is the abundance of zooplankton in a pond. Largemouth bass require a stable zooplankton population from yolk-sac absorption to the time they reach a length of approximately 50 mm at which time they can be trained to accept a pelleted feed. Without a natural food source, high mortality may occur as a result of starvation and cannibalism (Geiger 1983*a*). Although survival of fry may be relatively high, small size and emaciated condition of fry suggest that efforts should be directed toward maintaining a source of natural foods in hatchery ponds for a longer period of time (Young 1987).

In pond culture, an organic base must be present to promote bacterial growth. Zooplankton require bacteria and protozoans as a forage base. Zooplankton also

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feed upon phytoplankton (unicellular algae and diatoms) and organic detrital materials (Pennak 1955, Geiger 1983*b*). Organic and inorganic fertiliers such as phosphorus and nitrogen are most commonly used to create the base and promote phytoplankton growth. Phytoplankton also provides shading against "unwanted" submerged plants such as *Chara* spp. Submerged plants compete with phytoplankton for phosphorus and nitrogen. Zooplankton blooms are common about 7–14 days after initial addition of organic fertilizers, but it is often difficult to maintain a standing population of the organisms after the initial bloom (Geiger 1983*a,b;* Parmley and Geiger 1985).

While many studies have been undertaken to study zooplankton production, most of these have been conducted in Israel (Yashouv and Halevy 1972; Schroeder 1974, 1978; Rappaport et al. 1977) and in the southern and southeastern regions of the United States (McCarty et al. 1985, Parmley and Geiger 1985, Fitzmeyer et al. 1986), particularly on striped bass (*Morone saxatilis*) production (Snow et al. 1980; Geiger 1983 *a,b;* Geiger and Parker 1985; Geiger et al. 1985). Little to no effort has been focused on pond fertilization and zooplankton production for largemouth bass (Parmley et al. 1986), particularly in Colorado. Fertilization regimes have been based mainly on local availability of organic and inorganic fertilizers.

In 1986, a program was designed to concentrate on maintaining a stable zooplankton population comprised primarily of cladocerans. The goal was to maintain the plankton population until largemouth bass fry reached 50 mm, preferably in a 3-week time period.

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Methods

Rye grass seeds were sowed at 24 kg/ha in 6 0.4-ha ponds in January and at 18 kg/ha in 1 other 0.4-ha pond in April at the Colorado Division of Wildlife hatchery near Las Animas, Colorado. Cow manure was applied at 3,365 kg/ha in mid-March, and alfalfa hay was applied at 1,120 kg/ha in early April. Alfalfa meal and meat and bone meal were each initially added at 225 kg/ha during filling. Beginning 1 week later, each meal was applied at a rate of 55 kg/ha twice weekly. The high level of organic fertilization was required as a result of daily flushing and an inherent organic nutrient deficiency. The fertilization regime was attenuated when critically low dissolved oxygen (DO) levels ($\leq$ 1.0 mg/liter) were reached during the third week after filling started. Ponds were flushed daily to relieve rapid warming and stagnation conditions as a result of high daily temperatures (32°C) and shallow depths (0.61 m). Meals and other organics were dispersed over 75% of the pond using a paddlewheel with wind action completing the process.

Triple superphosphate (0-60-0) was applied to 3 ponds at a rate of 1.0 mg/liter. Liquid phosphoric acid (0-70-0) was applied to 2 ponds at a rate of 1.0 mg/liter. Ammonium nitrate (28-0-0) was applied at a rate of 0.5 mg/liter in combination with 1.0 mg/liter of the phosphoric acid to the final 2 ponds. Inorganic fertilizers were applied 3 times weekly for the 2 weeks before fry were stocked and 2 times a week post-stocking. Treatment was discontinued during the period of low DO levels 1 week post-stocking. Airlift pumps measuring 65 mm in diameter and 45 cm in height were placed 1 in each pond and powered by a 1.0-hp blower.

Zooplankton inoculum was obtained from John Martin Reservoir, located 32 km east of the hatchery, because the water supply was devoid of a large natural zooplankton population. Cladocerans, from the Texas Parks and Wildlife Hatchery located near Electra, Texas, were cultured in an aerated raceway (Alan Brandenburg, Little Grassy Hatchery, Carbondale, Ill., pers. commun.) to ensure a stable population for subsequent inoculations. Torula yeast was added at 250 kg/ha every other day beginning 1 week after an initial inoculation of 50 lb trout feed.

Grass carp (*Ctenopharyngodon idellus*) averaging 125 mm in length were stocked into the ponds at a rate of 740 fish/ha to control vegetation. Largemouth bass fry were stocked from 9 June to 12 June 1986 at an average rate of 96,370/ha, which was below average based on results reported for largemouth bass and striped bass (Geiger 1983*a*, Fitzmeyer et al. 1986, Parmley et al. 1986).

Twice each week for 5 weeks zooplankton were sampled with a flexible impeller pump (Farquhar and Geiger 1983). Pond water from 4 permanent sites on each pond was pumped through an 80-μm net at a total amount of 40 liters per pond. Zooplankton were placed into 4% buffered formalin solution with sucrose added to prevent swelling of carapaces (Haney and Hall 1973, Weber 1973, Prepas 1977). The specimens were enumerated and identified to species when possible. Once a week, 10 fish were collected from each pond, weighed, measured, and preserved in formalin for gut analysis.

Oxygen and water temperature readings were taken twice daily using a YSI, Model 51B oxygen meter calibrated with the Winkler titration method. Water temperature was also measured daily in 1 pond with a thermograph. The day after each application of inorganic fertilizer, pH, chlorophyll *a*, orthophosphate, and nitrogen-nitrate measurements were taken (8 samples total). Nitrate-nitrogen and pH measurements were made using a Hach DR3 spectrophotometer. Chlorophyll *a* measurements were made according to Standard Methods for the Treatment of Water and Wastewater (Am. Public Health Assoc. et al. 1985) and Boyd (1979). Orthophosphate measurements were made by the Colorado State University Soils Testing Laboratory. Hardness and alkalinity measurements were taken at the beginning and at the end of the study. Alkalinity levels were measured according to guidelines by American Public Health Association et al. (1985). Hardness was measured using methods described by Hach Chemical Company (1975). Results were statistically analyzed using ANOVA and correlation analysis. Unless otherwise stated, $P \leq 0.05$ was used for all analyses.

Results and Discussion

Significantly smaller and fewer fry were stocked in 1985 than in 1986 (Table 1). The size of fingerlings harvested in 1986, 717 fish/kg, was significantly greater than the size, 968 fish/kg, of those harvested in 1985. Additionally, the number of fingerlings per hectare harvested in 1986 was significantly higher at 74,935 than the 1985 figure of 66,865. The higher stocking rate was therefore appropriate since there was no significant difference between the survival of 81% for 1985 and 77.5% for 1986. Although the fish were more crowded in 1986, average lengths were greater signifying better utilization of available prey species. Gut analysis showed that almost all the stomachs were full at the time of sampling (Young 1987).

Although zooplankton densities were similar both years, species composition over the production periods were quite different (Fig. 1), particularly cladocerans, which are the preferred prey species of fry (Cooper 1936, Rogers 1967, Parmley et al. 1986). The cladoceran population in 1986 was less dense but relatively more stable than in 1985. This ensured an available preferred food source to the fry during the critical growth period.

The zooplankton population peaked later in 1986 than in 1985 (Fig. 1). The decline in 1986 occurred just prior to harvesting. In 1985, the decline occurred 1.5 weeks before the end of the 3-week production period. The fish in 1985 were emaciated and had to be harvested before they had reached the desired length of 50 mm. Additionally, the peak and decline of the zooplankton population followed a seasonal pattern in 1986 (Fig. 2). Cladoceran populations in Colorado generally peak

Table 1. Production of largemouth bass fingerlings from fry stocked in ponds ($N = 7$) at Las Animas hatchery, Colorado, in 1985 and 1986.

	1985	1986
Stocking		
Fry/ha	83,000	96,000
Fry/ml	47	32
Harvesting		
Days in pond	24	20
Fingerlings/kg of fish	970	720
Fingerlings/ha	67,000	75,000
Mean length (mm)	44[a]	48[b]
Yield (%)	81	78
Mean zooplankton/liter[c]	1,000	920

[a]An approximation based upon length-weight charts (Piper et al. 1982).
[b]Mean lengths based upon 10 fish/pond (7 ponds).
[c]Mean zooplankton/liter based upon 27 samples for 1985 and 70 samples for 1986.

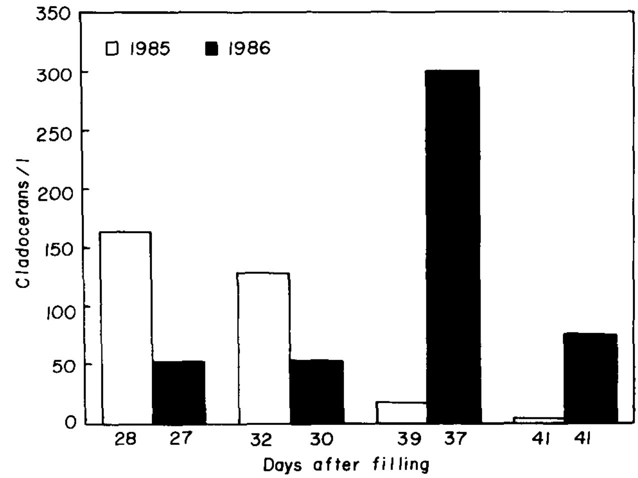

Figure 1. Mean cladoceran concentrations for 1985 and 1986 on similar sampling dates from the time filling of the ponds began, Las Animas hatchery, Colorado.

in late spring or early summer (Pennak 1955, Porter 1977) and decline until early fall. The pattern in 1985 was similar but occurred much too soon to be beneficial to the fry.

Although routine fertilization with alfalfa meal and meat and bone meal was discontinued after the drastic decline in DO levels, heavy fertilization previous to the DO decline evidently was sufficient enough to maintain the organic base. The slowly decomposing alfalfa hay and cow manure, combined with the frequent applications of the meals, plus the tremendous growth of rye grass prior to pond flooding contributed to the success in maintaining a stable zooplankton population.

Among treatments, there were no obvious trends (Table 2). The number of zooplankton (970 organisms/liter) was highest in the ponds treated with triple superphosphate. However, the only 50-mm fry were produced in ponds treated with the combination of ammonium nitrate and phosphoric acid where the number of zooplankton was intermediate (930 organisms/liter). The best survival, 96.7%, occurred in ponds treated with phosphoric acid where zooplankton/liter, 900, was lowest. These fish were also returned at the lowest weight, 885 fingerlings/kg. However, differences in size were not significant.

Liquid inorganic fertilizers have been proven to be more effective in producing higher yields (Yahouv and Halevy 1972, Rappaport et al. 1977, Schroeder 1978, Musig and Boyd 1980, Davidson and Boyd 1981) partly due to their fast dispersal time. Phytoplankton can readily utilize liquid fertilizers before nutrients are complexed with calcium to become unavailable (Boyd 1971, 1979). The problem associated with pelleted triple superphosphate is that it does not disperse as quickly and therefore is not as readily available to unicellular algae, an important item in the diet of many zooplankton. Yet in this study, the number of zooplankton per liter was

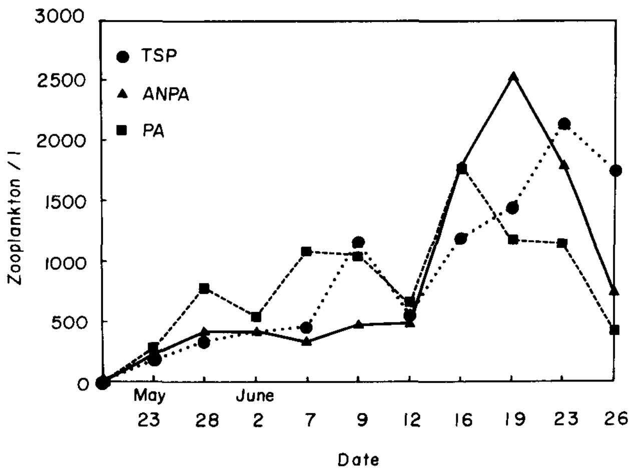

Figure 2. Mean total zooplankton for each treatment, triple superphosphate (TSP), ammonium nitrate and phosphoric acid (ANPA), and phosphoric acid alone (PA), during the period 23 May–26 June 1986.

highest in the triple superphosphate treated ponds. This may in part be due to the means of dissolving the triple superphosphate in saran screen socks tied over the inlet. Another problem with the liquids utilized at Las Animas was their caustic nature which could be quite hazardous to both equipment and personnel.

Water Characteristics

Chlorophyll *a* levels (12 μg/liter) were generally low, and there were no significant differences between treatments. Relatively high pH (8.4) and orthophosphate (0.63 mg/liter) levels resulted from increased photosynthesis and phosphoric acid additions, respectively. Total ammonia-nitrogen levels averaged 0.29 mg/liter which was slightly higher than expected, but the large biomass present in the ponds may have contributed a high level of nitrogenous waste from decomposition. Nitrate lev-

Table 2. Mean concentrations of zooplankton, lengths, and percent returns of largemouth bass fingerlings per treatment, Las Animas hatchery, Colorado, 1986 (±SE).

Treatment[a]	*N* ponds	Zooplankton/liter[b]	Lengths (mm)[c]	% returns
Triple superphosphate	3	970 (±170)	47 (±0.52)	65 (±12)
Phosphoric acid	2	900 (±40)	46 (±1.10)	97 (±9)
Ammonium nitrate and phosphoric acid	2	930 (±295)	52 (±3.70)	78 (±15)

[a]No significant differences between any of the treatments for any variable.

[b]Mean zooplankton/liter based upon 30 samples for triple superphosphate. The other 2 treatment means are based upon 20 samples each.

[c]Mean lengths based upon 30 fish for triple superphosphate treatment. The other 2 treatment means are based upon 20 fish each.

els remained negligible, averaging below 0.1 mg/liter. Alkalinity and hardness averaged 185 mg/liter and 829 mg/liter, respectively. The values were not unexpectedly high, given the inherent water quality of springs in that area.

Conclusions

Environmental factors such as climate, soil type, pond morphology and history, and water source and quality all influence production of healthy largemouth bass fry in hatcheries. With proper fertilization and zooplankton production techniques, largemouth bass fingerlings $\geq$ 50 mm in length and in good condition were produced in 3 weeks after fry were stocked into production ponds.

A stable cladoceran population was maintained at the Las Animas Hatchery by adequate fertilization and inoculations of adapted zooplankton species. Abnormally heavy fertilization was a critical factor necessary for the successful maintenance of a stable zooplankton population where the soil was deficient in nutrients. Low levels of DO resulting from an overload of organic fertilizers and biomass, may be avoided through careful attention to treatment levels. Results on the use of inorganic fertilizers are inconclusive. Further study using more ponds and more consistent timing may provide more definitive answers.

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