ELSEVIER

Aquaculture 126 (1994) 305-313

Aquaculture

Pond culture of female green sunfish (*Lepomis cyanellus*) × male bluegill (*L. macrochirus*) hybrids stocked at two sizes and densities

James H. Tidwell[a,*], Carl D. Webster[a], Julia A. Clark[a], Martin W. Brunson[b]

[a]*Aquaculture Research Center, Kentucky State University, Frankfort, KY 40601, USA*
[b]*Department of Wildlife and Fisheries, Mississippi State University, Mississippi State, MS 39762, USA*

Accepted 28 May 1994

Abstract

The hybrid produced by crossing the female green sunfish (*Lepomis cyanellus*) and male bluegill (*L. macrochirus*) was evaluated under production conditions for 1 year. Juveniles were stocked at two initial sizes (38 and 66 g) and two densities (6175 and 12350/ha) into twelve 0.04-ha ponds and fed a diet containing 36% protein for 371 days. Fish stocked at 6175/ha had significantly higher ($P<0.05$) final weights and average total and summer gains than fish stocked at 12350/ha. Although fish stocked at 38 g were significantly smaller ($P<0.05$) at harvest, percentage weight gain and feed conversion efficiencies were significantly higher ($P<0.05$) than for fish stocked at 66 g. There was a significant interaction ($P<0.05$) between stocking density and stocking size on net yield and gross yield which ranged from 838 and 1315 kg/ha, respectively for small fish stocked at low density to 1925 and 3565 kg, respectively for large fish stocked at high density. There were no significant differences ($P>0.05$) in percent protein, fat, and moisture of whole bodies of fish stocked in the different treatments. Stocking of large juveniles at high density produced more harvestable-size fish (>110 g) per ha. Effects of higher stocking densities on feed utilization and improved feeding regimes should be investigated.

Keywords: Sunfish hybrid; Pond culture; Size; Density

1. Introduction

The number of studies devoted to the intensive production of Centrarchidae species is relatively limited. The hybrid produced by crossing the female green sunfish (*Lepomis*

* Corresponding author.

0044-8486/94/$07.00 © 1994 Elsevier Science B.V. All rights reserved
SSDI 0044-8486(94)00143-C

cyanellus) with the male bluegill (*L. macrochirus*) (GS × BG) has several desirable attributes for intensively cultured fishes, including: ready acceptance of feed (Lewis and Heidinger, 1971), good summer growth and feed conversion (Brunson and Robinette, 1982), and a sex ratio highly skewed towards males (Brunson, 1983). This hybrid is also extremely susceptible to angling (Ellison and Heidinger, 1978). Heidinger (1975) suggested that in temperate regions the GS × BG hybrids may be more economical to raise, for either food fish or fee-fishing markets, than channel catfish.

Brunson and Robinette (1986) stated that the GS × BG hybrid may be particularly suited for marketing through fee-fishing operations. This could provide a ready market outlet in areas where food-fish processing is not well developed. Ellison and Heidinger (1978) stated that fish ≥ 110 g would be desirable for marketing through fee-fishing operations. As fish growth and ultimate harvest size are strongly influenced by stocking rate and initial stocking size, it is important to ascertain optimum combinations of these factors to achieve desired target weights.

The objective of this study was to evaluate the effects of initial stocking size, fish density, and their interactions on growth and body composition of second year GS × BG hybrids in ponds.

2. Materials and methods

Juvenile female green sunfish by male bluegill F_1 hybrids were stocked into twelve 0.04-ha ponds at rates of 6175 and 12350 fish/ha at initial fingerling sizes of either 38 g or 66 g. Each of the four treatment combinations was replicated in three ponds in a 2 × 2 factorial arrangement. All fish were fed a commercial diet containing 36% crude protein (Purina 5133) and extruded into 3.2 mm floating pellets. Feeding schedules and amounts were based on body weight and varied according to fish size, water temperature, and feed response. Rates varied from 4% of biomass daily for small fish after stocking to 0.5% of biomass per day for large fish during the winter. Calculated fish weights were updated every 2 weeks based on an assumed feed conversion of 1.5 (Brunson and Robinette, 1982). Fish were sampled monthly with biomass estimates and feed rates adjusted according to sample averages. The highest feeding rate achieved was 50 kg/ha day^{-1} in ponds stocked with large fingerlings at high density.

Ponds used in this study were approximately 1.5-m deep and were supplied with water from a reservoir filled by rain runoff. Water levels in the ponds were maintained at a constant depth by periodic additions. Water temperature and dissolved oxygen (DO) were monitored in each pond twice daily (09.00 and 16.00 h) at a depth of 0.5 m using a YSI Model 57 oxygen meter (YSI, Yellow Springs, OH). Mechanical aeration was supplied if DO was predicted (by graph) to fall below 5 mg/l during the night. Ammonia, nitrite, and pH were determined weekly (16.00 h) using a HACH DREL/2000 spectrophotometer (HACH, Loveland, Co., USA).

Data reporting summer growth include the period from the 14 April stocking to 27 November sampling, at which time survival was assumed to be 100%. Data reported as winter growth extend from the 29 November sampling until the 20 April final harvest. Total number and weight of fish in each pond were determined at harvest. Fifty fish were then randomly sampled from each pond and individually weighed (g) and measured for total length (cm). Fish within the sample weighing ≥ 110 g were considered marketable (Ellison and Heidinger, 1978) and the portion of the sample reaching the target size was reported as marketable percentage. Whole bodies (including heads, frames, and scales) of three fish sampled from each pond during fall sampling and at final harvest were individually homogenized in a blender and analyzed for fat, protein, and moisture. Protein was determined by the Kjeldahl method, fat by ether extraction, and moisture was measured by drying in an oven (95°C until constant weight) (AOAC, 1990).

Specific growth rate (SGR, % body wt/day) was calculated from SGR = (%/day) = [(ln W_f − ln W_i)/t] × 100, where W_f = mean weight at the end of the period, W_i = mean weight at the beginning of the period, and t = time in days of the period (Ricker, 1975). Condition factor (K) was calculated from $K = 100 \times W/L^3$, where W = weight (g) and L = total length (cm) (Weatherly and Gill, 1987). Feed conversion ratio (FCR) was calculated from FCR = weight of feed fed (g)/live weight gain (g). An overall sex ratio was determined by examining 500 fish randomly selected from all treatments at the termination of the study.

Data were analyzed by two-way analysis of variance (ANOVA) using the Statistical Analysis System (Statistical Analysis Systems, 1988) to determine the effects of stocking rate, initial stocking size, and their interactions on growth, condition factor, feed conversion, body composition, and survival. All percentage and ratio data were transformed to arc sin values prior to analysis (Zar, 1984).

3. Results

Environmental conditions

During the summer period (April 1992 to November 1992) morning and afternoon temperatures averaged 18.6 ± 5.5°C and 20.3 ± 5.9°C, respectively. Morning and afternoon DO averaged 8.5 ± 1.5 mg/l and 10.9 ± 1.0 mg/l, respectively and afternoon pH averaged 8.7 ± 0.6. During the winter period (December 1992 to April 1993) morning DO and temperature averaged 14.0 ± 3.2 mg/l and 5.4 ± 3.3°C, respectively. Afternoon temperature, DO, and pH averaged 6.3 ± 3.6°C, 14.8 ± 3.2 mg/l, and 8.4 ± 0.2, respectively. None of these variables was significantly affected ($P > 0.05$) by the four treatment combinations. The lowest DO encountered was 2.0 mg/l in a pond stocked with small fingerlings at high density.

Monthly averages of total ammonia-nitrogen (TAN) (Fig. 1) and nitrite-nitrogen (Fig. 2) were significantly affected by the treatment combinations during the summer period, when feeding rates were highest. During July, TAN was significantly higher ($P < 0.01$) in ponds stocked with large fish at high density than in ponds stocked with other treatments. Ponds stocked with small fish at high density or large fish at low density had higher TAN levels ($P < 0.05$) than ponds stocked with small fish at low density. During August TAN was significantly higher ($P < 0.05$) in ponds stocked with large fish at high density than in other ponds. There were no significant differences ($P > 0.05$) in TAN among other treatments. There were no significant differences ($P > 0.05$) in TAN among treatments during any other months. The maximum TAN concentration measured was 3.0 mg/l on 26 June 1992 in ponds stocked with small fingerlings at high density and large fingerlings at high

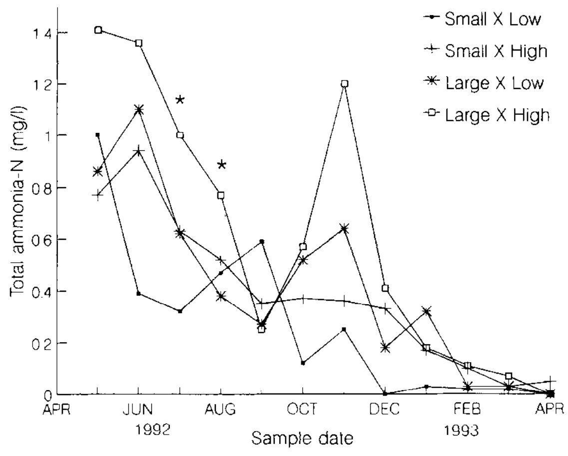

Fig. 1. Monthly means of total ammonia-nitrogen (mg/l) in ponds stocked with sunfish hybrids of 38 g (small) or 66 g (large) at 6175/ha (low) or 12350/ha (high). Each point represents three replicate ponds and four weekly samples per pond. An asterisk indicates a significant difference among treatments ($P<0.05$).

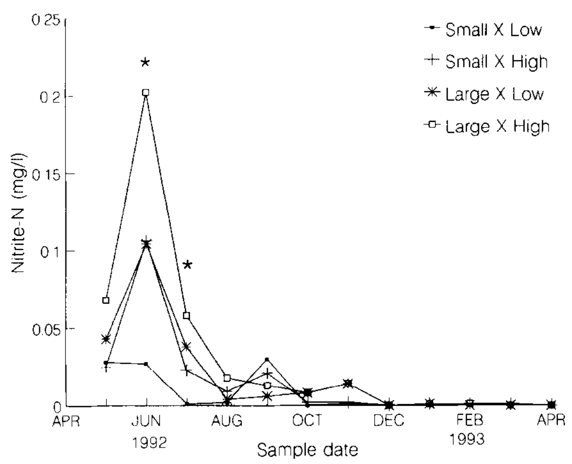

Fig. 2. Monthly means of nitrite-nitrogen (mg/l) in ponds stocked with sunfish hybrids of 38 g (small) or 66 g (large) at 6175/ha (low) or 12350/ha (high). Each point represents three replicate ponds and four weekly samples per pond. An asterisk indicates a significant difference among treatments ($P<0.05$).

density. Unionized ammonia concentrations as high as 0.85 were recorded without acute signs of stress.

During June, nitrite-nitrogen was significantly higher ($P<0.05$) in ponds stocked with large fish at high density than in ponds stocked with other treatment combinations. Nitrite concentrations in ponds stocked with small fish at high density or large fish at low density were not significantly different ($P>0.05$) but were both significantly higher than in ponds stocked with small fish at low density. During July, nitrite-nitrogen concentrations were significantly higher ($P<0.05$) in ponds stocked with large fish at high density and low

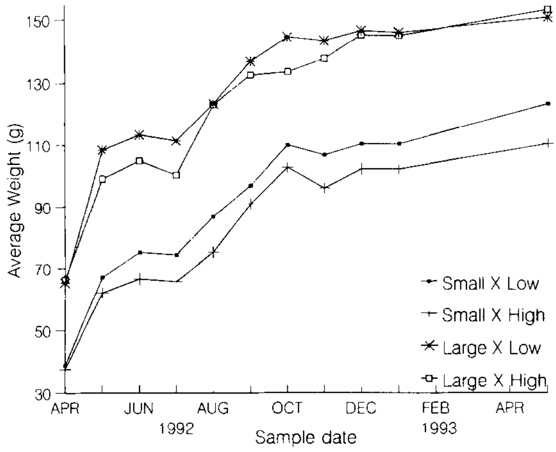

Fig. 3. Mean weight of sunfish hybrids stocked at two sizes, 38 g (small) or 66 g (large), at 6175/ha (low) or 12350/ha (high). Each point represents three replicate ponds. Fish were not sampled at temperatures ≤7°C to avoid stress.

density than in ponds stocked with small fish at low density. Nitrite concentrations in ponds stocked with large fish at low density were not significantly different ($P > 0.05$) from ponds stocked with small fish at high density. Nitrite concentrations in these ponds were not different ($P > 0.05$) from ponds stocked with small fish at high density. Nitrite concentrations did not differ significantly ($P > 0.05$) among ponds stocked with the different treatment combinations during other months.

Production

There were no significant interactions ($P > 0.05$) between stocking density and size at stocking on average harvest weight (Fig. 3), average harvest length, average individual gain (%), summer or winter average individual gain (g), total biomass increase (%), summer or winter SGR, survival, feed conversion ratio (FCR), or condition factor (K). The influence of main effects (stocking rate and stocking density) may then be considered separately for these variables (Dowdy and Wearden, 1983).

Stocking rate

Mean individual fish weight, total individual gain, and summer individual gains were significantly higher ($P < 0.05$) for fish stocked at 6175/ha (144.6 g, 186.9%, and 147.6%, respectively) than for those stocked at 12350/ha (134.6g, 167.2%, and 127.6%, respectively) (Table 1). Stocking rate had no significant effect ($P > 0.05$) on final length, biomass increase, average individual winter gain (Table 1), summer or winter SGR, FCR, condition factor, survival (Table 2), or body composition variables (Table 3).

Stocking size

Fish stocked at 66 g had significantly higher ($P < 0.05$) final individual weight (160.2 g), length (19.7 cm) (Table 1), and FCR (6.3) (Table 2) than hybrids stocked at 38 g (118.7 g, 18.4 cm, and 4.8, respectively). Total gain, summer gain, winter gain, and

Table 1

Main effect means* of final weight, final length, total average individual gain, summer and winter average individual gain, and total biomass increase of sunfish hybrids (*Lepomis cyanellus* × *L. macrochirus*) stocked at two initial sizes (38 and 66 g) and cultured in ponds for 371 days at two stocking densities

Main effect	Final weight (g)	Final length (cm)	Total average individual gain (%)	Summer average individual gain (%)	Winter average individual gain (%)	Total biomass increase (%)
Density (fish/ha)						
6175	144.6 ± 8.4[a]	19.1 ± 0.3[a]	186.9 ± 17.2[a]	147.6 ± 13.7[a]	16.4 ± 2.2[a]	143.5 ± 15.9[a]
12 350	134.6 ± 10.6[b]	19.0 ± 0.3[a]	167.2 ± 14.5[b]	127.6 ± 9.1[b]	17.1 ± 2.3[a]	128.7 ± 10.2[a]
Stocking size						
Small	118.7 ± 3.7[b]	18.4 ± 0.1[b]	210.6 ± 8.5[a]	161.5 ± 8.4[a]	18.9 ± 2.1[a]	157.6 ± 13.6[a]
Large	160.2 ± 2.6[a]	19.7 ± 0.1[a]	143.4 ± 4.3[b]	113.7 ± 3.3[b]	14.6 ± 1.9[b]	114.6 ± 2.9[b]

* Means (± s.e.) of six replicate ponds; means within a column within a main effect followed by different letters are significantly different ($P < 0.05$).

Table 2

Main effect means* of summer and winter specific growth rate (SGR), feed conversion ratio (FCR), condition factor, and survival of sunfish hybrids (*Lepomis cyanellus* × *L. macrochirus*) stocked at two initial sizes (38 and 66 g) and cultured in ponds for 371 days at two stocking densities

Main effect	Summer SGR (%/day)	Winter SGR (%/day)	Feed conversion ratio	Condition factor (*K*)	Survival (%)
Density (fish/ha)					
6175	0.40 ± 0.02[a]	0.10 ± 0.01[a]	5.4 ± 0.5[a]	2.2 ± 0.1[a]	84.9 ± 1.5[a]
12 350	0.35 ± 0.02[a]	0.11 ± 0.02[a]	5.7 ± 0.3[a]	1.9 ± 0.1[a]	86.2 ± 3.3[a]
Stocking size					
Small	0.42 ± 0.01[a]	0.12 ± 0.01[a]	4.8 ± 0.2[b]	2.1 ± 0.2[a]	82.7 ± 2.2[a]
Large	0.33 ± 0.01[a]	0.09 ± 0.01[a]	6.3 ± 0.2[a]	2.1 ± 0.1[a]	88.4 ± 2.2[a]

* Means (± s.e.) of six replicate ponds; means within a column within a main effect followed by different letters are significantly different ($P < 0.05$).

percentage increase in biomass were significantly lower ($P < 0.05$) for fish stocked at 66 g than for those stocked at 38 g (Table 1). Size at stocking had no significant effect ($P > 0.05$) on SGR (summer or winter), survival, condition factor (Table 2), or body composition variables (Table 3).

Stocking rate × stocking size

For two variables, gross and net yield, there was a significant interaction ($P < 0.05$) between main effects, and these variables must be discussed relative to treatment combinations. Gross yields ranged from 1316 kg/ha in ponds stocked with small fingerlings at low density to 3563 kg/ha in ponds stocked with large fingerlings at high density (Table 4). Differences between all four treatment combinations were statistically significant

Table 3
Main effect means* of moisture, fat, and protein of sunfish hybrids (*Lepomis cyanellus* × *L. macrochirus*) stocked at two initial sizes (38 and 66 g) and cultured in ponds for 371 days at two stocking densities

	Moisture (%)			Fat (%)		Protein (%)		
	Stocking	Fall sample	Spring harvest	Fall sample	Spring harvest	Stocking	Fall sample	Spring harvest
Density (fish/ha)								
6175	73.4 ± 0.8	73.8 ± 0.9	71.4 ± 1.2	2.8 ± 0.7	6.1 ± 0.4	16.4 ± 1.3	19.5 ± 0.6	16.8 ± 0.6
12 350	73.4 ± 0.8	73.6 ± 1.4	71.7 ± 1.3	2.8 ± 0.7	5.6 ± 0.7	16.4 ± 1.3	19.7 ± 0.5	16.8 ± 0.8
Stocking size								
Small	73.6 ± 0.6	73.8 ± 0.8	71.5 ± 1.4	2.6 ± 0.5	5.7 ± 0.6	16.0 ± 1.8	19.6 ± 0.4	17.1 ± 0.4
Large	73.1 ± 0.9	73.6 ± 1.5	71.7 ± 1.2	3.1 ± 0.8	6.0 ± 0.7	16.7 ± 0.7	19.6 ± 0.4	16.5 ± 0.8

* Means (± s.e.) of six replicate ponds. Differences in treatment means were not significantly different ($P > 0.05$). Fat levels at stocking were lost due to difficulties in analysis.

Table 4
Sub-class means* for net and gross yield of sunfish hybrids (*Lepomis cyanellus* × *L. macrochirus*) stocked at two initial sizes (38 and 66 g) and cultured in ponds for 371 days at two stocking densities

Treatment factor		Net yield (kg/ha)	Gross yield (kg/ha)
Density (fish/ha)	Stocking size		
6175	Small	837.5 ± 55.6[c]	1,316.5 ± 84.0[d]
6175	Large	901.4 ± 49.3[bc]	1,707.6 ± 92.3[c]
12 350	Small	1,299.5 ± 186.8[b]	2,227.4 ± 328.3[b]
12 350	Large	1,925.4 ± 4.8[a]	3,564.7 ± 8.2[a]

* Means (± s.e.) of three replicate ponds; means within a column followed by different letters are significantly different ($P < 0.05$).

($P < 0.05$). Net yield was also significantly higher ($P < 0.05$) in ponds stocked with large fingerlings at high densities (1925 kg/ha). Differences in production between ponds stocked with small fingerlings at high density and ponds stocked with large fingerlings at low density were not significantly different ($P > 0.05$). Net yield in ponds stocked with either stocking size at 6175 fish/ha was not significantly different ($P > 0.05$).

4. Discussion

Average individual gains (%) were higher in ponds stocked at low density or with small fingerlings. However, actual production figures (g/fish or kg/ha) were much higher in ponds stocked at high density and/or with larger fingerlings. Increased stocking size caused significant increases in harvest weight, total length, and proportion of population attaining harvestable size. Large fingerlings stocked at high density resulted in significantly higher gross and net yields.

Brunson and Robinette (1986) reported that GS × BG hybrids stocked at 2471 fish/ha and fed at supplemental levels reached an average weight of 165 g. In this study, GS × BG hybrids reached similar sizes (163 and 158 g) at approximately the same age when stocked at 2.5 and 5 times the stocking rate used by Brunson and Robinette (1986). Lewis and Heidinger (1971) reported a gross yield of 345 kg/ha in ponds stocked with GS × BG hybrids at 3713 fish/ha, and 568 kg/ha in ponds stocked at 7426 hybrids/ha with fish at both densities fed to satiation. Brunson and Robinette (1986) reported a gross yield of 328 kg/ha in ponds stocked at 2471/ha and fed at a supplemental rate. Lewis and Heidinger (1971) stated that even with feeding, hybrid bluegill biomass will likely be constrained to 2400 kg/ha by water quality. In this study, fish stocked at large size and high density attained an average harvest standing crop of 3565 kg/ha with the aid of emergency aeration.

Overall FCR (5.5) in this study was higher than reported in previous studies (Brunson and Robinette, 1982). However, previous studies were conducted at much lower densities, allowing natural foods to make a greater contribution. In the present study, feed rates were intentionally maintained at levels such that food availability was not limiting and growth differences would be due to treatment variables. This could have allowed overfeeding during certain periods. Once optimum stocking sizes and densities are identified, refinement of feeding rates and techniques should improve feed conversion efficiencies. Hybrids began to feed actively as temperatures rose above 8°C. The most active feeding period was during early summer (June). As water temperatures increased, feeding slowed. Active feeding ceased below 8°C. Floating diets were advantageous even during the winter period.

Overall, male:female sex ratio was very disproportionate (8.8:1) in this study. Of the 500 fish examined, 89.8% were male. This is similar to results of Ellison and Heidinger (1978) who reported that of 580 GS × BG hybrids examined, 80% were male. Hybrids were readily harvestable by seine and did not tend to burrow or jump. Fish also handled well at a wide range of temperatures without obvious signs of stress. No acute epizootics were encountered during the 1-year-culture period. Some fish (3–4) in early July were observed to be swimming in a listless manner. Examined fish were found to have internal *Plesiomonas shigelloides* bacteria. No treatment was recommended and no significant losses were incurred.

6. Summary

Individual weight gains and biomass increases were higher in fish stocked at small sizes and/or low densities. However, yield was much higher in ponds stocked with large fish at high density. Only 1% of fish stocked at large size (66 g) at high density did not reach marketable size ($\geq$ 110 g). When stocked at small size (38 g) at low density, 23% did not reach marketable size, and at high density 45%. Stocking large fish at low density actually increased the percentage of sub-harvestable size (5%) and did not improve FCR or survival compared to large fish stocked at high density. Stocking large fish at high density appears to be the most efficient use of pond resources and produces more fish of harvestable size. Effect of higher densities on feed utilization and improved feeding regimes should be investigated to increase production efficiency. Standardized evaluations of catchability

(hook and line harvest) of different sizes and densities should be conducted to evaluate the applicability of the hybrids to fee-fishing markets.

Acknowledgments

We thank Steve Mims, Laura Tiu, Daniel Yancey, Eddie Reed, Jr., and Wendell Harris for their assistance, and Karla Richardson and Stephanie Cassin for typing the manuscript. This research was funded by a USDA/CSRS grant to Kentucky State University under agreement KYX-80-91-04A.

References

AOAC, 1990. Official Methods of Analysis, 15th edition. K. Helrich (Editor). Association of Official Analytical Chemists, Inc., Arlington, VA, 1298 pp.

Brunson, M.W., 1983. Investigations in the use of male bluegill × female green sunfish hybrids for stocking Mississippi ponds. Doctoral Dissertation. Mississippi State University, Mississippi.

Brunson, M.W. and Robinette, H.R., 1982. Supplemental winter feeding of hybrid sunfish in Mississippi. Proc. Annu. Conf. S.E. Assoc. Fish and Wildlife Agencies, 36: 155–159.

Brunson, M.W. and Robinette, H.R., 1986. Evaluation of male bluegill × female green sunfish hybrids for stocking Mississippi farm ponds. North Am. J. Fish. Manage., 6: 156–167.

Dowdy, S. and Wearden, S., 1983. Statistics for Research. John Wiley and Sons, New York, NY, 537 pp.

Ellison, D.G. and Heidinger, R.C., 1978. Dynamics of hybrid sunfish in southern Illinois farm ponds. Proc. Annu. Conf. S.E. Assoc. Fish and Wildlife Agencies, 30: 82–87.

Heidinger, R.C., 1975. Growth of hybrid sunfishes and channel catfish at low temperatures. Trans. Am. Fish. Soc., 104: 333–334.

Lewis, W.M. and Heidinger, R.C., 1971. Supplemental feeding of hybrid sunfish populations. Trans. Am. Fish. Soc., 101: 619–623.

Ricker, W.E., 1975. Computation and interpretation of biological statistics of fish populations. Fish. Res. Board Can. Bull., 191.

Statistical Analysis Systems, 1988. SAS/STAT User's Guide. Release 6.03 Edition. SAS Institute, Inc., Cary, NC, 1028 pp.

Weatherly, A.H. and Gill, H.S., 1987. The Biology of Fish Growth. Academic Press, New York, NY, 113 pp.

Zar, J.H., 1984. Biostatistical Analysis, 2nd edition. Prentice-Hall, Englewood Hills, NJ, 383 pp.