# Fertilization Vs. Supplementary Feeding for Growout of Pond-raised Gulf Killifish

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*Abstract:* Replacement of supplementary feeding with enhancement of natural productivity by pond fertilization for growout of the Gulf killifish (*Fundulus grandis*) was evaluated in 2 successive trials stocked at 330,000 fish/ha and 150,000 fish/ha, respectively. The first trial compared fertilization only, fertilization plus feeding at 3% body weight, and feeding at 3% body weight only in replicated 0.1 ha ponds. Growth rates were not significantly different, although days to marketable fish were 80–94 in the fertilized treatments and 100–107 in the fed-only ponds. Overall production averaged 710 kg/ha; 689 kg/ha in fertilized-only ponds. The second trial compared fertilization only, feeding at 5% body weight, and feeding at 5% body weight split into 2 daily feedings. Again growth rates did not significantly differ. Low fall temperatures prevented attainment of marketable fish. Both labor and material costs are substantially reduced by using fertilization only.

Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies 37:335–342

The Gulf killifish (*Fundulus grandis*) is an important marine baitfish in sport fisheries for flounder and to a lesser extent for redfish and spotted trout. It is known locally as the bullminnow in Alabama and the mudminnow or mudfish in Texas. Recently, harvest of wild stocks have fallen short of fisherman needs (Tatum and Helton 1977, Waas et al. 1983). Research on the culture of *F. grandis* was initiated in 1975 at the Claude Peteet Mariculture Center, Gulf Shores, Alabama, to supplement supply and has continued to the present (Tatum and Helton 1977, Tatum et al. 1979). Culture techniques as detailed in Tatum et al. (1982) are similar to that of another baitfish, the golden shiner (*Notemigonus chrysoleucas*). Eggs are laid on wire-mesh mats stuffed with Spanish moss and transferred to hatching ponds. A 3-phase system is normally employed whereby the fry are transferred to growout ponds. In a 2-phase system in Texas the fry are allowed to grow to marketable size (approximately 3.0 g and 60 mm total length) in the hatching pond. Fish are fed a finely ground floating feed at 5% to 10% body weight daily.

During the past 4 years, additional work, including investigation of inexpensive feeds, has been performed on the pond culture of *F. grandis* at the Cedar Bayou Mariculture Laboratory, east of Baytown, Texas (Waas 1982, Waas et al. 1983). A significant finding was the similar growth rates of fish fed grain by-products compared to trout chow. Waas (1982) concluded that natural productivity must be of considerable importance in *F. grandis* culture.

The present study was undertaken to evaluate fish growth and economic return from ponds with enhanced natural productivity by fertilization compared to ponds receiving supplemental feeding. Tatum and Helton (1977) found *F. grandis* growth in a pond fertilized with chicken manure similar to that of fish in another pond fed at 10% body weight; however, fish were stocked at half the density in the fertilized pond. Felts (1979) has studied the effects of fertilization only in the pond culture of the golden shiner and Knoefes and Bachmann (1970) reported on growth of the fathead minnow (*Pimephales promelas*) in tertiary treatment ponds.

This study was supported by Houston Lighting and Power Co. by a grant to the Department of Wildlife and Fisheries Sciences, Texas A&M University, through the Texas Agricultural Experiment Station.

## Methods

The study was conducted from 21 June to 23 December 1982 on the grounds of the Cedar Bayou Generating Plant of the Houston Lighting and Power Co. east of Baytown, Texas. Water to fill the 0.1 ha ponds and replace evaporation came from Cedar Bayou after passing through the power plant and was filtered with saran socks. Salinities of the discharge from the plant varied, depending on the extent of rains, from virtually freshwater to approximately 15 ppt. The ponds were constructed from heavy gumbo clay. Fish to stock the 2 successive trials were raised from eggs spawned at the facility.

In both the first and second trials, 13-13-13 inorganic fertilizer (costing $0.33/kg), was broadcast as needed in 40 kg/ha doses to maintain Secchi disc visibility of 30–40 cm (Boyd 1979). Minnow meal (Mountaire Feed and Vitamin Premix Company, Inc., North Little Rock, Arkansas) costing $0.45/kg and containing 33% protein was fed 6 days/week during fry production and growout. Feed was adjusted at 2-week intervals based on average weight of 50 fish seined from each pond and assuming 4% mortality for the period or 80% survival over the course of the study. At 2-week intervals, primary production by the Winkler method was also measured (Boyd 1979). One light and one dark bottle were each suspended at 0.25 and 0.75 m for an incubation period between 1100 to 1500 hours on clear days. Water temperature was recorded at the time of feeding, generally at 1200 hours. Water temperature, conductivity, pH, and oxygen levels were also monitored daily at 0800 to 0900 hours with a Hydrolab instrument. Fish in the ponds were harvested with minnow traps and by pond draining and were sold to local bait dealers when marketable size (approximately 3.0 g and 60 mm total length) was reached.

The first trial utilizing spring-spawned fry consisted of 6 ponds randomly divided into 3 treatments: fertilization only, fertilization and feeding at 3% body weight per day, and feeding at 3% body weight only. The second trial was initiated following harvest of the first trial with fry from the summer spawnings. A different set of 6 ponds was divided into 3 treatments: fertilization only, feeding at 5% body weight once daily, and feeding at 5% body weight in 2 daily portions.

Pond biota and gut samples of fish were sampled at 2-week intervals during the study. This data will be analyzed and reported separately at a later date.

## Results

### Trial 1

On 21 June, 330,000 fry/ha at approximately 0.2 g were stocked in each of 6 ponds (Table 1). Growth from 0.2 g to 3.0 g was linear, as observed by Waas (1982) in *F. grandis* culture. Average daily gains ranged from a low of 0.022 g in a fed-only pond to 0.040 g in a fed-and-fertilized pond. However, student's *t*-test comparisons between means of daily gain from combined treatments produced no significant differences, due to the large standard deviations (Table 2). Average daily gain per treatment was 0.034, 0.035, and 0.022 g for fish in ponds which were fertilized only, fertilized and fed, and fed only, respectively. By 2 September, or after 80 days growout, fish in most of the ponds of the 2 fertilized treatments were ready to be harvested. Fish in the fed-only ponds took an additional 20–27 days to reach marketable size. Overall production averaged 710 kg/ha; 689 kg/ha in fertilized-only ponds. The range was 621 kg/ha to 800 kg/ha and reflected variable survival (61%–78%). However, survival did not appear to be related to treatment (Table 1). The average number of fish harvested per pond was 23,100 (range: 20,130–25,740) and at an easily-obtained, on-site selling price to bait dealers of $0.05 each were worth $1,155. At a delivered price of $0.07 each, the average number of fish harvested were worth $1,617. Ponds required fertilizer applications about every 7 days and averaged 560 kg/ha at a cost of $185 during the 107-day experiment. Use of minnow meal in fed ponds averaged 845 kg/ha or $380. Food conversion ratios were good, 1.2:1.0 to 1.6:1.0 (Table 1). Water temperatures and salinities were 27° to 31° C and 2 to 9 ppt, respectively. Oxygen ranged from less than 1.0 to 17.0

**Table 1.** Summary of production data for *F. grandis* stocked at 330,000 fish/ha on 21 June and harvested at marketable size (approximately 3.0 g and 60 mm).

| Pond[a] | Stocking weight (g) | Culture days | Average gain (g/day) | Average primary prod. (mg $O_2$/1/4 hr. incubation) | Fish production (kg/ha) | Fish production (no./ha) | Fish production Survival (%) | Fertilizer (kg/ha) | Feed (kg/ha) | Cost ($/ha) | Food conversion ratio |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1(A) | 0.20 | 80 | 0.036 ± 0.005 | 5.10 ± 1.04 | 621 | 201,800 | 61 | 640 | 0 | 210 | |
| 21(A) | 0.24 | 80 | 0.032 ± 0.014 | 4.52 ± 1.20 | 758 | 254,100 | 77 | 560 | 0 | 180 | |
| 2(B) | 0.28 | 80 | 0.040 ± 0.027 | 5.62 ± 0.59 | 800 | 211,200 | 64 | 400 | 850 | 523 | 1.2 : 1.0 |
| 24(B) | 0.25 | 94 | 0.029 ± 0.027 | 3.60 ± 1.10 | 688 | 231,000 | 70 | 640 | 960 | 653 | 1.6 : 1.0 |
| 22(C) | 0.25 | 100 | 0.023 ± 0.007 | 1.12 ± 0.49 | 660 | 231,000 | 70 | 0 | 770 | 354 | 1.3 : 1.0 |
| 25(C) | 0.25 | 107 | 0.022 ± 0.008 | 2.48 ± 0.82 | 735 | 257,400 | 78 | 0 | 800 | 368 | 1.2 : 1.0 |

[a] Pond treatment (A) fertilized to maintain a 30–40 cm Secchi disc visibility; (B) fertilized to maintain a 30–40 cm Secchi disc visibility and fed 3% body weight daily; (C) fed 3% body weight daily.

**Table 2.** Mean daily gains calculated from combined replicates and *t*-test comparisons from treatments in Trial 1 and Trial 2.

| Treatment | Mean daily gain (g/day) | df | | *t* value | |
|---|---|---|---|---|---|
| Trial 1 | | | | | |
| A. Fertilized | 0.034 ± 0.013 | A – B | 9 | 0.09 | NS |
| B. Fed (3%) + fertilizer | 0.035 ± 0.021 | B – C | 9 | 1.44 | NS |
| C. Fed (3%) | 0.022 ± 0.008 | C – A | 9 | 1.71 | NS |
| Trial 2 | | | | | |
| A. Fertilized | 0.024 ± 0.010 | A – D | 7 | 0.83 | NS |
| D. Fed (5%) | 0.019 ± 0.007 | D – E | 7 | 1.28 | NS |
| E. Fed (5%) – 2 portions | 0.017 ± 0.004 | E – A | 7 | 2.00 | NS |

ppm and pH values from 7.5 to 10.8; however, the fish were not observed in stress and no fish kills or sublethal effects were noted.

### Trial 2

On 18 October each of 6 ponds was stocked with 150,000 fry/ha. Average weight varied from 0.2 to 0.5 g (Table 3). Growth was again linear, and average daily gains from combined ponds in the treatments were 0.024, 0.019, and 0.017 g for fertilized only, fed 5%, and fed 5% in 2 feedings, respectively (Table 2). Student's *t*-test comparisons detected no significant differences between treatments, although it appears growth in fertilized ponds exceeded that of fish in ponds fed at 5% body weight. Presenting food in 1 vs. 2 feedings/day made no difference. Fish stopped active feeding by the 23 December sampling period due to water temperatures consistently below 20° C and thus ponds were drained and data taken before the fish had reached marketable size. Overall production averaged 200 kg/ha; 195 kg/ha in fertilized ponds. The range was 132–222 kg/ha (Table 3). Survival was higher than in Trial 1, averaging 87% vs. 70%; however, the culture period averaged 25 days longer in Trial 1. Food conversion ratios for fed fish were good (1.1:1.0 through 1.4:1.0). Water temperatures and salinities varied from 12° to 25° C and 12 to 22 ppt, respectively. The low water temperatures reduced primary productivity even though Secchi disc visibility was maintained at 30 to 40 cm (Table 3). Oxygen (7.2 to 18.8 ppm) and pH (7.8 to 9.5) levels were not limiting.

## Discussion

### Growth Rates

The high levels of growth in fertilized-only ponds were unexpected. In the original design, feeding of fish was to have begun in fertilized-only ponds when growth rates declined, indicating attainment of carrying capacity from

**Table 3.** Summary of production data for *F. grandis* stocked at 150,000 fish/ha on 18 October and harvested 23 December.

| Pond[a] | Stocking weight (g) | Culture days | Average gain (g/day) | Average primary prod. (mg $O_2$/1/4–hr. incubation) | Fish production (kg/ha) | (no./ha) | Survival (%) | Fertilizer (kg/ha) | Feed (kg/ha) | Food conversion ratio |
|---|---|---|---|---|---|---|---|---|---|---|
| 8(A) | 0.27 | 66 | 0.021 ± 0.009 | 3.27 ± 1.50 | 181 | 102,000 | 68 | 380 | 0 | |
| 10(A) | 0.31 | 66 | 0.026 ± 0.010 | 2.73 ± 1.63 | 209 | 138,000 | 92 | 360 | 0 | |
| 9(D) | 0.20 | 66 | 0.016 ± 0.007 | 1.13 ± 0.65 | 136 | 111,000 | 74 | 0 | 180 | 1.4 : 1.0 |
| 11(D) | 0.33 | 66 | 0.020 ± 0.006 | 1.15 ± 1.03 | 216 | 147,000 | 98 | 0 | 240 | 1.2 : 1.0 |
| 12(E) | 0.39 | 66 | 0.018 ± 0.005 | 1.17 ± 1.38 | 230 | 148,500 | 99 | 0 | 250 | 1.1 : 1.0 |
| 13(E) | 0.51 | 66 | 0.016 ± 0.004 | 1.18 ± 0.74 | 225 | 141,000 | 94 | 0 | 280 | 1.3 : 1.0 |

[a] Pond treatment (A) fertilized to maintain a 30–40 cm Secchi visibility; (D) fed 5% body weight once daily; (E) fed 5% body weight daily in 2 portions.

natural foods. As a decline in growth did not occur, production in fertilized ponds at the Cedar Bayou site should exceed the 758 kg/ha and 257,400 fish/ha observed in this study. These levels are among the highest reported for *F. grandis* culture. Growth rates and food conversion ratios in the first trial were similar or exceeded those obtained in studies at lower stocking levels and fed 5% to 10% body weight (Tatum et al. 1979, Waas 1982). The second trial was initiated too late in the year to obtain good growth rates, but served to compare rates within treatments.

Survival was highly variable between ponds and trials, and affected production levels. To test the effect of survival on growth rates in the first trial, average daily gains/pond were regressed against percentage survival. The correlation coefficient of −0.68, indicating faster growth with fewer fish, was not significant. Gains were better correlated with primary productivity, $r = 0.94$. In the second trial correlation coefficients for gain versus survival and primary productivity were 0.05 and 0.73 respectively. Thus growth rates were more responsive to higher primary productivity and by inference to the greater natural food than to variable survival. Preliminary analysis of gut contents indicates the fish were opportunistic feeders, consuming mainly filamentous algae and invertebrates.

Survival was lowest in ponds that were furthest removed from the fry ponds and that required the most time in transport during stocking (ponds 1, 2, and 8). Stress may have occurred due to the large numbers of fry transported and the high summer temperatures in Trial 1. Higher survival in Trial 2 may be a result of cooler temperatures present during stocking, fewer fry transported, and the shortened growing period.

### Economics

There are at present no commercial, private operations for *F. grandis* culture, even though studies have been encouraging with the exception of 1 which evaluated a closed, recirculating system (McIlwain 1977). Waas et al. (1983) prepared a budget analysis for a hypothetical 24-ha pond facility. Their study incorporated feeding with a food conversion ratio of 2.0:1.0 and a 3-phase production system consisting of spawning, hatching and fry production, and growout ponds. Labor costs were the highest variable cost, accounting for 38% of the annual operating cost and were more than 5 times greater than feed costs (7%). Profit potential was high. Projected net revenue was $4,700/ha with a 22% return to investment. Improvements from the incorporation of fertilization to enhance natural food and replace supplementary feeding and from a 2-phase production system which combines hatching and growout ponds and requires no transfer of fry would increase fry survival and reduce labor and material costs. Also the decrease by 20 to 27 days in stocking to harvest for fish in fertilized-only vs. fed-only ponds would help to insure more than 1 crop of market-sized fish/year. This would increase profits through better use of facilities and personnel and more fish sold.

Research evaluating 2-phase culture plus pond fertilization is being evaluated at the Cedar Bayou facility. Further experimentation may indicate that a less expensive fertilizer than 13-13-13 used in this study would give equal or better results. Quick et al. (1978) utilized a mixture of urea (46-0-0) and superphosphate (0-21-0) to provide a 5:1 ratio of nitrogen to phosphorus. Two applications of 5 kg/ha produced a continuous bloom of phytoplankton for 50 days in white shrimp (*Penaeus setiferus*) culture ponds. Sewage effluent as a fertilizer source would also be appropriate as *F. grandis* is a non-food species.

## Literature Cited

Boyd, C. E. 1979. Water quality in warmwater fish ponds. Auburn Univ. Agric. Exp. Sta. 359pp.

Felts, S. K. 1979. Evaluation of supplemental diets for golden shiners. PhD Dissertation. Auburn Univ., Auburn, Ala. 67pp.

Knoefes, J. L. and R. W. Bachmann. 1970. Growth of fathead minnow (*Pimephales promelas*) in tertiary treatment ponds. Proc. Iowa Acad. Sci. 77: 104–111.

McIlwain, T. D. 1977. Bait fish rearing. Project GR-76-005. Miss. Mar. Res. Council Long Beach. 14pp.

Quick, J. A., D. J. Milligan, S. E. Hill, R. J. Hover, and W. F. McIlhenny. 1978. Field demonstration of shrimp mariculture feasibility in dredged material containment areas. U.S. Army Engineer Waterways Exp. Sta. Tech. Rep. D-78-53. 129pp.

Tatum, W. M. and R. F. Helton. 1977. Preliminary results of experiments on the feasibility of producing bullminnows (*Fundulus grandis*) for the live bait industry. Proc. World Maricult. Soc. 8:49–54.

———, W. C. Trimble, and R. F. Helton. 1979. Production of Gulf killifish in brackish water ponds. Proc. Annu. Conf. Southeast. Assoc. Fish and Wildl. Agencies. 32:502–508.

———, J. P. Hawke, R. V. Minton, and W. C. Trimble. 1982. Production of bullminnows (*Fundulus grandis*) for the live bait market in coastal Alabama. Ala. Mar. Res. Bul. 13. 35pp.

Waas, P. B. 1982. Development and evaluation of a culture system suitable for the production of Gulf killifish (*Fundulus grandis* Baird and Girard) for live bait in the thermal effluent of a power plant. PhD Dissertation. Texas A&M Univ., College Station. 142pp.

———, K. Strawn, M. Johns, and W. Griffin. 1983. The commercial production of mudminnows (*Fundulus grandis*) for live bait: a preliminary economic analysis. Texas Jour. Sci. 35:51–60.