Evaluation of Fertilization Techniques used in Striped Bass, Florida Largemouth Bass, and Smallmouth Bass Rearing Ponds

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Abstract: A study was conducted in 9 striped bass (*Morone saxatilis*), 7 Florida largemouth bass (*Micropterus salmoides floridanus*), and 6 smallmouth bass (*M. dolomieui*) rearing ponds to evaluate the effects of various traditional and experimental fertilization regimes utilizing both organic and inorganic fertilizers. No significant differences were found in water quality, zooplankton populations, or fingerling production among any of the fertilization treatments. All treatments produced adequate zooplankton densities for fry survival and growth without detrimental effects on water quality. Low chlorophyll *a* values revealed inorganic fertilization rates could be increased to enhance phytoplankton production. A significant ($P < 0.001$) negative relationship between zooplankton densities and chlorophyll *a* levels suggested zooplankton grazing reduced phytoplankton populations. Fish predation may have reduced zooplankton densities as indicated by a significant ($P < 0.001$) negative relationship between total crustacean zooplankton and fish yield; however, some factor other than food availability limited fish yield.

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The culture of predatory sport fishes such as striped bass (*Morone saxatilis*), Florida largemouth bass (*Micropterus salmoides floridanus*), and smallmouth bass (*M. dolomieui*) traditionally takes place in shallow hatchery ponds which are fertilized to enhance zooplankton populations used as the primary food source for fingerlings. The optimal fertilization regime for this type of culture should promote the development of large zooplankton populations quickly and maintain them under heavy predation throughout the culture period.

The effects of various fertilizers on fish production in farm ponds have been studied extensively (Swingle and Smith 1939, Hasler and Einsele 1948, Bennett 1970). The use of inorganic fertilizers in farm ponds is a common practice (Boyd 1972, Boyd 1976, Dobbins and Boyd 1976, Lichtkoppler and

Boyd 1977, Boyd and Sowles 1978, Metzger and Boyd 1980, Musig and Boyd 1980, Davidson and Boyd 1981) while in hatchery ponds, organic fertilizers are more commonly used (Bardach et al. 1972). Geiger (1983*a*) reported increased survival of striped bass in rearing ponds by using a combination of inorganic fertilizer (phosphoric acid and ammonium nitrate) and organic fertilizer (chicken manure-litter). Geiger (1983*b*) also reviewed pond zooplankton production and fertilization for the culture of larval and fingerling striped bass. However, there is little other published data concerning effects of the combined use of inorganics and organics on zooplankton populations and fish production in hatchery ponds.

The culture of striped bass, Florida largemouth bass, and smallmouth bass at Texas hatcheries has primarily involved the use of organic fertilizers supplemented occasionally with inorganic fertilizers. Ground peanut hay and cottonseed meal have been used at various rates and combinations in the past depending on availability, cost, and success at each hatchery. However, the success of each method has been measured only in final fish yield, and no quantitative data on zooplankton population dynamics have been gathered.

This study was conducted to determine the effects of various traditional and experimental fertilization techniques on water quality, zooplankton densities, and fish yields in hatchery ponds, and to determine relationships among these factors.

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Methods

Study Sites and Fertilization Techniques

Striped bass.—The striped bass portion of this study was conducted in 9 production ponds located at the Dundee State Fish Hatchery, Archer County, Texas. Chemical characteristics of the water source for this hatchery are given in Table 1. Mean surface area of the ponds was 0.28 ha (range 0.19–0.58 ha).

Three ponds were fertilized according to a regime traditionally used at striped bass hatcheries in Texas. These ponds were fertilized with 450 kg/ha ground peanut hay immediately prior to filling and were subsequently supplemented with weekly applications of 56 kg/ha cottonseed meal (referenced as the traditional treatment).

Three ponds were fertilized according to a method proposed by Geiger (1983*b*). These ponds were fertilized with granular ammonium nitrate (0.5 mg N/liter) and liquid phosphoric acid (1.0 mg P_2O_5/liter) based on full pond volume as they were filled and 365 kg/ha chicken manure-litter 3 days after

Table 1. Chemical characteristics of water sources of 3 Texas hatcheries used for pond fertilization study in 1982 (except for last 2 parameters all all values are in mg/liter).

Parameter	Dundee	Huntsville	Eagle Mountain
Total dissolved solids	3,088	172	500
Total alkalinity	78	111	130
Total hardness	998	142	168
Calcium	296	58	39
Magnesium	63	5.6	11
Sodium	760	28	31
Sulfates	780	80	29
Chlorides	1,899	65	43
Nitrates	0.15	0.15	0.30
Total phosphates	0.06	0.10	0.03
pH (standard units)	7.5	7.6	6.7
Conductivity (μmhos/cm)	4,750	395	265

filling. They subsequently received weekly supplements of 120 kg/ha chicken manure-litter (referenced as the experimental treatment).

Three ponds were fertilized with a combination of the above 2 methods. These ponds were fertilized with 450 kg/ha ground peanut hay immediately prior to filling. As the ponds were filled they received granular ammonium nitrate (0.5 mg N/liter) and liquid phosphoric acid (1.0 mg P_2O_5/liter) based on full pond volume. They subsequently received weekly supplements of 56 kg/ha cottonseed meal (referenced as the combination treatment).

Florida largemouth bass.—The Florida largemouth bass portion of this study was conducted in 7 production ponds located at the Huntsville State Fish Hatchery, Walker County, Texas. Chemical characteristics of the water source for this hatchery are given in Table 1. Mean surface area of the ponds was 0.49 hectares (range 0.34–0.65 ha).

Two ponds were fertilized according to a regime traditionally used at Florida largemouth bass hatcheries in Texas. These ponds were planted with rye grass seed (16.8 kg/ha) in the fall, prior to the rearing season. Immediately prior to filling, they received 280 kg/ha cottonseed meal. They also received weekly applications of 56 kg/ha cottonseed meal (referenced as the traditional treatment).

Three ponds were fertilized according to the method proposed by Geiger (1983*b*) as previously described in the striped bass section. This treatment will be referred to as the experimental treatment.

Two ponds were fertilized with a combination of the above 2 methods using liquid 10-34-0 (N-P-K) as the inorganic fertilizer rather than ammonium nitrate and phosphoric acid. These ponds were planted with rye grass seed (16.8 kg/ha) the previous fall. They were fertilized with 280 kg/ha cottonseed meal and 112 kg/ha 10-34-0 liquid inorganic fertilizer as the ponds were filled, supplemented with weekly applications of cottonseed meal (56 kg/ha) and 10-34-0 liquid (22.5 kg/ha) (referenced as the combination treatment).

Smallmouth bass.—The smallmouth bass portion of this study was conducted in 6 production ponds located at the Eagle Mountain State Fish Hatchery, Tarrant County, Texas. Chemical characteristics of the water source for this hatchery are given in Table 1. Mean surface area of the ponds was 0.61 ha (range 0.53–0.78 ha).

Three ponds were fertilized according to a regime traditionally used at smallmouth bass hatcheries in Texas. These ponds were fertilized with 56 kg/ha cottonseed meal and 112 kg/ha 16-20-0 (N-P-K) granular fertilizer as they were filled. This was subsequently supplemented with 28 kg/ha cottonseed meal weekly (referenced as the traditional treatment).

Three ponds were fertilized with the experimental regime proposed by Geiger (1983*b*) as previously described in the striped bass section (referenced as the experimental treatment).

Due to the lack of additional rearing ponds, no combination treatment was used for smallmouth bass.

Water Quality

Water quality parameters in all experimental ponds were monitored using the same schedule. Pond water temperatures and dissolved oxygen (D.O.) concentrations were measured daily in each pond using YSI Model 57 oxygen-temperature meter. Measurements were taken at approximately sunrise, 30 cm above the bottom of the pond in the drain box area. Chlorophyll *a* was measured weekly in each pond using acetone extraction and spectrophotometry procedures described by Lind (1974). Secchi disk transparency was measured in each pond concurrent with chlorophyll *a* determinations.

Zooplankton Sampling

Zooplankton populations in all ponds were monitored using the flexible-impeller pump apparatus described by Farquhar and Geiger (1984, in press). Zooplankton samples were taken on Mondays, Wednesdays, and Fridays each week beginning when the ponds were filled and continuing through the production season. Each pond was sampled at 3 permanent sample stations; 1 at the drain box and 1 approximately midway down each side of the pond. A 20-liter sample was taken at each station and concentrated through an 80-micron net. Zooplankters were preserved in 4% buffered formalin and sucrose (Haney and Hall 1973) and enumerated by taxonomic group. Enumeration procedures consisted of taking 3 separate 1-ml aliquots from each sample using a Henson-Stemple pipette and counting all organisms contained in the aliquots using a Sedgewick-Rafter cell. The mean of the 3 counts was then used to calculate the number of organisms per liter of pond water. All rotifers were combined into 1 category, cladocerans were identified to genus, and copepods were classified as calanoid, cyclopoid, or nauplii according to Pennak (1978).

Fish Production

All striped bass ponds were stocked simultaneously with 5-day-old fry (4–6 mm) at a rate of 494,000 fry/ha 27 days after filling. Striped bass in all ponds were fed artificial feed at a rate of 3.4 kg/ha/day equally divided between a morning and afternoon feeding beginning 17 days after stocking.

All Florida largemouth bass ponds were stocked at 74,000 fry/ha 10 days after filling. Fry were 10 to 20 mm total length when stocked into the ponds.

Four smallmouth bass ponds, 2 from each treament, were stocked 30 to 32 days post-filling at a rate of 65,000 fry/ha. The other 2 ponds, which were filled 1 month later, were stocked 14 days after filling at a rate of 100,000 fry/ha. Fry were stocked into the ponds when they reached the swim-up stage (8–9 mm).

All ponds were drained and harvested when the fish reached the mean total length routinely stocked into public waters (35–50 mm). Days in production were kept as uniform as possible between treatments for each species. At harvest, for each pond, the total weight of all fish was determined, and 100 fish (random sample) were individually weighed to the nearest 0.1 gram and measured (total length) to the nearest 1 mm. These data were used to calculate total fingerling yield (kg/ha), percent return, growth rates (mm/day) and condition factors (K_{TL}). Condition factors were calculated using the formula

$$K_{TL} = \frac{W \times 10^5}{L^3}$$

where: W = weight in grams and L = total length in millimeters.

Data Analyses

Water quality parameters were analyzed for each hatchery separately to determine differences among fertilization techniques. Weekly means for D.O., temperature, chlorophyll *a*, and Secchi disk transparency from each pond were calculated and a 2-way analysis of variance (ANOVA) for each of the variables was run using weeks and fertilization techniques as treatment factors. If significant differences among treatments were detected ($P < 0.05$), Bonferroni pairwise comparisons (Neter and Wasserman 1974) were used to identify statistically significant treatment comparisons. Regression analysis was used to estimate the relation between Secchi disk transparency and chlorophyll *a*.

Zooplankton samples from each hatchery were analyzed separately using the categories *Daphnia, Bosmina, Ceriodaphnia, Chydorus, Diaphanosoma,* cyclopoid copepods, calanoid copepods, copepod nauplii, rotifers, total cladocerans, total adult copepods, and total crustacean zooplankton. The 3 stations in each pond were combined for each sampling date and all counts were $\log^{10}(X+1)$ transformed before analysis. Weekly means for each pond were calculated and a 2-way analysis of variance was run using weeks and fertilization techniques as treatment factors. If significant differences between treatments were detected for any category ($P < 0.05$) the Bonferroni pairwise comparisons were used to identify statistically significant treatment comparisons.

Differences in fish yield among fertilization treatments were analyzed using one-way analysis of variance for each hatchery. These analyses were performed using total biomass harvested, percent return, mean total length, mean weight, condition factor, and growth rates as parameters.

Regression analysis was used to determine general relationships between water quality parameters, zooplankton densities, and fish yield. Data from all 22 ponds were combined and annual means for zooplankton densities and chlorophyll *a* levels were compared to fish yield (kg/ha). Weekly means were used to determine the relationship between chlorophyll *a* values and zooplankton densities.

Results and Discussion

Water Quality

Striped bass.—Analyses of water quality data from striped bass ponds revealed no meaningful differences among fertilization treatments. Weekly comparisons of all water quality parameters among treatments showed no statistically significant differences with the exception of D.O. during the week prior to stocking. At that time D.O. was significantly higher in the experimental treatment ponds (mean 8.3 mg/liter) than in the traditional treatment ponds (mean 7.2 mg/liter); however, this difference was considered too small to be biologically significant. Pairwise comparisons between water temperature, chlorophyll *a* levels, and Secchi disk transparency showed no differences between treatments. Therefore, water quality data were combined for all striped bass ponds and presented as weekly means.

Dissolved oxygen levels were adequate in all ponds throughout the season (Fig. 1); however, low chlorophyll *a* levels (less than 10 μg/liter, Fig. 1) indicated the inorganic fertilization rate was probably too low. A significant negative relationship ($r^2 = 0.32$; $P < 0.005$) existed between chlorophyll *a* levels and Secchi disk transparencies.

Florida largemouth bass.—Analyses of water quality data from Florida largemouth bass ponds again showed very little difference that could be attributed to fertilization treatments. Statistically, D.O. was significantly higher during the first week following stocking in the experimental treatment ponds (mean 4.5 mg/liter) than in the combination treatment ponds (mean 3.0 mg/liter), but this difference was not considered biologically important. No differences were found in water temperature, chlorophyll *a*, or Secchi disk trans-

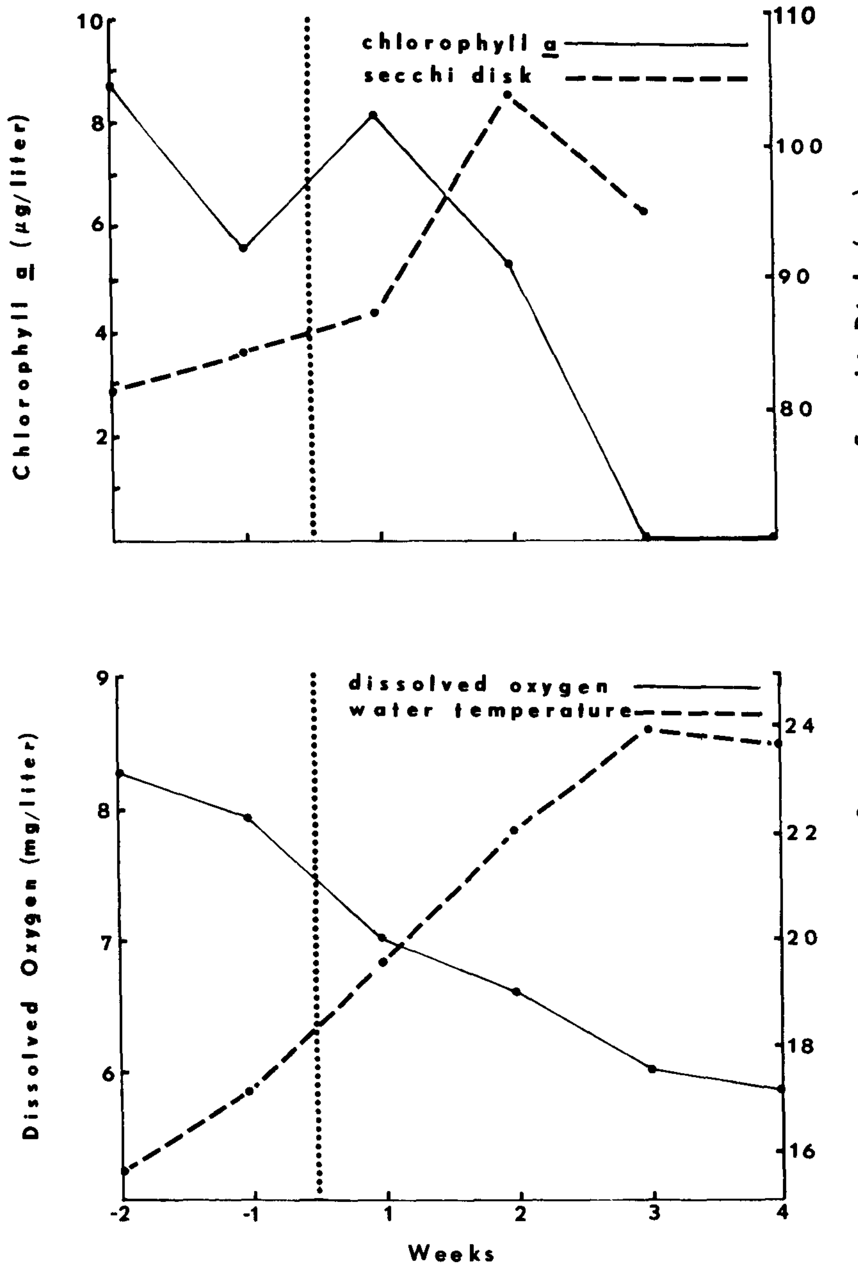

Figure 1. Mean weekly values for dissolved oxygen, water temperature, chlorophyll *a* and Secchi disk transparency from nine striped bass rearing ponds, Dundee State Fish Hatchery, Texas, 1982. Stocking date (dotted line) was 7 May.

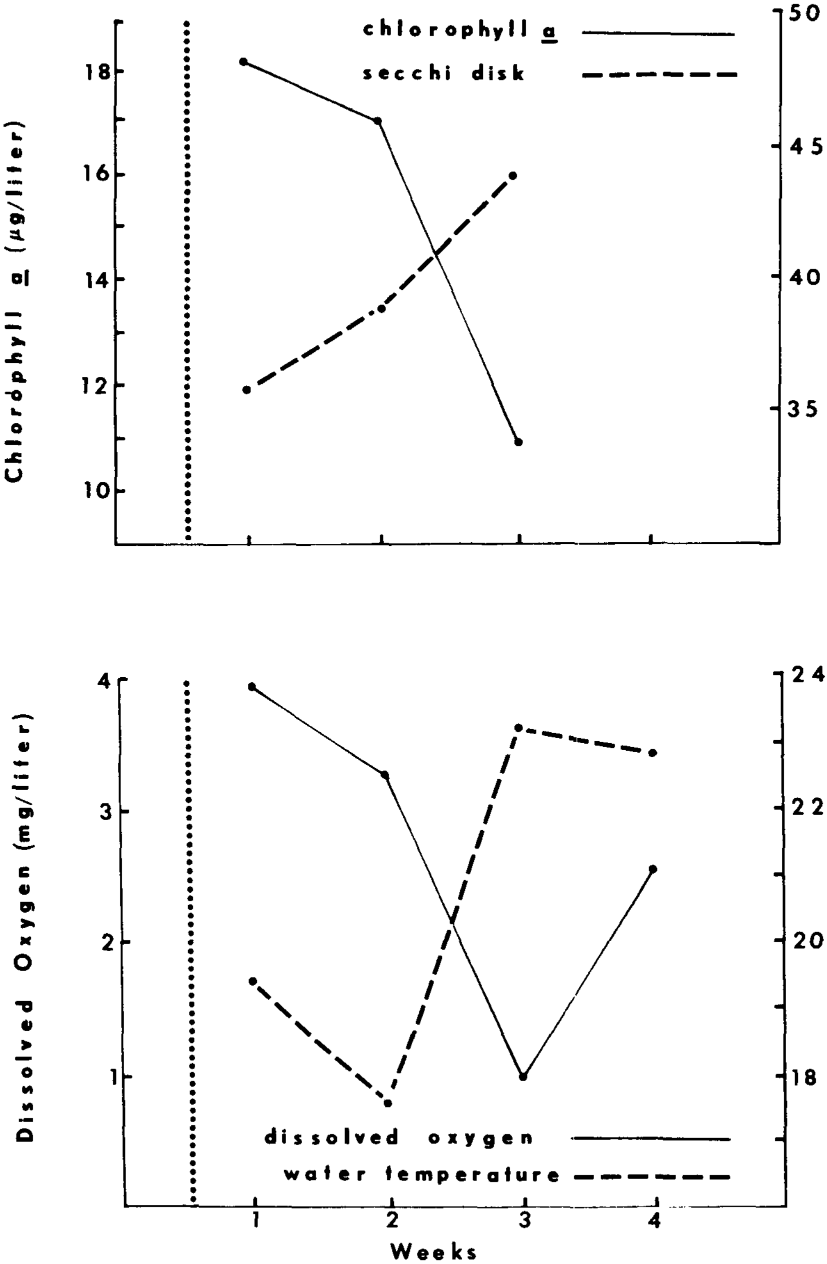

Figure 2. Mean weekly values for dissolved oxygen, water temperature, chlorophyll *a* and Secchi disk transparency from 7 Florida largemouth bass rearing ponds, Huntsville State Fish Hatchery, Texas, 1982. Stocking date (dotted line) was 14 April.

parency. Water quality data were therefore combined for all Florida largemouth bass ponds and presented as weekly means.

Dissolved oxygen levels did approach critically low values (mean 0.97 mg/liter) the third week after stocking (Fig. 2) but low D.O. levels have been a chronic problem on this hatchery and were not considered a result of the fertilization treatments. D.O. levels were similar among traditional, experimental, and combination treatments. Chlorophyll *a* levels (Fig. 2) were higher than those in striped bass ponds, probably due to a more fertile water source. However, inorganic fertilizer levels were again too low to produce the desired phytoplankton blooms. No relationship was found between chlorophyll *a* levels and Secchi disk transparenceis, probably due to the confusing influence of clay turbidity from the water source and a high degree of siltation.

Smallmouth bass.—No difference between treatment was found in D.O., water temperature, chlorophyll *a* levels, or Secchi disk transparency in smallmouth bass ponds. Mean weekly D.O. levels remained above 6.0 mg/liter (Fig. 3) indicating the rates of organic fertilization were minimal and probably could be increased. Chlorophyll *a* levels were relatively high early in the season (Fig. 3) but dropped over time, again indicating inorganic fertilization rates should be increased for greater phytoplankton production. As in the striped bass ponds, there was a negative relationship between chlorophyll *a* levels and Secchi disk transparencies ($r^2 = 0.21$; $P < 0.05$).

Zooplankton Populations

Striped bass.—Analysis of the zooplankton data from striped bass ponds revealed no differences in densities for any of the zooplankton categories among fertilization treatments. Since both overall and weekly means showed that no significant difference could be attributed to fertilization techniques, zooplankton data from all ponds were combined for data presentation.

Zooplankton populations were dominated by *Ceriodaphnia, Daphnia,* copepods, and rotifers (Table 2). Numerically, copepod nauplii and rotifers dominated the samples; however, adult copepods and cladocerans did reach population levels above 500 organisms/liter during the season. Total crustacean zooplankton numbers peaked during the week following stocking and declined as the season progressed (Fig. 4). The slight increase in the fourth week was a result of increased copepod nauplii at a time when the fingerlings may have reached sufficient size to select larger food items.

Florida largemouth bass.—There were no significant differences in either overall or weekly mean zooplankton densities for any category among fertilization treatments in Florida largemouth bass ponds. The zooplankton community was more diverse than on the other hatcheries, but only *Bosmina, Ceriodaphnia,* copepods, and rotifers were numerous enough to be considered important food items (Table 2).

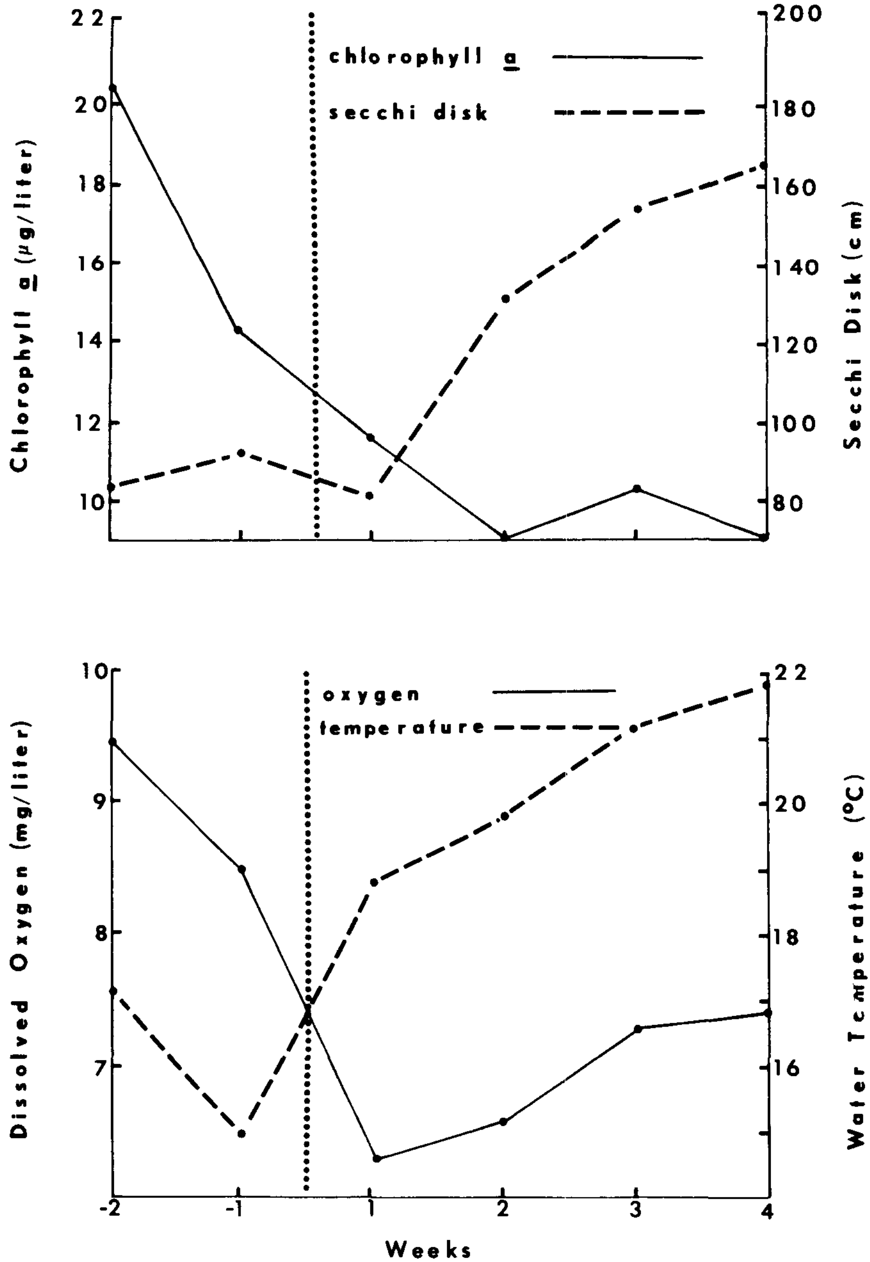

Figure 3. Mean weekly values for dissolved oxygen, water temperature, chlorophyll *a* and Secchi disk transparency from 6 smallmouth bass rearing ponds, Eagle Mountain State Fish Hatchery, Texas, 1982. Stocking date (dotted line) was 19 April.

Table 2. Overall mean and maximum zooplankton densities for dominant (mean > 1.0 organisms/liter) categories collected from striped bass, Florida largemouth bass and smallmouth bass rearing ponds at the Dundee, Huntsville, and Eagle Mountain State Fish Hatcheries, Texas, 1982, respectively. SD given in parentheses.

	Dundee		Huntsville		Eagle Mountain	
Category	Mean	Maximum	Mean	Maximum	Mean	Maximum
Bosmina	—	—	7.7 (5.7)	3,862	8.9 (6.7)	858
Daphnia	3.7 (5.2)	324	1.2 (1.7)	28	2.5 (3.3)	158
Ceriodaphnia	6.7 (6.0)	937	2.1 (3.3)	588	3.8 (5.4)	474
Chydorus	2.4 (3.0)	41	1.1 (1.4)	7	1.1 (1.5)	68
Diaphanosoma	—	—	1.5 (2.4)	81	—	—
Cyclopoid copepods	9.1 (7.0)	558	9.1 (4.2)	284	6.1 (3.6)	206
Calanoid copepods	4.4 (3.3)	450	6.8 (3.9)	221	12.1 (4.5)	941
Copepod nauplii	197 (3.4)	2,787	81 (4.0)	2,230	121 (4.6)	1,955
Rotifers	156 (6.5)	5,453	84 (5.3)	6,081	59 (5.1)	1,675

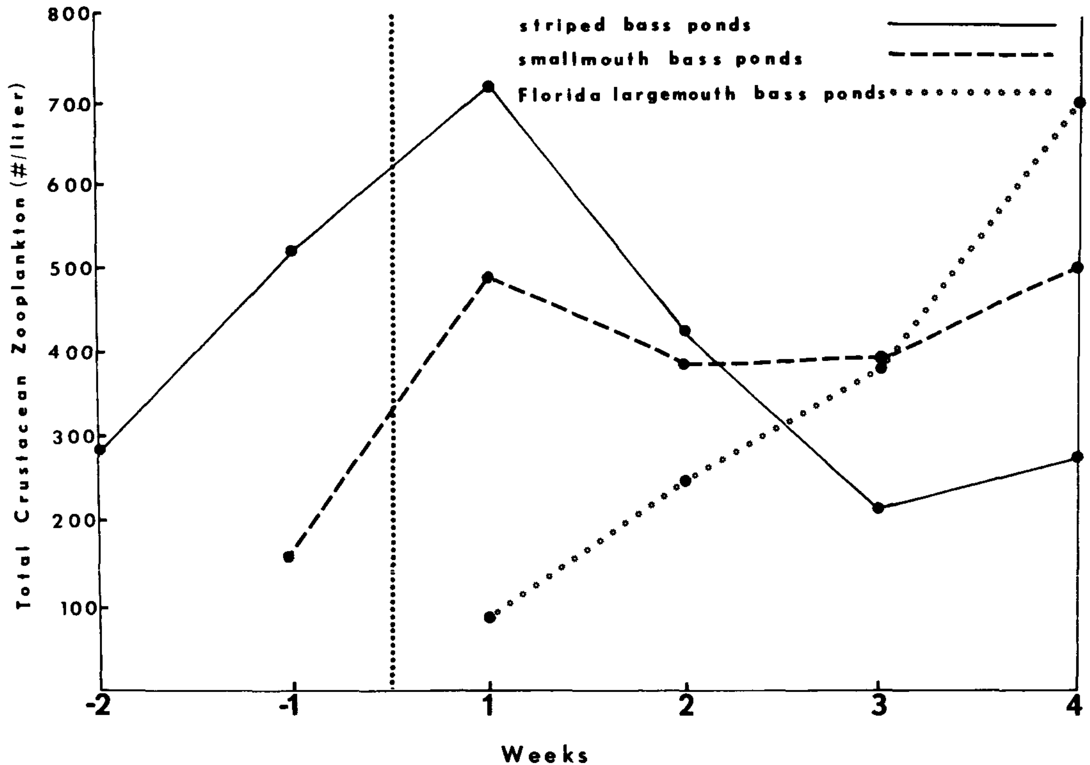

Figure 4. Mean weekly population estimates for total crustacean zooplankton from nine striped bass, 7 Florida largemouth bass and 6 smallmouth bass rearing ponds at Dundee, Huntsville, and Eagle Mountain State Fish Hatcheries, Texas, 1982, respectively. Fish stocking date is indicated by dotted line.

Combined weekly means for total crustacean zooplankton numbers indicated numbers increased through the production season to a high of approximately 700 organisms/liter during the fourth week (Fig. 4). There are 2 possible explanations for this population increase: either the stocking rate for Florida largemouth bass was too low, or as the fry increased in size they switched to other food sources, reducing predation on zooplankton. Possibly a combination of these factors led to increasing zooplankton densities; however, without food habit data for fingerlings from these ponds the exact cause cannot be determined.

Smallmouth bass.—Fertilization treatments showed no statistically significant effect on zooplankton numbers at Eagle Mountain. Since analysis of variance by season and week showed no difference in zooplankton density for any of the categories, data from all ponds were combined for presentation. Dominant zooplankters were *Bosmina, Daphnia, Ceriodaphnia,* copepods, and rotifers (Table 2). Zooplankton densities remained relatively high throughout the production season (Fig. 4). As with Florida largemouth bass ponds, this is probably an indication the stocking rate for smallmouth bass could be increased without depletion of zooplankton densities. The importance of food items other than zooplankton should, however, be investigated before stocking rates are altered.

Fish Yield

Striped bass.—Total biomass harvested and percent return were low in 7 of the 9 striped bass ponds (Table 3). This inconsistency has been typical for striped bass rearing ponds in the past, where production has been relatively high in a few ponds and much lower in the remaining ponds. Overall return for the 9 study ponds was 10.7%; however, production on the entire hatchery (32 ponds) was low in 1982 with an overall return of 7.2%. This may have been due to difficulty encountered in collecting sufficient quality broodfish and resulting low quality fry.

Striped bass production was similar for all fertilization treatments in this study (Table 3). There were no significant differences (ANOVA; $P > 0.05$) in total biomass harvested, percent return, mean total length, mean weight, K_{TL}, or growth rates among the 3 treatments. Condition factors, growth rates, and mean total length and weight were all higher for fish from experimental treatment ponds; however, this was more likely due to low survival, and thus reduced density, than to treatment effects.

Florida largemouth bass.—Overall return (99%) and biomass harvested (44.3 kg/ha) from the Florida largemouth bass ponds (Table 4) were relatively high and similar to those from other ponds at the same hatchery where return was 97% and biomass harvested was 50.1 kg/ha for the entire hatchery (14 ponds). Percent returns greater than 100% are indicative of errors in estimating fry numbers at stocking.

Table 3. Production summary for striped bass harvested from rearing ponds subjected to 3 fertilization programs, Dundee State Fish Hatchery, Texas, 1982. SD given in parentheses.

Fertilization program	Pond replicate	Biomass harvested (kg/hectare)	% return	Mean total length[a] (mm)	Mean weight[a] (g)	Condition[a] (K_{TL})	Mean growth[a] (mm/day)
Traditional[b]	1	64.8	32	32.2 (2.8)	0.42 (0.10)	1.24	0.79
	2	20.3	4	37.8 (6.6)	0.68 (0.40)	1.22	0.97
	3	4.4	1	35.5 (4.6)	0.59 (0.20)	1.25	0.88
	MEAN	29.8	12	35.2	0.56	1.24	0.88
Experimental[c]	1	4.4	1	41.6 (6.3)	0.96 (0.40)	1.31	1.08
	2	13.1	4	40.6 (4.0)	0.87 (0.30)	1.29	1.02
	3	14.4	2	34.4 (5.4)	0.55 (0.30)	1.26	0.83
	MEAN	10.6	2	38.9	0.79	1.29	0.98
Combination[d]	1	7.4	5	38.1 (5.2)	0.67 (0.20)	1.20	0.97
	2	52.1	43	26.8 (2.5)	0.22 (0.10)	1.12	0.65
	3	13.4	5	36.8 (3.9)	0.62 (0.20)	1.23	0.91
	MEAN	24.3	18	33.9	0.50	1.18	0.84

[a] $N = 100$

[b] 450 kg/ha ground peanut hay initially, supplemented with 56 kg/ha cottonseed meal weekly.

[c] 365 kg/ha chicken manure-litter, granular ammonium nitrate (0.5 mg/liter N) and liquid phosphoric acid (1.0 mg/liter P_2O_5) initially, supplemented with 120 kg/ha chicken manure-litter weekly.

[d] 450 kg/ha ground peanut hay, granular ammonium nitrate (0.5 mg/liter N) and liquid phosphoric acid (1.0 mg/liter P_2O_5) initially, supplemented with 56 kg/ha cottonseed meal weekly.

Table 4. Production summary for Florida largemouth bassgiven in parentheses.

Fertilization program	Pond replicate	Biomass harvested (kg/hectare)	% return	Mean total length[a] (mm)	Mean weight[a] (g)	Condition[a] (K_{TL})	Mean growth[a] (mm/day)
Traditional[b]	1	41.3	105	34.9 (3.8)	0.56 (0.20)	1.28	0.89
	2	57.6	88	42.9 (8.6)	1.00 (0.70)	1.21	1.22
	MEAN	49.4	96	38.9	0.78	1.24	1.06
Experimental[c]	1	32.0	102	38.4 (2.8)	0.64 (0.10)	1.13	1.03
	2	25.2	73	33.9 (3.7)	0.47 (0.10)	1.16	0.89
	3	35.3	79	37.9 (5.8)	0.68 (0.30)	1.20	1.00
	MEAN	30.8	85	36.7	0.60	1.16	0.97
Combination[d]	1	51.3	94	42.4 (3.6)	1.00 (0.20)	1.31	1.11
	2	67.2	157	38.7 (3.5)	0.63 (0.10)	1.07	1.03
	MEAN	59.2	125	40.5	0.81	1.19	1.07

[a] $N = 100$

[b] 280 kg/ha cottonseed meal initially, supplemented with 56 kg/ha cottonseed meal weekly. Pond bottoms were planted in rye grass (16.8 kg/ha seed) in fall prior to rearing season.

[c] 365 kg/ha chicken manure-litter, granular ammonium nitrate (0.5 mg/liter N) and liquid phosphoric acid (1.0 mg/liter P_2O_5) initially, supplemented with 120 kg/ha chicken manure-litter weekly.

[d] 280 kg/ha cottonseed meal and 112 kg/ha 10-34-0 (N-P-K) liquid inorganic fertilizer initially, supplemented with 56 kg/ha cottonseed meal and 22.5 kg/ha 10-34-0 liquid weekly. Pond bottoms were planted in rye grass (16.8 kg/ha seed) in fall prior to rearing season.

Table 5. Production summary for smallmouth bass harvested from rearing ponds subjected to 2 fertilization programs, Eagle Mountain State Fish Hatchery, Texas, 1982. SD given in parentheses.

Fertilization program	Pond replicate	Biomass harvested (kg/hectare)	% return	Mean total length[a] (mm)	Mean weight[a] (g)	Condition[a] (K_{TL})	Mean growth[a] (mm/day)
Traditional[b]	1	11.0	32	33.7 (6.1)	0.61 (0.40)	1.47	0.93
	2	27.1	117	29.8 (2.5)	0.38 (0.10)	1.40	0.96
	3	64.5	160	32.0 (2.9)	0.49 (0.10)	1.47	1.11
	MEAN	34.2	103	31.8	0.49	1.45	1.00
Experimental[c]	1	13.0	39	34.4 (4.1)	0.62 (0.20)	1.48	0.93
	2	23.9	116	29.9 (2.8)	0.39 (0.10)	1.41	0.96
	3	65.0	170	31.0 (2.5)	0.45 (0.10)	1.48	1.15
	MEAN	34.0	108	31.8	0.49	1.46	1.01

[a] $N = 100$

[b] 56 kg/ha cottonseed meal and 112 kg/ha 16-20-0 (N-P-K) granular inorganic fertilizer initially, supplemented with 28 kg/ha cottonseed meal weekly.

[c] 365 kg/ha chicken manure-litter, granular ammonium nitrate (0.5 mg/liter N) and liquid phosphoric acid (1.0 mg/liter P_2O_5) initially, supplemented with 120 kg/ha chicken manure-litter weekly.

No statistically significant differences (ANOVA; $P > 0.05$) among the 3 treatments were found for biomass harvested, percent return, mean total length, mean weight, K_{TL}, or growth rates.

High populations of clam shrimp (suborder Conchostraca) were observed in 2 of the experimental treatment ponds (replicates 1 and 2) and may have adversely affected fish production. Clam shrimp infestations have been a problem at this hatchery in past years and were probably not a result of the fertilization regime.

Smallmouth bass.—Lack of adequate numbers of fry for stocking smallmouth bass ponds was a major limiting factor in 1982. Unpredictable weather conditions resulted in interrupted spawning and thus relatively low numbers of fry were available at any one time. Ponds were stocked in pairs, 1 from each treatment, resulting in 3 different stocking dates and 3 separate types of pond conditions for each treatment. The first pair of ponds were stocked from the first spawns which resulted in high egg mortality and poor fry quality. This resulted in the relatively low survival rates of 32% and 30% in these 2 ponds (Table 5). The next pair of ponds were stocked 2 days later from a second set of spawns and resulted in much higher returns (116% and 117%). Remaining ponds were not stocked until approximately 1 month later when water temperatures had risen significantly. Fish from these 2 ponds (replicate 3; Table 5) had higher survival and faster growth (Table 5). As with Florida largemouth bass, the inaccuracy of fry estimating procedures can be seen in the percent returns over 100%.

No statistically significant difference (ANOVA; $P > 0.05$) was found for biomass harvested, percent return, mean total length, mean weight, K_{TL}, or growth rates between the 2 fertilization treatments (Table 5). Fertilization regimes apparently had far less impact on fish production than the quality of fry stocked into the rearing ponds or water temperatures during the rearing season.

Factors Affecting Fish Yield

A definite relationship between annual zooplankton mean densities and fish yield indicated fish predation probably affected zooplankton populations. Negative relationships existed between fish yield and total cladoceran numbers ($r^2 = 0.17$; $P < 0.05$), fish yield and total adult copepod numbers ($r^2 = 0.14$; $P < 0.09$) and between fish yield and total crustacean zooplankton numbers; the latter relationship (Fig. 5) was highly significant ($r^2 = 0.47$; $P < 0.001$).

A significant positive relationship ($r^2 = 0.25$; $P < 0.05$) between fish yield and chlorophyll *a* (Fig. 6) agreed with relationships found by Jones and Hoyer (1982) for midwestern reservoirs. This relationship, in conjunction with a significant negative relationship ($r^2 = 0.16$; $P < 0.001$) between total

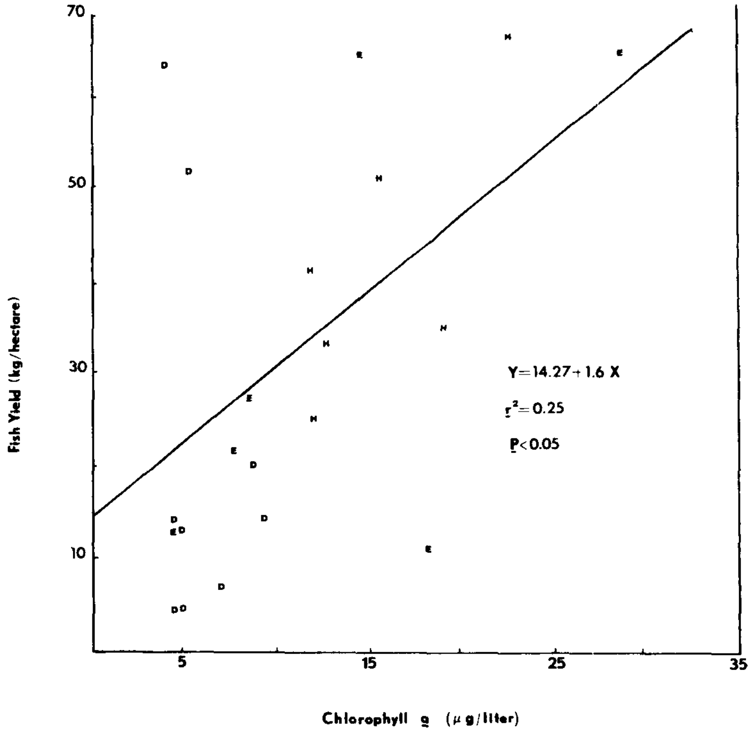

Figure 5. Relationship between annual means for total crustacean zooplankton densities and fish yield in striped bass, Florida largemouth bass and smallmouth bass rearing ponds, Dundee (D), Huntsville (H), and Eagle Mountain (E) State Fish Hatcheries, Texas, 1982, respectively.

crustacean zooplankton numbers and chlorophyll *a* values (Fig. 7), indicated in ponds with low fish survival decreased predation allowed zooplankton numbers to remain high, and thus, grazing reduced chlorophyll *a* levels.

While the negative relationship between fish yield and zooplankton densities (Fig. 5) indicated fish apparently cropped zooplankton populations, it does not appear that food was the major limiting factor in fish production. Striped bass ponds were categorized as those with high survival (>30%) and those with low survival (≤5%), and zooplankton densities compared (Fig. 8). During the week prior to stocking and continuing throughout the season, the 2 high survival ponds had lower numbers of total crustacean zooplankton than the seven low survival ponds suggesting that food was available in all ponds for adequate survival. The high survival ponds did demonstrate increased cropping of crustacean zooplankton as the season progressed, but during the critical period immediately after stocking they had no better food availability than the other ponds. Factors such as fry quality, handling or stocking mor-

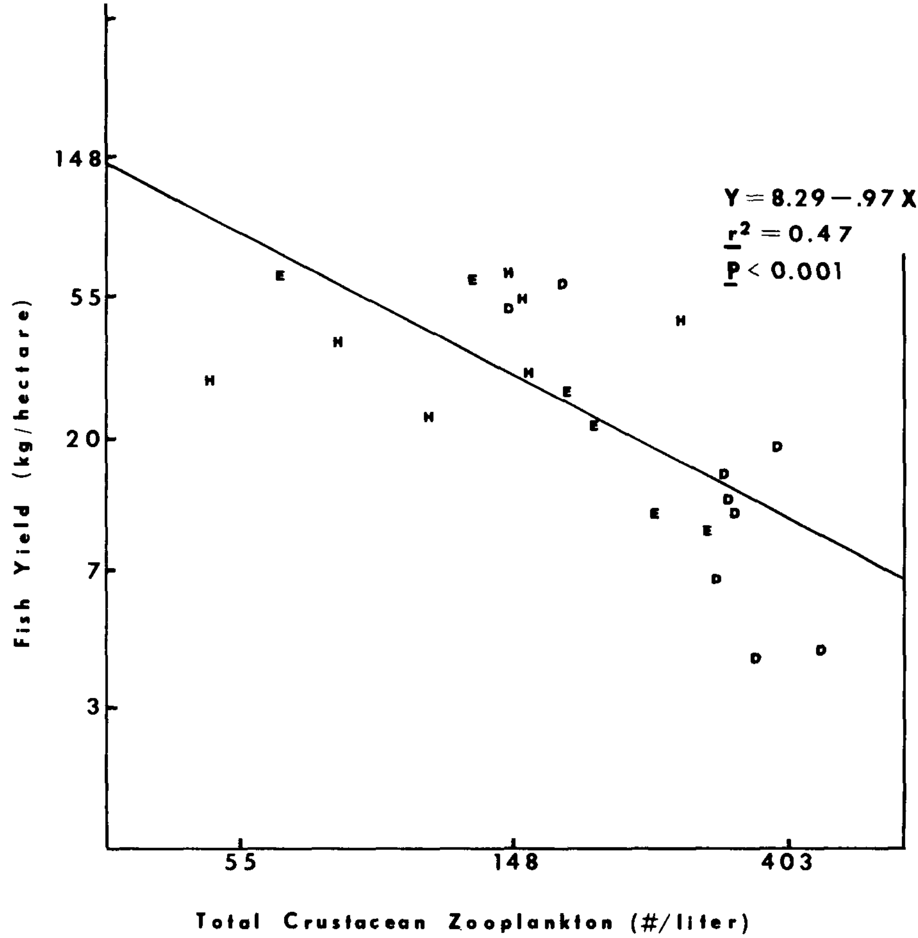

Figure 6. Relationship between mean annual chlorophyll *a* values and fish yield in striped bass, Florida largemouth bass and smallmouth bass rearing ponds, Dundee (D), Huntsville (H), and Eagle Mountain (E) State Fish Hatcheries, Texas, 1982, respectively.

tality may have caused low survival in the majority of striped bass ponds. This same trend can be seen in smallmouth bass ponds (Fig. 8) where low survival ponds (<40%) had higher zooplankton population levels than high survival ponds (>95%). These results agree with Eldridge et al. (1981) who found that striped bass larvae in the laboratory need food densities greater than 100 organisms/liter to attain normal growth rates. They found growth and mortality

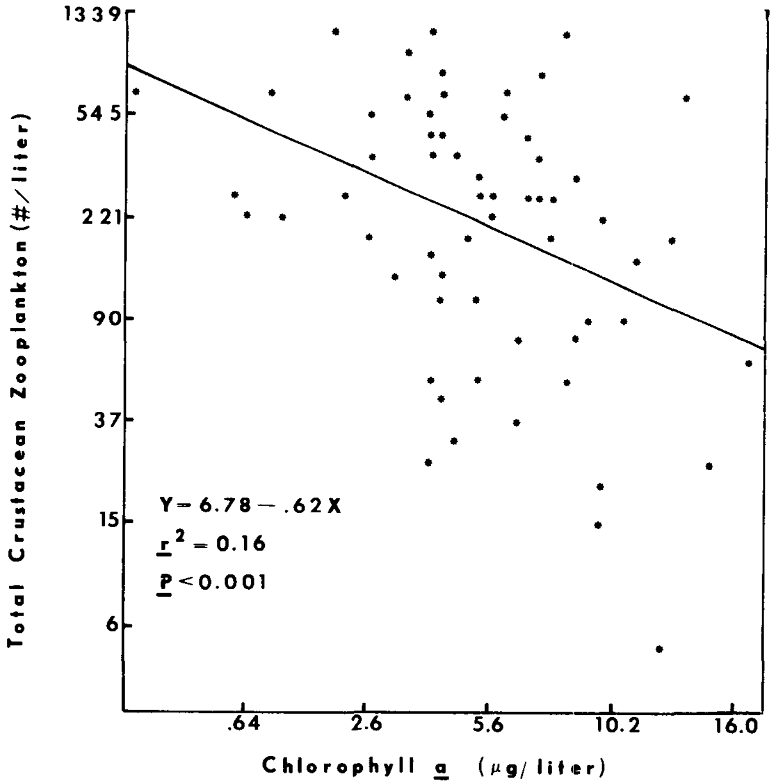

Figure 7. Relationship between weekly chlorophyll *a* values and mean weekly total crustacean zooplankton densities in striped bass, Florida largemouth bass, and smallmouth bass ponds, Dundee (D), Huntsville (H), and Eagle Mountain (E) State Fish Hatcheries, Texas, 1982, respectively. Equation was calculated using $\log_{10}$ (total crustacean zooplankton + 1) and the square root of chlorophyll *a*.

directly related to food density; however, at their highest feeding density of 5,000 organisms/liter growth only approximated that of wild larvae where prey populations had been estimated to be only 100 organisms/liter. This discrepancy was explained as either the ability of larval fish to locate concentrations of zooplankton, or the fact that in the laboratory the food density was not constant over time. In either case, the zooplankton populations in the hatchery ponds far exceeded the minimum requirements necessary for survival and did not drop below 200 organisms/liter (exclusive of rotifers) in striped bass ponds until the third week after stocking (Fig. 4). Increasing zooplankton densities in Florida largemouth bass and smallmouth bass ponds indicated food was also sufficient for survival of these species.

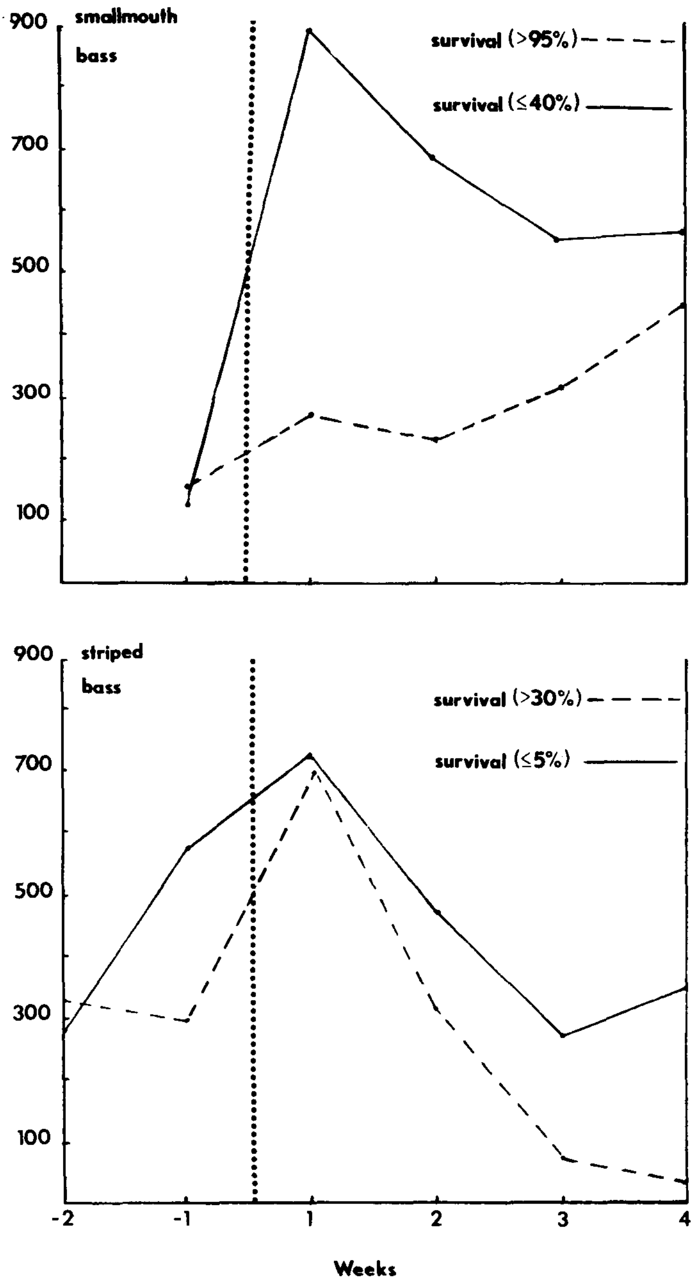

Figure 8. Mean weekly population estimates for total crustacean zooplankton from ponds displaying high and low fish survival for striped bass and smallmouth bass, Dundee and Eagle Mountain State Fish Hatcheries, Texas, 1982, respectively.

Conclusions

The following general conclusions can be reached from the data collected:

1) There were negligible differences among the different fertilization treatments for all 3 species in terms of water quality, zooplankton densities, and fish yield; any differences were obscured by factors such as fry quality or water temperatures.

2) Water quality remained high at 2 of the 3 hatcheries indicating organic fertilization rates could be increased on a hatchery-specific basis.

3) Relatively low chlorophyll *a* values suggest inorganic fertilization rates should be increased to achieve higher phytoplankton production.

4) Zooplankton densities were adequate for survival and growth of fry for all three species.

5) A significant negative relationship existed between zooplankton densities and chlorophyll *a* levels and also between zooplankton densities and fish yields. There was a positive relationship between fish yield and chlorophyll *a*.

In addition, this study demonstrates the need for further research concerning fry mortality, food habits of fish in rearing ponds, and stocking rates. Accurate fry counting procedures for Florida largemouth bass and smallmouth bass need to be developed if evaluation of hatchery production strategies for these 2 species are to be meaningful.

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