Effects of Zooplankton Additions on Zooplankton Populations and Fingerling Florida Largemouth Bass Production in Plastic-Lined Ponds

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Management Data Series
No. 283
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TEXAS PARKS & WILDLIFE
INLAND FISHERIES DIVISION
4200 Smith School Road
Austin, Texas 78744

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ABSTRACT

Texas Parks and Wildlife Department freshwater fish hatcheries manage zooplankton populations in ponds for production of 75-mm Florida Largemouth Bass *Micropterus salmoides floridanus* (FLB) from fry by regular additions of zooplankton into ponds. Though this strategy was implemented in the early 1990s and about 250 man-hours are spent each season at each hatchery, its efficacy in improving fish production has not been adequately investigated at these facilities. We conducted this study to evaluate the effects of zooplankton supplementation (3 weekly additions of zooplankton to ponds during most of the culture period) on zooplankton density and 75-mm FLB production at the Texas Freshwater Fisheries Center Fish Hatchery. Three ponds each were randomly assigned to treatment (zooplankton supplementation) and control (no zooplankton supplementation) groups. All ponds were similarly filled with lake water, managed with organic and inorganic fertilizers, and stocked with FLB fry (7-10 d post hatch; 384,615/ha). Treatment ponds received zooplankton additions 3 d after filling began and subsequent additions three times weekly through the week before pond draining for fish harvested. Water, along with its microorganisms, was pumped from a zooplankton culture pond into a 3,407-L transport tank and then approximately equal volumes were transferred into treatment ponds on each treatment day. Mean pond water temperatures, dissolved oxygen concentrations, and pH levels did not statistically differ between treatment and control ponds ($P \geq 0.05$). Zooplankton densities were similar between treatment and control ponds ($P \geq 0.05$). Fish production variables including survival rate, harvest weight, harvest length, and growth rate also did not statistically differ between treatment and control. Zooplankton supplementation of culture ponds had no effects on zooplankton population and fingerling FLB production.

INTRODUCTION

Successful production of fingerling Florida Largemouth Bass (FLB) *Micropterus salmoides floridanus* in hatchery ponds is dependent on zooplankton populations of the proper quality (species or size composition; Wickstrom and Applegate 1989) and quantity (Morris and Mischke 1999; Barkoh et al. 2005). Rotifers, cladocerans, and copepods are zooplankters considered essential food items for survival and growth of predatory fish from fry to fingerling stage (Barkoh and Modde 1987; Pennak 1989; Ludwig 1993). Fertilization and zooplankton inoculation (1 or 2 additions usually before fry stocking) of fry rearing ponds are common practices for establishing adequate quantities and quality of zooplankton for fish (Geiger and Turner 1990; Hoff and Snell 1993; Kurten 2001). Routinely, organic and inorganic fertilizers are used to stimulate phytoplankton blooms to support zooplankton populations in fingerling production ponds (Geiger and Turner 1990; Anderson 1993; Barkoh et al. 1993), and zooplankton culture ponds are used as sources of seed zooplankton for establishing desirable zooplankton populations in fish rearing ponds (Geiger 1983a, b; Geiger et al. 1985; Parmley et al. 1986; Geiger and Turner 1990; Opuszynski and Shireman 1993).

In addition to zooplankton inoculation to establish initial zooplankton populations in fingerling production ponds, Geiger (1983a) recommended that culturists should fine-tune zooplankton inoculation rate to each specific situation to improve and manipulate forage production and maximize crustacean zooplankton foods in fry rearing ponds. Based on this suggestion TPWD hatchery staff implemented, as standard practice, zooplankton supplementation (multiple additions over an extended period) of fingerling Largemouth Bass production ponds. Though this practice was implemented in the early 1990s, it was not evaluated until recently. Martinez et al. (2005) evaluated the efficacy of weekly zooplankton additions to FLB fry rearing ponds to promote increased fingerling production at the A. E. Wood Fish Hatchery (AEW), San Marcos, Hays County, Texas. The results revealed that zooplankton density was increased but fingerling FLB production was not significantly improved. The authors suggested that the benefits (e.g. improved fish production) of zooplankton supplementation might be realized where zooplankton densities are lower or smaller-size zooplankters occur compared to those at AEW. Typically at AEW, zooplankton populations in fingerling FLB production ponds average 596 organisms/L and dominated by large crustacean zooplankters (e. g., *Daphnia* spp.).

In the past 12 years, total zooplankton densities in Texas Freshwater Fisheries Center Fish Hatchery (TFFC) ponds have averaged approximately 10% less than those of AEW ponds. Thus, zooplankton supplementation of FLB fry rearing ponds has been practiced at the TFFC for several years. Typically at AEW and TFFC, fry rearing ponds are fertilized with organic and inorganic fertilizers and inoculated with zooplankton 7-10 d before fry stocking. These fry rearing ponds are sampled twice weekly to monitor zooplankton densities. When the zooplankton density of a pond is less than 200 organisms/L (adopted after Geiger and Turner 1990), the pond is provided with supplemental zooplankton (Martinez et al. 2005). Zooplankton additions and pond fertilization continue weekly until 1-2 weeks before fingerling harvest. Approximately 250 man-hours are spent each production year to supplement FLB rearing ponds with zooplankton. Nonetheless, the efficacy of this practice in terms of improved fish production has not been adequately investigated in TPWD inland hatchery ponds. The objectives of this study were to determine the effects of zooplankton supplementation on zooplankton populations and fish production variables (survival, growth, and harvest weight) in fingerling FLB production ponds.

MATERIALS AND METHODS

Pond Management

Six 0.13-ha plastic-lined ponds at the TFFC in Athens, Henderson County, Texas were used for this study. Before filling ponds with water from Lake Athens, the water source to the hatchery, as much of the sediments as possible were removed from pond liners and kettles. All ponds were filled on 7-9 May 2009 with water that was filtered through a 400-µm-mesh sock filter to exclude wild fish and predatory insects. Water quality characteristics of the incoming water were: total hardness, 12 mg/L as $CaCO_3$; total alkalinity, 12 mg/L as $CaCO_3$; total phosphorus, 0.02 mg P/L; nitrate nitrogen, 0.01 mg N/L, and ammonium nitrogen, 0.03 mg N/L. Ponds received initial fertilizations with 57 kg/ha cottonseed meal, 0.08 mg P/L from 53% liquid phosphoric acid, and 0.3 mg N/L from 70% liquid uran 1 d after pond filling was started. Ponds received follow-up fertilizations with 227 kg/ha cottonseed meal, 0.16 mg P/L, and 0.6 mg N/L 5 d after filling began. Subsequently, ponds received 57 kg/ha cottonseed meal twice weekly until one week before pond draining began to harvest the fish. Cottonseed meal was manually broadcast with a scoop onto each pond water surface, and liquid fertilizers were each diluted with water from the receiving pond before broadcasting unto the water surface.

Ponds were randomly assigned to treatment (zooplankton supplementation) and control (no zooplankton supplementation) groups. Treatment ponds received the first zooplankton additions 3 d after filling was started and subsequent additions three times weekly (Mondays, Wednesdays, and Fridays) through the week before fish harvest. Zooplankton supplements for treatment ponds were collected from a zooplankton culture pond between 0800-1000 hours with a submersible water pump (Model WE0511H; ITT Goulds Pumps, Seneca Falls, New York) from depths of 15-16 cm near the kettle. Water, along with its microorganisms, was pumped from the zooplankton culture pond into a 3,407-L, three-compartment transport tank (supplement water) and then approximately equal volumes were transferred into treatment ponds. The zooplankton culture pond was prepared and fertilized as described for the study ponds but was completely filled with lake water 7 d before filling of the study ponds began.

Zooplankton Monitoring

Zooplankton samples for population density estimates were collected predawn (0500-0530 hours) from the zooplankton culture and study ponds by oblique 4-m tows of Wisconsin plankton net (5.75-cm diameter and 80-µm mesh) on Mondays and Thursdays, beginning 2 d after ponds were filled. Zooplankton samples for estimating densities in supplement waters were collected by the volume sampler method (Bottrell et al. 1976 in Geiger and Turner 1990) from the three compartments of the transport tank immediately following each collection from the zooplankton culture pond. Each compartment was sampled with a 1-L graduated cylinder which was submerged at the center of the compartment from the water surface to the bottom of the tank and then retrieved. The 3-compartment samples were combined as a pooled sample for the tank.

Each tank sample (3 L) was concentrated to 100 mL with the Wisconsin plankton net and further concentrated to 9 mL by removing excess water with a pipette. For all samples, the densities of the major zooplankton groups (cladocerans, copepod nauplii, copepod adults, and rotifers) were determined from two separate 1-mL aliquots of each concentrate on a zooplankton counting wheel (Aquatic Eco-systems, Inc., Apopka, FL) examined under a variable magnification dissecting microscope. Densities were expressed as number of organisms per L.

Water Quality Monitoring

Water quality was monitored in study ponds and zooplankton culture pond daily starting on the day pond filling began and continued throughout the study. Water temperature, dissolved oxygen concentration (DO), and pH were measured twice daily (0700-0800 and 1600-1700 hours) with YSI 650 MDS handheld meter fitted with YSI 600 XL multiprobe sonde (Yellow Springs Instruments, Yellow Springs, Ohio).

Fingerling Production

Study ponds were each stocked with 50,000 swim-up FLB fry (7-10 d post hatch; 384,617 fry/ha) 7 d after filling with water began. These fry were acclimated to receiving pond water temperatures and pH before stocking. This was accomplished by slowly exchanging approximately half of the water containing the fish with pond water at 15-min intervals for 45 min. The fry were stocked before 0800 hours to avoid potential adverse effects of elevated afternoon pond water temperatures and pH (Bergerhouse 1992; Ludwig 1999). Fingerlings were harvested 32 d after fry stocking. All ponds were harvested in 2 d and within 1 d apart in replicate pairs (one treatment and one control pond per pair) to equalize the average production days for treatment and control ponds. At pond harvest, all fish from each pond were weighed, 30 fish in a sample from each pond were individually measured for total lengths, and three grab samples of approximately 100 fish each from each pond were weighed on a Mettler PE11 scale to determine the number of fish/kg. These and fish stocking data were used to calculate production performance (e.g., survival rate, growth rate, harvest length, and harvest weight) values.

Data Analysis

The zooplankton, water quality, and fish production data were each compared between treatment and control ponds with the *t*-test procedure in SAS (SAS Institute, Inc., SAS Campus drive, Cary, North Carolina). Where necessary, appropriate data transformation was performed before statistical analysis. For all analyses, differences were considered significant at $P \leq 0.05$.

RESULTS AND DISCUSSION

Mean morning and afternoon values of water temperature, DO, and pH did not statistically differ between treatment and control ponds (Table 1) and likely had no effect on zooplankton populations or fish production. Similarly, zooplankton density did not significantly differ between treatment and control ponds during the 7-d period before fry stocking or over the course of the study (Table 2). Because densities of zooplankton in treatment and control ponds did not significantly differ (Table 2; Figures 1 and 2), we conclude that the goal of providing higher densities of prey organisms for the fish through regular zooplankton additions to ponds over extended period was not achieved in this study.

Our results did not support reports that higher zooplankton densities in fingerling production ponds were achieved by zooplankton inoculation or supplementation of ponds (e.g., Geiger 1983a; Martinez et al. 2005). Reasons for failure to increase densities of desired zooplankton in ponds that receive zooplankton additions include inadequate input of seed zooplankton of the proper quality into ponds and inadequate forage base (e.g., phytoplankton biomass) to support zooplankton population growth. We added more and diverse zooplankters to treatment ponds than Geiger (1983a). Average densities of zooplankters (organisms/L) in the supplemental waters added to ponds were rotifers 1,803, cladocerans 154, copepod nauplii 439, copepod adults 110, and total zooplankton 2,506. Thus, each treatment pond received an average of about 21.3 million organisms\ha per feeding three times weekly, starting on day 3 after pond filling began and ending a week before fish harvest. Added zooplankters were approximately 1.31 million cladocerans\ha and 20.03 million non-cladocerans\ha three times a week per pond. Overall, rotifers dominated the added zooplankton by a factor of 2.6 compared to non-rotifers. Probably, our failure to increase crustacean zooplankton populations in treatment ponds was due to the large numbers of rotifers introduced into these ponds, which apparently did not contribute appreciably to the established zooplankton communities. Whereas rotifers comprised approximately 72% of the zooplankton added to ponds, they were only 30% of the zooplankton communities of these ponds over the course of the study (Table 2). Density dilution of the added zooplankton or competition for food may explain the inability of rotifers to occur in high densities in treatment ponds (Schwartz and Ballinger 1980; Geiger 1983a; Morris and Mischke 1999).

Conversely, Geiger (1983a) reported success with zooplankton inoculation of ponds though only the cladoceran *Daphnia pulex* (12,500/ha or 1.47/L), a preferred prey organism, was added to ponds on each of days 3 and 6 after pond filling (i.e., total of 25,000/ha). Crustacean zooplankters comprised 48-63% of the total zooplankton biomass in treatment ponds, which was achieved with an organic plus inorganic fertilization strategy that promoted a large and diverse forage base for zooplankters (Geiger 1983a). Parmley et al. (1986) inoculated fertilized ponds with *D. rosea* (8,000/ha) and achieved desirable populations of zooplankters with the density of cladocerans far greater than that of copepods. These results suggest that success in establishing or maintaining desirable densities of preferred prey organisms of FLB fry requires additions of preferred prey organisms to ponds.

Zooplankton population growth is depended upon adequate proper forage base (e.g., green phytoplankton). Geiger (1983a) found that for ponds inoculated with *D. pulex*, those treated with chicken litter-chicken manure mix (2,986-4,480 kg/ha) plus liquid inorganic (N and P) fertilizers supported high densities of crustacean zooplankters (60-63% of the zooplankton community) than ponds treated with only ground coastal Bermuda hay (1,120 kg/ha; 31% zooplankton community). He attributed success of the zooplankton inoculation strategy to the large and diverse zooplankton food base, especially the phytoplankton biomass (chlorophyll a), promoted by the fertilization strategy. We fertilized study ponds with cottonseed meal and liquid inorganic sources of N and P and followed a strategy reported to support growth of crustacean zooplankters (Geiger et al. 1985), and we know promotes increased phytoplankton biomass to support zooplankton populations in fry rearing ponds at TPWD inland hatcheries. However, in this study we did not collect phytoplankton biomass (i.e., chlorophyll-*a*) data to be able to assess the effect of our fertilization strategy on zooplankton supplementation success. Because total zooplankton density did not significantly differ between treatment and control ponds, when these pond groups received the same fertilization treatment, zooplankton food resources were likely similar between groups. Future studies should collect phytoplankton data to be able to adequately explain the zooplankton population dynamics in ponds.

Fish production variables (survival, harvest weight, harvest length, and growth rate) did not significantly differ between treatment and control ponds, despite differences of approximately 12-34%, probably because of high variability in the data and small sample size ($N = 3$; Table 3). The lack of significant difference in the production variables could suggest that pond carrying capacity was not exceeded and food supply for fish was not limiting in either group of ponds. More importantly, that lack of statistical differences in production variables between treatment and control ponds suggests that supplementation with preferred (crustacean) zooplankters was too small to matter. Over the course of the study, we found zooplankton densities and composition to be statistically similar between treatment and control ponds (Table 2; Figures 1 and 2). Total crustacean zooplankton was below the 100/L minimum required at time of fry stocking but was within the post-stocking range (100-500/L) associated with successful production of fingerlings (Geiger and Turner 1990).

Unlike Geiger (1983b), additions of zooplankton to FLB fry rearing ponds did not enhance crustacean zooplankton densities in the present study. A major difference between the two studies was the type of zooplankton introduced into treatment ponds. Geiger inoculated ponds with concentrates of *D. pulex*, a preferred prey organism of planktivorous fry, whereas we added water with its natural community of zooplankton dominated by rotifers which are not preferred food items of FLB fry (Parmley et al. 1986). Previous studies that achieved success in increasing crustacean zooplankton densities in fry rearing ponds introduced mainly crustacean zooplankters into ponds (e.g., Martinez 2005; Parmley et al. 1986; Geiger et al. 1985; Farquhar and Geiger 1984; Geiger 1983a, b). In both research and routine pond management, desirable zooplankters have been size-selectively collected, often passively, by pumping pond water through a net of appropriate mesh size (e.g., 150- to 183-µm mesh, Geiger and Turner 1990; 500-µm mesh, Barkoh 1996) or other forms of strainers (e.g., Proulx and De La Noüe 1985; Misra and Phelps 1992). Further, techniques for improving zooplankton collection success, in terms of numbers of preferred zooplankters, include collection at night with light to attract zooplankton to pump hose inlet (Graves and Morrow 1988; Geiger and Turner 1990) or before sunrise to avoid negative vertical migration of zooplankters. Several studies have described vertical migration in zooplankton as a survival or predator escape mechanism (e.g., Hairston 1980; Lampert 1989; Ringerlberg 1999; Boeing et al. 2004; Cohen and Forward 2009). We recommend that these techniques be considered in designing future studies or in strategies that use zooplankton additions for managing fry rearing ponds.

REFERENCES

Anderson, R. O. 1993. Effects of organic and chemical fertilizers and biological control of problem organisms on production of fingerling Striped Bass *Morone saxatilis.* Pages 119-149 *in* R. O. Anderson and D. Tave, editors. Strategies and tactics for management of fertilized hatchery ponds. Food Products Press, Binghamton, New York.

Barkoh, A., and T. Modde. 1987. Feeding behavior of intensively cultured bluegill fry. Progressive Fish-Culturist 49:204-207.

Barkoh, A., R. O. Anderson, and C. F. Rabeni. 1993. Effects of pond volume manipulation on production of fingerling Largemouth Bass *Micropterus salmoides.* Pages 151-170 *in* R. O. Anderson and D. Tave, editors. Strategies and tactics for management of fertilized hatchery ponds. Food Products Press, Binghamton, New York.

Barkoh, A. 1996. Effects of three fertilization treatments on water quality, zooplankton, and Striped Bass fingerling production in plastic-lined ponds. Progressive Fish-Culturist 58:237-247.

Barkoh, A., S. Hamby, G. Kurten, and J. W. Schlechte. 2005. Effects of rice bran, cottonseed meal, and alfalfa meal on pH and zooplankton. North American Journal of Aquaculture 67:237-243.

Bergerhouse, D. L. 1992. Lethal effects of elevated pH and ammonia on early life stages of walleye. North American Journal of Fisheries and Management 12:356-366.

Boeing, W. J. 2004. Damaging UV radiation and invertebrate predation: conflicting selective pressures for zooplankton vertical distribution in the water column of low DOC lakes. Oecologia 138:603-612.

Cohen, J. H., and R. B. Forward, Jr. 2009. Zooplankton diel vertical migration - a review of proximate control. Oceanography and Marine Biology: An Annual Review 47:77-110.

Geiger, J. G. 1983a. Zooplankton production and manipulation in Striped Bass rearing ponds. Aquaculture 35:331-351.

Geiger, J. G. 1983b. A review of pond zooplankton production and fertilization for the culture of larval and fingerling Striped Bass. Aquaculture 35:353-369.

Farquhar, B. W., and J. G. Geiger. 1984. Portable zooplankton sampling apparatus for hatchery ponds. Progressive Fish-Culturist 46:209-211

Geiger, J. G., K. Fitzmayer, C. J. Turner, and W. C. Nichols. 1985. Feeding habits of larval and fingerling Striped Bass and zooplankton dynamics in fertilized rearing ponds. Progressive Fish-Culturist 47:213-233.

Geiger, J. G., and C. J. Turner. 1990. Pond fertilization and zooplankton management techniques for production of fingerling Striped Bass and Hybrid Striped Bass. Pages 79-98 *in* R. M. Harrell, J. H. Kerby, and R. V. Minton, editors. Culture and propagation of Striped Bass and its hybrids. American Fisheries Society, Southern Division, Striped Bass Committee, Bethesda, Maryland.

Graves, K. G., and J. C. Morrow. 1988. Methods for harvesting large quantities of zooplankton from hatchery ponds. Progressive Fish-Culturist 50:184-186.

Hariston N. G., Jr. 1980. The vertical distribution of diaptomid copepods in relation to body pigmentation. Pages 98-100 *in* W. C. Kerfoot, editor. Evolution and ecology of zooplankton communities. University Press of New England, Hanover, New Hampshire.

Hoff, F. H., and T. W. Snell. 1993. Plankton culture manual. 3rd edition. Florida Aqua Farms, Inc., Dade City, Florida.

Kurten, G. 2001. Evaluation of fertilization of Florida largemouth bass fingerling rearing ponds at the A.E. Wood fish hatchery: a baseline study. Management Data Series 190, Texas Parks and Wildlife Department, Austin.

Lampert, W. 1989. The adaptive significance of diel vertical migration of zooplankton. Functional Ecology 3(1):21-27.

Ludwig, G. M. 1993. Effects of trichlorfon, fenthion and diflubenzuron on the zooplankton community and on production of reciprocal-cross hybrid Striped Bass fry in culture ponds. Aquaculture 110:301-319.

Ludwig, G. M. 1999. Zooplankton succession and larval fish culture in freshwater ponds. Publication Number 700, Southern Regional Aquaculture Center, Texas A&M University, College Station, Texas.

Martinez, J. G., T. A. Wyatt, and G. L. Kurten. 2005. Effect of inoculation and supplemental feeding of zooplankton on Florida Largemouth Bass *Micropterus salmoides floridanus* fingerling production in plastic-lined ponds. Management Data Series 237, Texas Parks and Wildlife Department, Austin.

Misra, S. K., and R. P. Phelps. 1992. A zooplankton harvester designed to collect rotifers. Progressive Fish-Culturist 54:267-269.

Morris, J. E., and C. C. Mischke. 1999. Plankton management for fish culture ponds. Technical Bulletin Series 114, Iowa State University Agricultural Experiment Station, Ames, Iowa.

Opuszynski, K. K., and J. V. Shireman. 1993. Strategies and tactics for larval culture of commercially important carp. Pages 189-219 *in* R. O. Anderson and D. Tave, editors. Strategies and tactics for management of fertilized hatchery ponds. Food Products Press, Binghamton, New York.

Parmely, D. C., and J. G. Geiger. 1985. Succession patterns of zooplankton in fertilized culture ponds without fish. Progressive Fish-Culturist 47:3:183-186.

Parmley, D., G. Alvarado, and M. Cortez. 1986. Food habits of small hatchery-reared Florida Largemouth Bass. Progressive Fish-Culturist 48:264-267.

Pennak, R. W. 1989. Freshwater invertebrates of the United States. 3rd edition. John Wiley, New York, NY.

Proulx, D., and J. De La Noüe. 1985. Harvesting *Daphnia magna* grown on urban tertiary-treated effluents. Water Research 19:1319-1324.

Ringerlberg, J. 1999. The photobehaviour of *Daphnia* spp. as a model to explain diel vertical migration in zooplankton. Biological Reviews 74:397-423.

Schwartz, S. S., and R. E. Ballinger. 1980. Variations in life history characteristics of *Daphnia pulex* fed different algal species. Oecolgia (Berlin) 44:181-184.

Wickstorm, G. A, and R. L. Applegate. Growth and feed selection of intensively cultured Largemouth Bass fry. Progressive Fish-Culturist 51:79-82.

TABLE 1.—Mean ± SD values (ranges in parentheses) of water quality variables for fingerling Florida Largemouth Bass production ponds (N = 3) that received three times weekly zooplankton additions (Treatment) or no zooplankton (Control) at the Texas Freshwater Fisheries Center Fish Hatchery, 2 April to 3 May 2009. Differences were considered significant at $P \leq 0.05$.

Variable	Treatment	Control	*P*-value
Morning temperature (°C)	25.5 ± 0.01 (25.5 – 25.6)	25.4 ± 0.14 (25.5 – 25.6)	0.240
Afternoon temperature (°C)	27.7 ± 0.04 (27.6 – 27.1)	27.6 ± 1.21 (27.3 – 27.7)	0.411
Morning dissolved oxygen (mg/L)	6.6 ± 0.25 (6.5 – 6.9)	6.1 ±0 .52 (5.7 – 6.7)	0.185
Afternoon dissolved oxygen (mg/L)	9.9 ± 0.19 (9.8 – 10.1)	10.1 ± 0.18 (9.9 – 10.3)	0.382
Morning pH	8.9 ± 0.10 (8.9 – 9.0)	9.0 ± 0.55 (8.9 – 9.1)	0.369
Afternoon pH	9.9 ± 0.02 (9.8 – 9.9)	9.9 ± 0.78 (9.8 – 10.0)	0.464

TABLE 2.—Mean ± SD values (ranges in parentheses) of zooplankton densities in fingerling Florida Largemouth Bass production ponds ($N = 3$) that received three times weekly zooplankton additions (Treatment) or no zooplankton (Control) at the Texas Freshwater Fisheries Center Fish Hatchery, 2 April to 3 May 2009. Differences were considered significant at $P \leq 0.05$.

Organisms/L	Treatment	Control	*P*-value
7 d prior to stocking fish			
Cladocera	35.8 ± 23.9 (14 - 79)	36.5 ± 23.2 (9 - 65)	0.960
Copepod adult	1.8 ± 1.4 (0 - 3)	0.5 ± 0.7 (0 - 2)	0.077
Copepod nauplii	6.3 ± 4.8 (2 - 12)	4.5 ± 4.9 (0 – 12)	0.532
Rotifers	26.2 ± 11.1 (11 - 40)	42.1 ± 27.8 (14 - 87)	0.222
Total zooplankton	70.1 ± 31.8 (30 - 112)	83.6 ± 42.9 (23 - 121)	0.548
Post fish stocking (14 May – 16 June)			
Cladocera	493.3 ± 539.2 (14 – 2,953)	418.1 ± 589.1 (9 – 3,290)	0.588
Copepod adult	13.2 ± 27.6 (0 - 155)	7.0 ± 8.5 (0 - 39)	0.221
Copepod nauplii	39.2 ± 62.0 (0 - 351)	22.2 ± 21.8 (0 - 78)	0.142
Rotifers	231.3 ± 200.1 (11 – 777)	169.7 ± 127.7 (14 – 529)	0.138
Total zooplankton	776.9 ± 679.5 (30 - 3,668)	617.1 ± 636.8 (23 – 3,575)	0.324

TABLE 3.—Mean ± SD values (ranges in parentheses) of harvest variables for fingerling Florida Largemouth Bass production ponds (N = 3) that received three times weekly zooplankton additions (Treatment) or no zooplankton (Control) at the Texas Freshwater Fisheries Center Fish Hatchery, 2 April to 3 May 2009. Differences were considered significant at $P \leq 0.05$.

Variable	Treatment	Control	Percent difference	*P*-value
Survival (%)	79 ± 4.93 (74 – 87)	59 ± 6.51 (51 - 72)	34	0.057
Harvest weight (fish/kg)	2,654 ± 274.61 (2,429 – 2,960)	3,120 ± 1,636.07 (1,493 - 4,765)	15	0.652
Harvest length (mm)	38.2 ± 1.30 (37.2 – 39.7)	34.2 ± 7.10 (27.5 - 41.7)	12	0.388
Growth rate (mm/d)	0.97 ± 0.05 (0.92 – 1.02)	0.84 ± 0.23 (0.62 - 1.08)	15	0.420

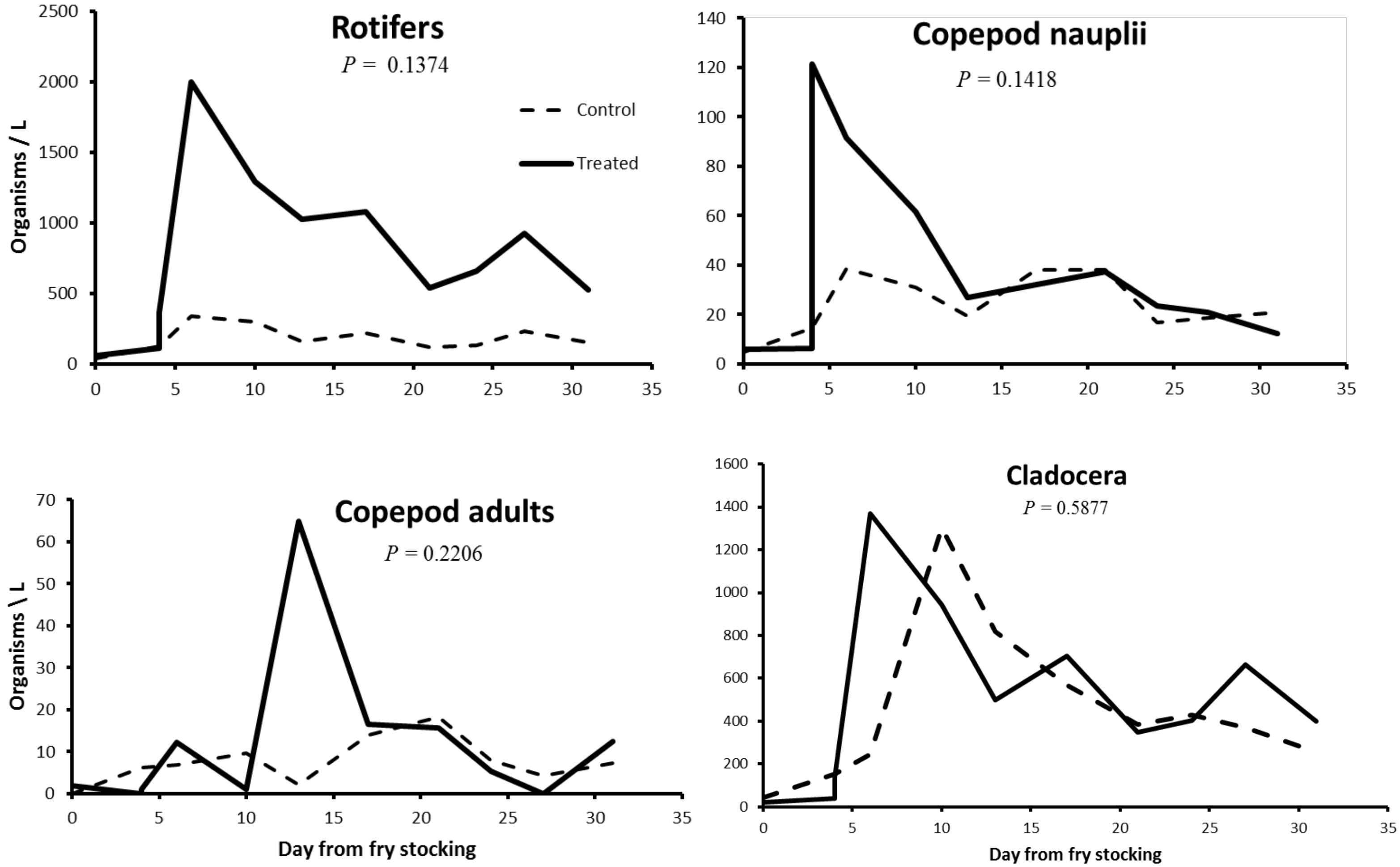

FIGURE 1.—Zooplankton densities in fingerling Florida Largemouth Bass production ponds (N = 3) that received three times weekly zooplankton additions (Treatment) or no zooplankton (Control) at the Texas Freshwater Fisheries Center Fish Hatchery, 7 May-16 June 2009.

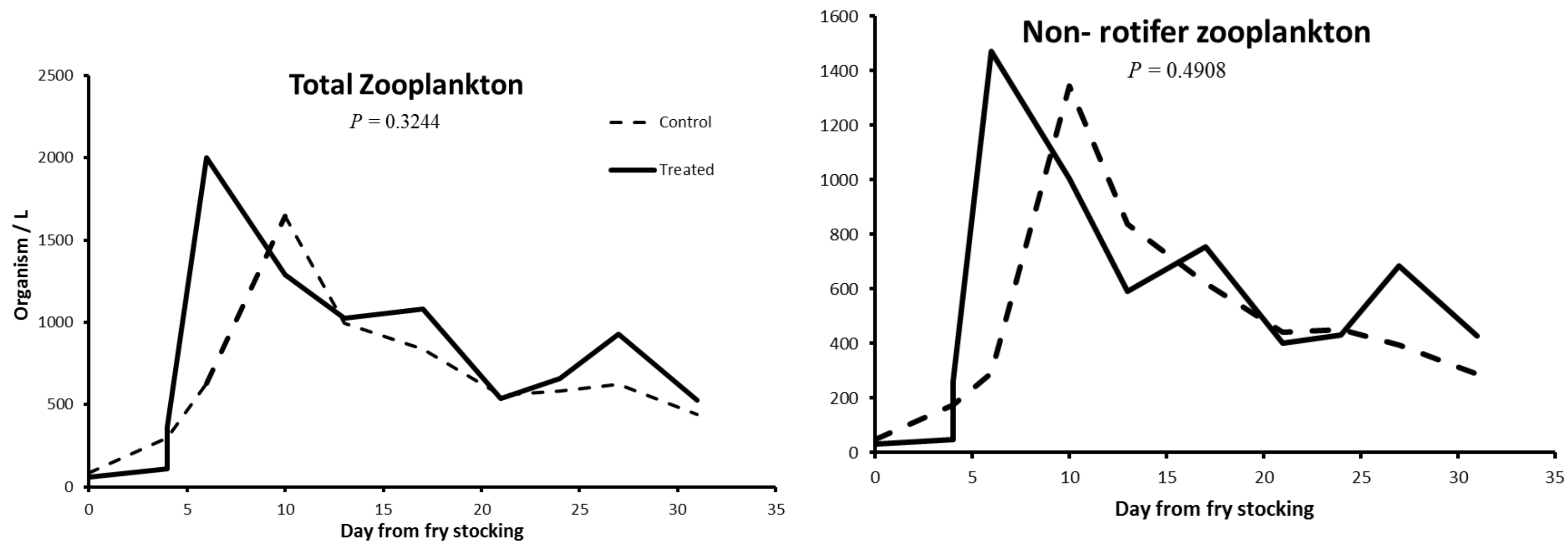

FIGURE 2.— Densities of zooplankton groups in fingerling Florida Largemouth Bass production ponds ($N = 3$) that received three times weekly zooplankton additions (Treatment) or no zooplankton (Control) at the Texas Freshwater Fisheries Center Fish Hatchery, 7 May-16 June 2009.

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