EVALUATION OF HYBRID BLUEGILL FOR USE IN URBAN RECREATIONAL FISHERIES

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INTRODUCTION

Hybrid sunfish (*Lepomis* spp.) were first described by Hubbs and Hubbs (1931) and are characterized as intermediates between the parent species (Lagler and Steinmetz 1957; Smitherman and Hester 1962). Hybrid sunfish are fertile; however, males usually greater than 80% of the population (Ricker 1948; Krumholz 1950; Heidinger and Lewis 1972; Laarman 1974; Tidwell et al. 1994). This skewed sex ratio leads to reduced reproduction and helps prevent overpopulation and stunting in sunfish species (Bennett 1971). Laarman (1979) found that reproduction by bluegill was 279 times greater than that of hybrid bluegill. In addition, hybrid bluegill do not successfully backcross with either parental species in ponds or laboratory settings (Brunson and Robinette 1987).

Due to their rapid growth, high percentage of males, and acceptance of a supplemental diet (Lewis and Heidinger 1971), hybrid sunfish have received considerable attention from sport fishermen and the aquaculture industry. They have become increasingly popular over the last decade for use in recreational fisheries due to their aggressive nature and vulnerability to angling (Childers 1967; Childers and Bennett 1967; Henderson and Whiteside 1976; Ellison and Heidinger 1978; Brunson and Robinette 1986). Some state fish and wildlife agencies have begun stocking them into urban fisheries to ensure success of youth fishing events.

Of all possible hybrids studied, the F_1 hybrid bluegill (male bluegill Lepomis macrochirus x female green sunfish L. cyanellus) appears to be the most desirable because it readily accepts supplemental feed (Lewis and Heidinger 1971), shows better growth and condition, produces fewer F_2 hybrids, and is easier to catch than other sunfish hybrids (Crandall and Durocher 1980). Therefore, we chose to evaluate hybrid bluegill for use in urban recreational fisheries. We were interested in production of hybrid bluegill for stocking in recreational fisheries and management of those populations.

We evaluated strategies to increase production of hybrid bluegill and assessed the costs of these strategies. The stocking of hybrid bluegill for youth fishing clinics is becoming increasingly popular, thereby creating short-term put-and-take fisheries. Fish used for this purpose need to be of a harvestable size at the time of stocking. These fish are relatively expensive to produce and typically require three years of growth. Laboratory studies have shown that alternative feeding strategies can improve performance of hybrid bluegill by increasing growth rate and reducing size variation. We evaluated these feeding strategies in a production setting to determine their usefulness to fish producers.

We also evaluated factors influencing management of sustained populations of hybrid bluegill in urban fisheries. Numerous studies have recommended stocking a predator to control reproduction, and only largemouth bass have been evaluated with hybrid bluegill. However, largemouth bass/hybrid bluegill populations may result in stunted bass because hybrid bluegill probably do not have the reproductive potential to support a quality bass population. Other predatory species need to be evaluated to determine the best hybrid bluegill/predator combination. Additionally, no investigation has evaluated the potential of fishing regulations for managing hybrid bluegill. Fishing mortality has not been studied and has great potential to impact populations of hybrid bluegill because of their high catch rates. Ultimately, knowledge of the effects of fishing pressure, catch rate, and fishing mortality will be crucial to the formulation of management decisions for hybrid bluegill.

The objectives of this study were to:

1. Evaluate alternative feeding strategies for the production of hybrid bluegill.
    a. Evaluate the production potential of a feeding strategy known to increase growth by inducing compensatory growth in hybrid bluegill.
    b. Determine effects of feeding frequency on production of hybrid bluegill in ponds.
2. Evaluate factors that influence management of hybrid bluegill in recreational fisheries.
    a. Determine short-term catch and release mortality and catch rates of hybrid bluegill at young fishing clinics.
    b. Evaluate channel catfish as a predator species for stocking with hybrid bluegill

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CHAPTER I

EVALUATION OF ALTERNATIVE FEEDING STRATEGIES FOR THE PRODUCTION OF HYBRID BLUEGILL

COMPARISON OF FEEDING REGIME AND DIET ON COMPENSATORY GROWTH OF HYBRID BLUEGILL*

* Sager, C. R. and D. L. Winkelman. Comparison of feeding regime and diet on compensatory growth of hybrid bluegill. Proceedings of the Southeastern Association of Fish and Wildlife Agencies. *In press.*

ABSTRACT

We conducted two experiments to evaluate the potential of feeding schedules designed to elicit compensatory growth and increase growth of hybrid bluegill (F_1: male bluegill *Lepomis macrochirus* x female *L. cyanellus*). The first experiment evaluated a commercially prepared pellet and consisted of three treatments; fish fed everyday and fish starved for 2 or 4 days after cessation of hyperphagia. A second experiment evaluated two diets, mealworms and commercial pellets, fed everyday and on a 2-d starvation schedule. Growth and feed consumption in starvation treatments did not significantly exceed that of controls in either experiment. Our results contradict those of earlier studies that showed increased growth and consumption with similar feeding methods. Our results suggest that increasing growth rate using feeding schedules designed to elicit compensatory growth may not be practical when feeding an artificial pelleted diet, and feeding strategies of this type may be difficult to implement for large-scale hybrid bluegill production. However, our results suggest that hybrid bluegill do not need to be fed everyday to optimize growth and alternative feeding regimes could significantly reduce labor costs.

INTRODUCTION

Compensatory growth is a period of rapid weight gain following a period of food deprivation. Compensatory growth has been observed in invertebrates, mammals, birds, and fish (Wilson and Osbourn 1960, Broekhuizen et al. 1994, Jobling 1994); however the mechanisms underlying this phenomenon are not fully understood. Most studies suggest a physiological change, whereby organisms reduce their basal metabolic rate, increase food conversion efficiency, and begin excessive consumption (hyperphagia) once food supplies are available (Miglavs and Jobling 1989, Russell and Wootton 1992, Wieser et al. 1992, Jobling 1994).

Regardless of the mechanism, compensatory growth has potential for increasing commercial production in aquaculture. Hayward et al. (1997) were the first to show that compensatory growth occurred in hybrid bluegill fed mealworms (*Tenebrio molito*) on various feeding schedules. We attempted to duplicate their experiment using a commercially produced diet. Our first experiment used a commercially prepared pelleted diet and three treatments used by Hayward et al., fish fed everyday, fish starved for two days and four days. We performed a second experiment to more closely duplicate the protocol and experimental design of Hayward et al. (1997), as well as directly compare mealworms to a commercial pellet diet.

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METHODS

Experiment 1

We acclimated approximately 70 hybrid bluegill to laboratory conditions (14 h light: 10 h dark photoperiod and 20 °C water) for two weeks and trained them to consume a pelleted diet. During September 1999, fish were selected for size uniformity (2.90 – 3.27 g) and individuals were placed into 15, 20-L aquaria. Each aquarium was equipped with an airstone, a 100-watt aquarium heater, and visual dividers to prevent agonistic behavior from influencing neighboring fish. These fish were acclimated for eight days prior to the initiation of feeding trials. During acclimation fish were fed to satiation and water temperatures were elevated to 24 °C, the water temperature used by Hayward et al. (1997).

The experiment consisted of three treatment groups, selected on the basis of their performance as reported in Hayward et al. (1997); a continuously fed control (PC) and two treatments consisting of two and four day starvation periods following feeding (P2 and P4, respectively). The feeding schedule of each group followed the procedures described by Hayward et al. (1997) with one exception. Hayward et al. (1997) removed food items after 24 h; however, because pellets dissolved, we removed excess pellets after 2 h so we could make accurate estimates of consumption. Observations indicated that fish consumed food primarily during the first 30 minutes after feeding and rarely consumed additional food when fed twice per day. Therefore, we concluded that a two-hour feeding period was sufficient to estimate daily consumption. The experimental diet was a commercially produced 2.4 mm floating pellet (EXTR 450, Rangen Inc., Angleton TX). All feedings took place between 0800 and 0830 daily. Aquaria were cleaned and quarter volume water changes were made every 3-5 d to maintain water quality.

We monitored daily food consumption by feeding an excess number of pellets, counting and removing all pellets remaining after 2 h, and multiplying the number consumed by the mean dry pellet weight (0.0121 g). Each fish was measured (nearest 1 mm) and weighed (nearest 0.01 g) weekly, one hour before feeding. At the conclusion of each feeding day, the daily weight-specific consumption for treatments P2 and P4 was evaluated. Each starvation treatment (P2 or P4) was fed on consecutive days until the daily weight-specific consumption no longer significantly exceeded that of the control group (Student's t-test; $P<0.05$), then the predetermined starvation period (2 or 4 d) was initiated the following day. The experiment was scheduled to end at the conclusion of a feeding cycle on or beyond 80 days for both treatment groups.

Absolute growth rate (AGR) and gross growth efficiency (GGE) were calculated using the following formulae:

$$AGR = (W_f - W_i)/T \qquad GGE = (W_f - W_i)/CC$$

where W_f and W_i are the final and initial weights, respectively, T is the total number of days and CC is the cumulative consumption. Growth, consumption, and food conversion efficiency data were analyzed using analysis of variance (SAS Institute 1998). Post hoc contrasts were made using least square means. Comparisons were considered significant if $P<0.10$ and all probabilities are reported. We performed correlations between CC and AGR to estimate the effect of consumption on growth.

Experiment 2

We acclimated approximately 100 hybrid bluegill to the laboratory for two weeks. Thirty-two hybrid bluegill (11.25-14.75 g) were selected in the same manner as in Experiment 1, except we chose fish similar in size to Hayward et al. (1997; Table 1). These fish were randomly placed into individually numbered, 3.25-L chambers (20 X 12.5 X 13 cm) of clear plexiglass. Each chamber was perforated with 32 holes (3.5 mm) on the sides to allow water circulation and fitted with a clear plexiglass lid. The chambers were placed side by side on a rack that elevated them 30 cm off the bottom of a 2.7 X 0.6 X 0.6 m flow through circulation tank. Municipal water, filtered through an organic filtration cartridge, filled the tank to within 1 cm of the top of the chambers. The tank was fitted with airstones and eight 300-watt submersible aquarium heaters to maintain water temperatures at 24 ± 1 °C throughout the experiment. The lab was maintained at a constant photoperiod of 14 h light: 10 h dark.

This experiment consisted of two diet types and two feeding schedules. The diet types were a 4.8 mm floating pellet (EXTR 400, Rangen Inc., Angleton TX) and mealworms. The feeding schedules consisted of a control group fed everyday and a 2-d starvation group. This resulted in 4 treatments, pellet control (PC), mealworm control (MC), pellet 2-d starvation (P2), and mealworm 2-d starvation (M2). The feeding protocols for the control and 2-d starvation groups were similar to Experiment 1. Due to differences in chamber size and feed type in Experiment 2, pellets broke down more slowly and were allowed to remain for 7 hours after feeding. Feedings occurred between 1000 and 1015 daily. Consumption data was collected by weighing and feeding a known number of food items (pellets or mealworms), counting the number removed, and multiplying the number consumed by the mean weight of the fed items. Collection of fish live weights, statistical analyses, and termination of the feeding trials were performed identically to Experiment 1. Two fish were excluded from the PC treatment on day 45 of the experiment due to apparent illness, and were not included in the final analyses. None of the remaining fish exhibited signs of illness and remained healthy throughout the experiment.

RESULTS

Experiment 1

Differences in mean final weights ($F = 3.46$; $df = 2, 12$; $P=0.065$) and absolute growth rates ($F = 3.42$; $df = 2, 12$; $P=0.067$) were significant (Table 1) among treatments. Pairwise comparisons indicated treatment P4 had a significantly lower final weight and absolute growth rate ($P<0.05$) than the control, whereas treatment P2 was not significantly different ($P>0.10$) than either group. No significant difference occurred between mean gross growth efficiencies ($F = 0.96$; $df = 2, 12$; $P=0.4104$) (Table 1).

Growth was positively correlated with cumulative consumption ($R^2=0.95$, $P<0.01$). Differences in cumulative consumption were significant among treatments ($F = 7.98$; $df = 2, 12$; $P=0.0063$). Controls consumed significantly more food than both the P2 and P4 treatments (1.7 and 2.3 times more than P2 and P4, respectively, $P<0.05$, Table 1). Mean consumption per feeding day did not differ among treatments ($F = 0.63$; $df = 2, 12$; $P=0.5473$, Table 1).

The mean feeding period following starvation for treatments P2 and P4 was 1.9 and 2.2 d, respectively. This resulted in feeding day to deprivation day ratios less than 1.0 (Table 1). For treatment P2, 7 of the 21 no-feed/refeed cycles did not induce hyperphagia and resulted in a one-day feeding period. Treatment P4 followed each starvation period with at least one day of hyperphagia.

Treatments PC, P2, and P4 concluded on days 82, 82, and 81 of the experiment, respectively. Because only 1 d separated the conclusion of the three groups, the final weights were compared without adjusting for the additional day; however, all other calculations were based on the total number of days. Water temperatures fluctuated throughout the experiment (mean temperature = 23.4 °C, range = 19.5 - 29.0 °C) and daily temperature fluctuations may have influenced daily consumption. This problem was alleviated in the second experiment.

Experiment 2

Absolute growth rates did not differ among treatments ($F = 0.41$; $df = 3, 26$; $\underline{P}=0.75$), Table 1). Mean gross growth efficiencies (Table 1) were significantly higher for pellet diets (treatments P2 and PC) than mealworm diets (treatments M2 and MC) ($F = 60.0$; $df = 1, 26$; $\underline{P}=0.0001$). Pellets consisted of 40.0% protein and 6.1% moisture, while mealworms consisted of 21.6% protein and 58.9% moisture. These differences in diet composition may have resulted in the differences in utilization efficiencies.

Growth was positively correlated with cumulative consumption (Pellet $R^2=0.95$ and Mealworms $R^2=0.97$, $P<0.01$). There was no significant difference in cumulative consumption between treatments M2 and P2 and their corresponding control groups ($\underline{P}>0.10$, Table 1). Mean consumption per feeding day was significantly different among the four groups ($F = 7.64$; $df = 3, 26$; $\underline{P}=0.0008$). Pairwise comparisons revealed that M2 consumed a significantly greater amount per feeding day than all other groups ($\underline{P}<0.01$). Differences in consumption per feeding day were not significant for MC, P2, and PC

(Table 1). Feeding periods for treatments M2 and P2 averaged 2.5 and 2.3 d, respectively. Hyperphagia was not induced during 2 cycles for treatment M2 and 3 cycles for treatment P2.

Treatment groups fed mealworms and those fed pellets concluded on day 86 and 82 of the experiment, respectively. Because of the difference in termination dates, only absolute growth rates were statistically analyzed.

DISCUSSION

Our results differ dramatically from those of Hayward et al. (1997, 2000), which indicated that hybrid bluegill fed mealworms on a 2-d no-feed/refeed schedule would significantly outgrow continuously fed controls. Initially, we wished to evaluate feeding schedules that elicited compensatory growth (Hayward et al. 1997) using a commercially prepared fish feed. We expected that fish fed a pelleted diet would increase their growth rate in response to starvation schedules and that the response might differ in magnitude to that of fish fed mealworms. However, we could not duplicate the results of Hayward et al. (1997, 2000) with either mealworms or a commercially prepared diet.

The differences in results between our study and those of Hayward et al. (1997, 2000) are probably due to differences in duration of hyperphagia. In two previous experiments (Hayward et al. 1997, 2000) fish were hyperphagic for approximately six days after a 2-d starvation period. Fish in our experiments did not exhibit these prolonged periods of hyperphagia. Hybrid bluegill growth is directly correlated to consumption (Wang et al. 1998, and the present study), therefore reduced feeding periods in our experiments negatively influenced growth.

We have no explanation for the differences in the duration of hyperphagia between the studies. The only major deviation between our second experiment and previous work was the length of time food remained in the water. Because commercial pellets dissolved, it was not practical to allow the feed to remain in the aquaria for a 24 h period as was done by Hayward et al. (1997, 2000). Based on our observations, however it appears that most feeding occurred during the first 30 minutes after food was introduced and we do not feel that the shortened feeding period greatly reduced daily consumption.

Social interactions have been shown to negatively affect growth (Jobling and Reinsnes 1986, Jobling and Baardvik 1994) and may be detrimental to feeding strategies of this type. Hayward et al. (2000) tested 2-day no-feed/refeed schedules on group held hybrid bluegill in the laboratory and found that the growth of treatment groups did not significantly exceed that of continuously fed controls. The effects of social interactions on feeding regimes designed to elicit compensatory growth need further evaluation before these strategies are implemented for large-scale production.

To be useful for aquacultural production, compensatory growth must be easy to induce and monitor, practical in a production setting, and occur over a range of environmental conditions. Biomass and consumption must be estimated daily to accurately estimate hyperphagia and this would not be practical in a production setting. Additionally, our experiments indicated that compensatory growth may be difficult to induce. Finally, experiments holding fish in groups indicate that compensatory growth may be overcome by social interactions (Hayward et al. 2000). Although we did not increase absolute growth rate, our results suggest that fish do not need to be fed daily to optimize growth and alternative feeding strategies could significantly reduce labor costs associated with feeding. Our results, as well as Hayward et al. (1997, 2000) suggest that feeding strategies could be useful to fish producers and are worth further study.

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Table 1. Sample size (N), total number of experimental days, mean (standard error) start and finish weights, absolute growth rates (AGR), gross growth efficiency (GGE), mean cumulative consumption, consumption per feeding day (FD), number of no-feed/refeed cycles completed and mean feeding days per deprivation days (DD) for treatment groups of hybrid bluegill. Treatment means with different upper case letters are significantly ($\underline{P}< 0.10$) different from other treatments within that experiment.

Experiment	Treatment	N	Total days	Initial weight (g)	Final weight (g)	AGR (g/d)		GGE	Cumulative Consumption		Consumption per FD		Total Cycles	FD/DD
Experiment 1	PC	5	82	3.67 (0.17)	12.23 (2.04)	0.10 (0.02)	A	1.13	7.3 (1.1)	A	0.09	A		
	P2	5	82	3.53 (0.13)	9.12 (1.00)	0.07 (0.01)	AB	1.23	4.4 (0.6)	B	0.11	A	21	0.95
	P4	5	81	3.78 (0.21)	7.25 (0.57)	0.04 (0.01)	B	1.08	3.2 (0.4)	B	0.11	A	13	0.56
Experiment 2	MC	8	86	11.98 (0.19)	20.28 (1.95)	0.10 (0.02)	A	0.35	21.6 (3.4)	A	0.25	A		
	M2	8	86	12.17 (0.18)	23.79 (2.91)	0.14 (0.03)	A	0.43	23.0 (3.9)	A	0.48	B	19	1.26
	PC	6	82	11.76 (0.24)	20.96 (1.87)	0.11 (0.02)	A	0.76	11.7 (1.4)	B	0.14	A		
	P2	8	82	12.29 (0.23)	21.99 (1.03)	0.12 (0.01)	A	0.83	11.5 (0.8)	B	0.26	A	19	1.16
Hayward et al. (1997)	MC*	7	105	13.84 (1.16)	23.13 (3.43)	0.09 (0.02)	A	0.31	27.5 (4.1)		0.26			
	M2*	7	105	13.99 (1.21)	32.70 (5.40)	0.18 (0.04)	B	0.35	48.7 (9.8)		0.64		13	2.92
	M4*	7	105	13.64 (1.22)	26.04 (4.78)	0.12 (0.04)	A	0.31	35.9 (9.2)		0.56		10	1.60

* Treatments MC, M2, and M4 correspond to C, D2, and D4 in Hayward et al. (1997).

EFFECTS OF INCREASED FEEDING FREQUENCY ON GROWTH OF HYBRID BLUEGILL IN PONDS

ABSTRACT

Increased feeding frequency has been used as an aquaculture tool to increase growth and food conversion efficiency. Recent laboratory studies have indicated that feeding frequency could be used to reduce size variation within groups of hybrid bluegill. Our experiment evaluated growth of pond-reared hybrid bluegill (F1: male bluegill *Lepomis macrochirus* x female *L. cyanellus*) when fed equal amounts of food either once or four times per day. We were particularly interested in reducing size variation and increasing the percentage of harvestable size fish ($\geq$ 110g). After 194 days, there was no significant effect of feeding frequency on growth, food conversion efficiency, size variation, or percentage of harvestable size fish.

INTRODUCTION

High levels of growth variation have been observed in centrarchids and can be partially or wholly attributed to social interactions (Hubbs and Cooper 1935). Aggression and formation of dominance hierarchies are well documented in sunfish (Allee et al. 1948; Erickson 1967; Janssen 1974; Chiszar et al. 1976; Henderson and Chiszar 1977; Beacham 1987) and are believed to reduce food intake and suppress growth (Li and Brocksen 1977; Noakes and Leatherland 1977; Ejike and Schreck 1980). Aggressive behavior seems to be size dependent (Chiszar et al. 1972), with the largest, most dominate fish having an advantage (McComish 1971; Chiszar et al. 1972; Beacham 1987; Henderson and Chiszar 1977). Allee et al. (1948) and MacPhee (1961) showed that within *Lepomis*, dominant fish obtain more food and grow faster than subordinates. The response of growth to social interactions may create bimodal size-frequency distributions and reduced overall production.

There are numerous benefits to reducing size variation, such as maximizing production efficiency, reducing food wastage, and improving water quality (McCarthy et al. 1992; Jobling and Baardvik 1994). If dominance hierarchies could be broken down under culture conditions, it might be possible to increase overall production. One way to reduce aggressive behavior is to increase food availability. Magnuson (1962) showed that medaka (*Oryzias latipes*) exhibited aggressive behavior only when food supplies were limited. McCarthy et al. (1992) reduced variability in individual consumption and feeding hierarchies by increasing the daily ration for rainbow trout *Oncorhynchus mykiss*. Another approach is to distribute food more uniformly throughout a population by increasing the frequency of feedings (Jobling 1983; Wang et al. 1998). Wang et al.

(1998) used multiple meals each day to break down hierarchies and reduce size variation of group-held hybrid bluegill in a laboratory setting. Increased feeding frequency significantly increased consumption and growth rate over groups fed once daily (Wang et al. 1998).

Previous pond growth experiments with hybrid bluegill have focused on stocking density (Tidwell et al. 1994;Tidwell and Webster 1993) and diet composition (Tidwell and Webster 1993; Tidwell et al. 1992). To our knowledge there has been no attempt to determine effects of feeding frequency on hybrid bluegill in pond aquaculture. Our goal was to determine effects of two feeding frequencies on production of hybrid bluegill in ponds. The primary objectives were to 1) compare growth rates and size variation between feeding regimes consisting of one or four feedings per day, and 2) determine effects of these treatments on food conversion and water quality.

METHODS

Feeding frequency experiments were conducted at the Oklahoma Cooperative Fish and Wildlife Research Unit Pond Facility. In late April 2000, Age-1 hybrid bluegill were harvested by seine (23 x 1.8 m bag seine with 6.35 mm mesh) and sorted with a 26-mm plastic coated wire-mesh grader. All fish not passing easily through the grader (91-157 mm) were counted, weighed and stocked into ten 0.1-ha ponds at a density of 6,000 fish/ha. Forty fish from each pond were weighed and measured to determine initial size variation.

Two treatment groups were evaluated: one group was fed once per day (FRQ1) and the other was fed four times per day (FRQ4). Each treatment group was replicated 5 times and assigned to ponds randomly. All FRQ4 ponds were equipped with a tripod and automatic feeder (Sweeney Inc, Model DF5) adjusted to dispense one-fourth of the daily meal at 0830, 1200, 1530 and 1900. FRQ1 ponds were fed at 0830 by broadcasting feed by hand to an area similar to that of the automatic feeder. Fish were fed a commercially produced pellet (Rangen Inc. EXTR 400, 3.2-4.8 mm) at a rate of 3% of the mean biomass per treatment every other day. Biomass was estimated every 28 days by weighing and measuring 50 fish from each pond. Because ponds were fed at different times, sampling occurred ≥ 36 h after the last feeding to remove bias associated with stomach fullness.

Temperature and dissolved oxygen was monitored (YSI Model 57) at 0800 on feeding days. Ammonia, nitrite, pH, and Secchi depth were monitored (Hach Model FF-1A) biweekly. Because ponds were not equipped with aeration, feeding was suspended if dissolved oxygen level in any pond was < 3.0 mg/L.

Feeding trials concluded after 194 days. The ponds were drained, all fish were counted for an estimate of survival and they were weighed collectively to determine biomass. A total of 50 fish per pond were weighed and measured to determine final size variation. Weight gain, food conversion ratio (FCR), percent survival, and percent of fish reaching harvestable size were calculated as: weight gain (g) = $(W_f/n_f - W_i/n_i)$, where W_i and W_f are the initial and final biomasses within a pond, and n_i and n_f are the initial number of fish stocked and the number removed from a pond; FCR = [total weight of food provided/$(W_f - W_i)$]; percent survival = (number removed/number stocked); % harvestable size = percent of fish ≥ 110 g. Weight frequency distributions were tested using a Kolmogorov-Smirnov two-sample test. Inter-individual weight variation was evaluated using percent change in coefficient of variation (CV). CV change (%) =

$100^*(CV_f - CV_i)/CV_i$, where CV_i and CV_f are the initial and final CVs of fish weights in each pond. Water quality parameters were evaluated using repeated measures ANOVA.

We determined production costs for rearing age-1 and age-2 hybrid bluegill during this experiment. Due to the high variability in fixed costs (pond construction, equipment, and water licenses), we focused only on variable costs (feed and labor). Variable costs included feed costs and labor for feeding, testing water quality, and stocking or sampling fish. Labor costs were set at $6.00/hr.

RESULTS

Final mean weight, weight gain, FCR, and percentage of harvestable fish were not significantly different between treatments ($P > 0.10$; Table 1). The Kolmogrov-Smirnov test revealed no significant difference in the distributions of weights in the final sample between treatments ($P > 0.10$; Figure 1). Coefficient of variation for weights was reduced in all ponds during the experiment; however, percent change in CVs was not significantly different between treatments ($P > 0.10$). Mean changes in CV were 52.7% and 53.9% for FRQ1 and FRQ4, respectively.

One pond (treatment FRQ1) was dropped from the analyses due to excessive rooted vegetation and consistently low dissolved oxygen levels. Feeding was suspended on 6 occasions due to low dissolved oxygen levels. Temperature, dissolved oxygen, ammonia, nitrite, pH and Secchi depth measurements were not significantly different between treatments ($P > 0.10$).

No significant difference in growth or biomass occurred between feeding strategies, therefore, production costs of fish from each treatment were combined for this budget (Table 2-A). Due to our experimental protocol, production costs may be inflated. A considerable surplus of juvenile fish was produced during year-1 that were not used in our experiment; however, all fish produced would be used or sold by fish producers, resulting in a reduced price per kilogram during year-1. Our inflated production cost carries over to estimates made in the second year. Therefore, we developed an alternative budget that would more closely represent commercial production costs of 2nd year hybrid bluegill (Table 2-B). We removed the abnormally high production cost from year-1 and assumed fish were purchased at $0.05 each. Because extensive sampling is not required for production, we removed labor costs associated with monthly sampling. This alternative budget reduced production costs by 33% and was used to calculate the production costs per kilogram and per harvestable size fish (Table 3). We produced 449.2 Kg (988.3 lbs) of 2nd year hybrid bluegill at $5.76/Kg ($2.62/lb). A total of 2,957 harvestable sized fish were produced at $0.87 each.

DISCUSSION

Feeding frequency had no significant effect on growth or food conversion of hybrid bluegill reared in ponds. Wang et al. (1998) reported increased growth and reduction in size variation for small groups (10 fish) of hybrid bluegill fed multiple meals per day. They conducted their experiments in a laboratory and were able to monitor feeding behavior and adjust feeding levels based on feeding rate. We could not make such specific observations, nor would it be practical to observe feeding four times daily in a commercial production setting. Fish in our experiment were supplied with ample amounts of feed, as indicated by poor food conversion for both groups.

There was a substantial reduction in size variation in all ponds during the experiment. This indicates that the initial size variation may have been too large, thereby masking treatment effects. However, we made a concerted effort to minimize size variation at the beginning of the experiment and initial size distributions between treatments did not differ. Additional studies should consider grading the fish more precisely to alleviate potential problems. Further reductions in initial size variation would not be a practical option for fish producers, because of stress to fish and labor costs associated with increased grading and sorting.

Gebhart (2001) estimated production costs for 2nd year hybrid bluegill at $3.43/Kg ($1.56/lb). Although our total production costs and Gebhart's (2001) were similar over two years, Gebhart's (2001) estimate was $2.33 less per kilogram, probably due to the number of fish produced. If we had put all fish produced in year-1 into production, our labor costs would have been marginally higher, but the biomass produced during year-2 would have been much greater. This would have resulted in a reduced price per kilogram. Therefore, Gebhart's (2001) estimate of $3.43/Kg may be closer to the true commercial production cost.

Feeding once daily requires less labor and reduced cost for automatic feeders. Because growth performance did not differ between groups, we recommend feeding once per day when hybrid bluegill are cultured in ponds.

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Table 1. Mean initial and final weights, weight gain, food conversion ratio (FCR) and the percent of harvestable fish for treatments FRQ1 and FRQ4. Standard error is given in parentheses. Variables were not significantly different between treatments.

Treatment	Mean initial weight (g)	Mean final weight (g)	Mean Weight gain (g)	FCR	% Harvestable
FRQ1	35 (0.78)	124 (3.8)	87 (4.7)	3.47 (0.20)	73 (1.6)
FRQ4	36 (2.44)	127 (2.9)	83 (2.4)	3.45 (0.15)	80 (3.6)

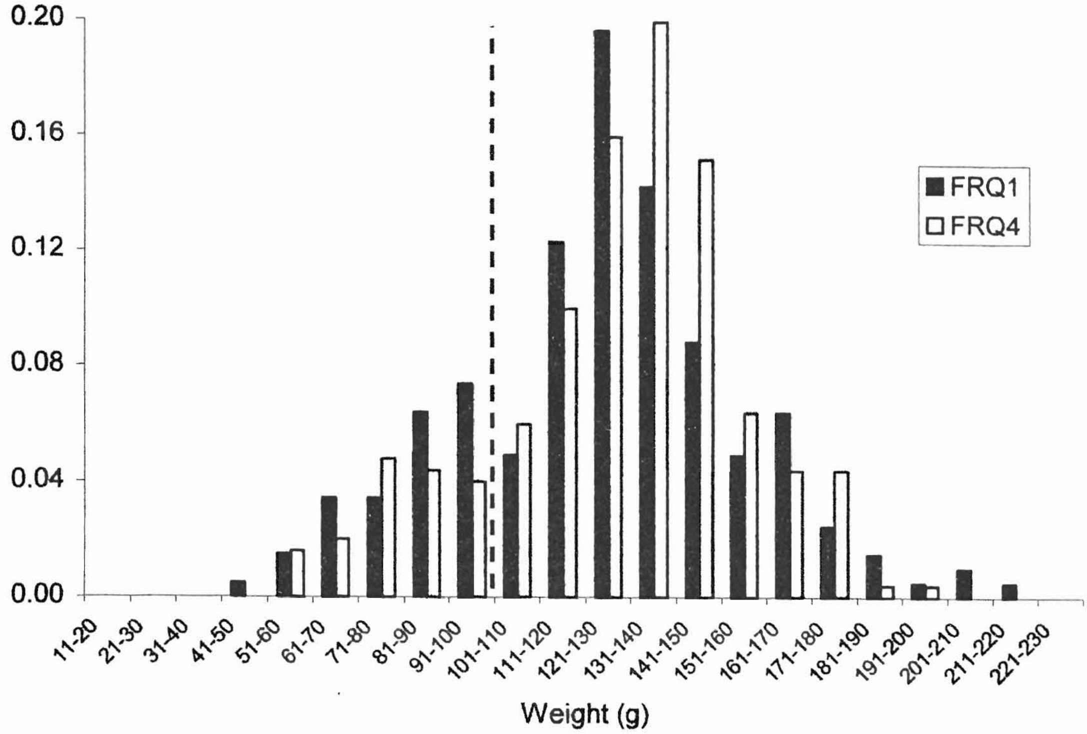
Table 2. Two 2-year budgets for hybrid bluegill production. Column A shows variable costs throughout this experiment. Column B assumes fish were purchased initially at $0.05/fish and labor costs for monthly sampling have been removed. Fixed costs are not included in this budget.

Expenses:			**A**	**B**
Year-1				
	Personnel ($6.00/hr)			
	Feeding	33.0 hrs	$198.00	$0.00
	Water quality analysis	10.0 hrs	$60.00	$0.00
	Stocking/Sampling	79.0 hrs	$474.00	$0.00
	Subtotal		$732.00	$0.00
	Feed	364.5 Kg @ $0.79	$288.00	$0.00
	Total		**$1,020.00**	**$300.00**
Year-2				
	Personnel ($6.00/hr)			
	Feeding	41.8 hrs	$250.80	$250.80
	Water quality analysis	35.6 hrs	$213.60	$213.60
	Stocking/Sampling	296.5 hrs	$1,779.00	$1236.00
	Subtotal		$2,243.40	$1700.40
	Feed	942.6 Kg @ $0.62	$584.44	$584.44
	Total		**$2,827.84**	**$2,284.84**
Grand Total			**$3,847.84**	**$2,584.84**

Table 3. Production costs per pound and per harvestable fish (Table 2-B).

	Net Kg Produced	Harvestable fish	Price/ Kg	Price/Harvestable fish
Year-1	173.2	0	$1.74	-
Year-2	276.0	2957	$8.27	$0.77
Total	449.2	2957	$5.76	$0.87

Figure 1. Weight distribution of hybrid bluegill fed once daily (FRQ1) or four times daily (FRQ4) after 194 days. Dashed line indicates harvestable size (> 110 g).



CHAPTER II

HYBRID BLUEGILL MANAGEMENT ISSUES

EFFECTS OF YOUNG ANGLERS ON HYBRID BLUEGILL POPULATIONS

ABSTRACT

Hybrid bluegill are becoming increasingly popular for stocking at youth fishing clinics and urban recreational fisheries. However, no studies have evaluated potential impacts of young anglers (ages 12 and under) on hybrid bluegill. Our objective was to quantify catch rate and short-term angling mortality associated with young anglers on hybrid bluegill. We held two fishing clinics to estimate catch rates of stocked hybrid bluegill. Anglers were observed for 10-minute intervals throughout the clinic. We also conducted catch and release mortality trials to estimate short-term mortality of fish captured by young anglers. Fish were held in net pens and observed for 36 h following capture. Mean catch rates for hybrid bluegill at the two fishing clinics were 6.6 and 4.4 fish/hour. We estimated that 66% of stocked hybrid bluegill were captured during a 2-h fishing period. We observed only one death from a total of 80 captured fish during our mortality trials. These data indicate that hybrid bluegill are suitable candidates for catch and release management.

INTRODUCTION

Hybrid sunfish have become increasingly popular for use in urban fisheries due to their exceptional catch rates, which are important in urban fishing programs for young or inexperienced anglers. Although catch rates for hybrid sunfish have been documented (Crandall and Durocher 1980; Brunson and Robinette 1986), the catch rates by young anglers have not been evaluated. Additionally, the impacts of catch and release mortality have not been evaluated for hybrid sunfish, and due to their high catch rates, angling mortality could have a large impact, even under strict fishing regulations. Future efforts to manage hybrid sunfish populations will depend on the impacts of angling.

Very few studies have assessed the effects of angling mortality on sunfish. Siewert and Cave (1990) reported 88% mortality for bluegill (*Lepomis macrochirus*) caught on worm-baited hooks and held for 10 days. Muoneke (1992) found mortality rates to be significantly higher for bluegills caught on baited hooks during the summer than those caught during the winter. Bluegill are characterized as having relatively small mouths compared to the relatively large mouthed green sunfish (*L. cyanellus*). Mouth size of hybrid bluegill (male bluegill x female green sunfish) is intermediate between the parent species (Smitherman and Hester 1962). We hypothesized that angling mortality of hybrid bluegill would be higher than that of bluegill because hybrid bluegill are more aggressive, and the increased mouth size would allow deeper hooking locations.

Primary factors contributing to the mortality of released fish include water temperature (Dotson 1982; Shramm et al. 1987), handling stress (Harrell 1987), live bait (Clapp and Clark 1989; Payer et al. 1989; Siewert and Cave 1990), and hooking location (Marnell and Hunsaker 1970; Hulbert and Engstrom-Heg 1980; Siewert and Cave 1990).

Youth fishing clinics usually occur during the summer when water temperatures are highest and live bait is often used. Therefore, we expected to see high mortality rates under these conditions. Our objectives were to determine 1) short-term catch and release mortality and 2) catch rates of hybrid bluegill at youth fishing clinics.

METHODS

Catch-and-Release Mortality

Two catch-and-release mortality experiments were conducted during May and June 2001. Prior to the May trial, 260 hybrid bluegill (14–20 cm) were stocked into a 0.01-ha pond (max depth = 1.8 m) and allowed to acclimate for 7 d. The pond was equipped with 12 net pens (1.2 x 1.2 x 1.2 m, 6.35 mm mesh) anchored with metal stakes in the center of the pond. The experiment contained two treatment groups; angled fish (caught by young anglers) and control or non-angled fish (captured by seine). Eight net pens were randomly assigned to the angled group (N=40) and 4 pens were used for control fish (N=20) during each trial.

Young anglers (ages 3-12; mean 10.2) were supplied with lightweight fishing tackle, #4 aberdeen style hooks, bobbers, and worms. During both trials, angling occurred between 1800 and 2100 h. Observers recorded hook location and presence of bleeding at the hook location. Hooking locations were grouped into one of eight categories: upper jaw, lower jaw, roof of mouth, cheek, gills/gill arch, esophagus, eye or other. Observers were allowed to aid in hook removal because we felt that this replicated conditions and handling of fish at youth fishing clinics. Fish were measured, given an individual fin clip, and placed in a net pen. Once 40 fish were caught, the pond was seined to obtain 20 control fish. Controls were measured, fin clipped, and placed in the designated net pens.

Each pen was observed at intervals of 1, 12, 24, and 36 h after being stocked. All dead fish were removed and fin clip location was recorded. Water temperature and dissolved oxygen were recorded at each interval.

Catch Rate

Catch rates were estimated at two youth fishing clinics during June (Clinic 1) and September (Clinic 2) of 2001. Both clinics were hosted at a 0.8-ha public pond located near Lake Carl Blackwell, OK. The pond contained largemouth bass (*Micropterus salmoides*), channel catfish (*Ictalurus punctatus*), white crappie (*Pomoxis annularis*), bluegill, longear sunfish (*Lepomis megalotis*), and green sunfish. Three days prior to Clinic 1, 620 hybrid bluegill (775 fish/ha; 17-20 cm) were released into the pond. Prior to Clinic 2, an additional 150 hybrid bluegill (188 fish/ha) of similar size were stocked.

All participants were 12 years of age or younger. Fishing tackle and worms were supplied to all participants. Anglers were observed over 10-min intervals while actively fishing. For each observation, age and sex of the angler were recorded, as well as bait type used and number of each species caught. Total number of anglers was recorded every 30 minutes to determine total angler effort. Observations were pooled into 30-min intervals and catch rate data was averaged and used to estimate overall catch rate and total number of fish caught.

RESULTS

Catch and Release Mortality

One fish died during both catch and release mortality experiments combined, resulting in a 1.3% mortality rate. This fish was hooked in the gills, bleeding profusely, and died within minutes of being caught. All other fish appeared healthy throughout the 36-h observational period. The fate of two fish, a control and an angled fish, was unknown during the May experiment. These fish probably escaped from the net pens because the tops were not covered in the May experiment.

Ninety-four percent of fish caught in our trials were hooked in non-sensitive locations, whereas 6% were hooked in the esophagus or gills (Figure 1). Thirteen percent bled from the hooking location and only 3 of these were hooked in sensitive areas.

Mean temperature and dissolved oxygen during the May experiment was 24.3 C and 8.5 mg/L. During June, temperatures averaged 30.8 C and dissolved oxygen levels averaged 11.1 mg/L. Anglers ranged from 3 to 12 years of age with a mean age of 10.2 over both experiments.

Catch Rate

Overall catch rates for hybrid bluegill from Clinics 1 and 2 were 6.6 and 4.4-fish/angler hour, respectively (Table 1). Catch rates for all species and total angler effort for both clinics are listed in Table 1. Fishing at Clinic 1 and 2 lasted for 2 and 3 h, respectively. We estimate that 400 hybrid bluegill, or 65% of the total fish stocked, were captured during Clinic 1, and 220 fish were caught during Clinic 2. Hybrid bluegill dominated the catch during both clinics, accounting for 86 % of fish caught. Harvest of fish was low, with < 20 hybrid bluegill being kept in either clinic.

Catch rates for 3-year-old anglers was three times the overall average for both clinics combined, indicating that they were receiving a high level of assistance. There were also very few observations for this age class, so all data collected from 3-year-old anglers was removed from the analyses.

Catch rates from Clinics 1 and 2 were grouped into 30-min intervals. Catch rates declined or remained steady over time until the final period, when they increased dramatically (Figure 2). We feel that this increase was due to experienced anglers continuing to fish until the end of the clinics. Additionally, sample sizes were small (< 10 observations) for the final period in both clinics, allowing relatively few individuals to greatly influence the average catch rate. Therefore, we removed the final period from analyses of catch rates. During Clinic 1, catch rate was negatively correlated over time ($p = 0.0320$). Catch rates for Clinic 2 were more variable and not significantly correlated with time ($p = 0.6138$).

In the analysis of angler age versus catch rates, sample sizes were small, and only ages with > 3 observations were used in the analyses. Catch rates were positively correlated with age for Clinic 1 ($p = 0.0435$) but not for Clinic 2 ($p = 0.7021$). There was no significant difference between catch rates of male and female anglers (t-test; p 0.5355) during the two clinics.

DISCUSSION

Our estimate of catch and release mortality in hybrid bluegill was considerably lower than the 25% reported for bluegill by Muoneke (1992). Temperatures and gear in that study were similar to those in our experiments, but we held fish for only 36 h, whereas Muoneke (1992) held them for 72 h. Mortality might have been higher if fish were held longer, but our goal was to evaluate short-term mortality. Additionally, mortality may increase over longer holding periods due to agonistic interactions between confined fish, thereby biasing estimates of mortality due to angling.

The percentage of fish hooked in sensitive locations during our experiments may be underestimated due to the high abundance of hybrid bluegill in the pond. We stocked fish at a higher density than would be expected at fishing clinics to reduce the span of time over which fish were caught for the experiment. This high abundance may have lead to increased catch rates and interest by the anglers, resulting in anglers giving more attention to their gear. Lower catch rates would likely lead to less interest and unattended fishing gear, that could result in a greater percentage of fish being hooked in sensitive areas.

Catch rates in our experiment were considerably lower than previously reported for hybrid sunfish (Brunson and Robinette 1986). Brunson and Robinette (1986) report catch rates ranging from 12 – 22 fish/h; however, they used volunteers proficient with the specified gear types. Level of angling experience was not quantified for anglers in our experiment; however, we believe that angler age and inexperience was the primary factor accounting for our reduced catch rates. This is supported by the positive correlation between ages and catch rate in Clinic 1.

Although catch rates were relatively low, potential exploitation was extremely high due to the concentrated fishing effort over a short period of time. We estimated that 65% of the hybrid bluegill stocked for Clinic 1 were captured during the 2-h fishing clinic. This level of exploitation is similar to the highest level reported by Brunson and Robinette (1986).

Our results illustrate the need for intensive management of hybrid bluegill in urban fisheries. Due to potentially high exploitation rates and fishing pressure that urban fisheries might receive, populations could be rapidly decimated unless strict fishing regulations are enforced. Hybrid bluegill could be managed through restrictive creel or length limits or maintained as catch-and-release fisheries. Hybrid bluegill are excellent candidates for catch-and-release management due to their low catch and release mortality.

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Table 1. Number of observations, mean age, angler sex ratio (M:F), total angler hours, and catch rates for hybrid bluegill (HBG), all other sunfish species, largemouth bass (LMB) and channel catfish (CCF), during Clinics 1 and 2.

Clinic	# Obs	Mean age	M:F	Angler Hrs	Catch Rate (fish/angler hr)			
					HBG	Sunfish	LMB	CCF
1	81	8.6	1.2	64	6.6	0.68	0.76	0.76
2	64	7.7	0.9	47	4.4	0.58	0.10	0.00

Figure 1. Distribution of hooking locations for 80 F1 hybrid bluegill. All fish caught by anglers ages 12 and under using worms, and #4 aberdeen style hooks.

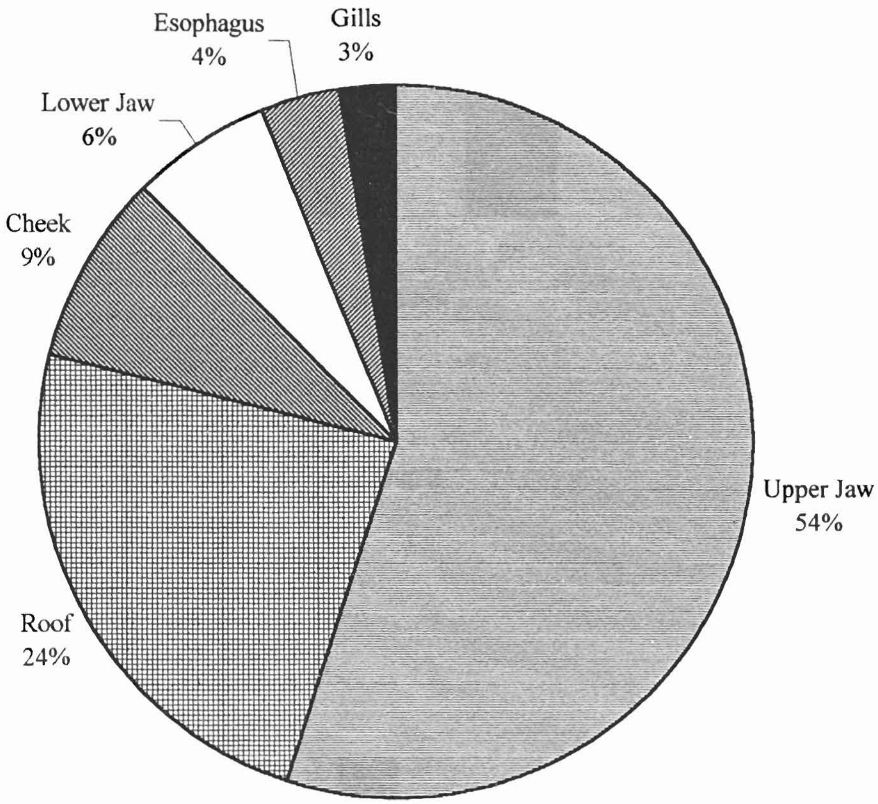
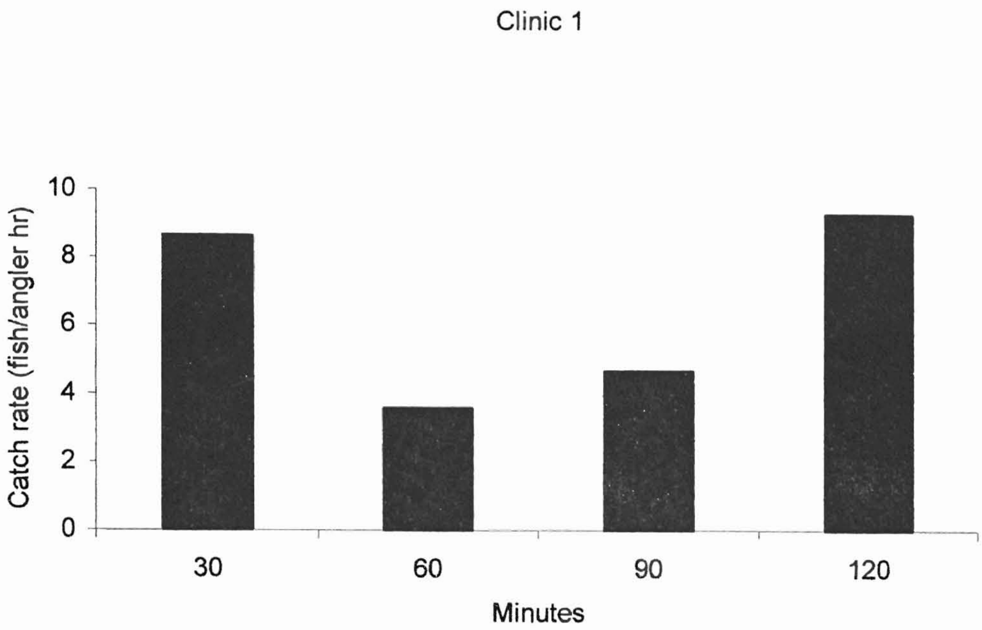
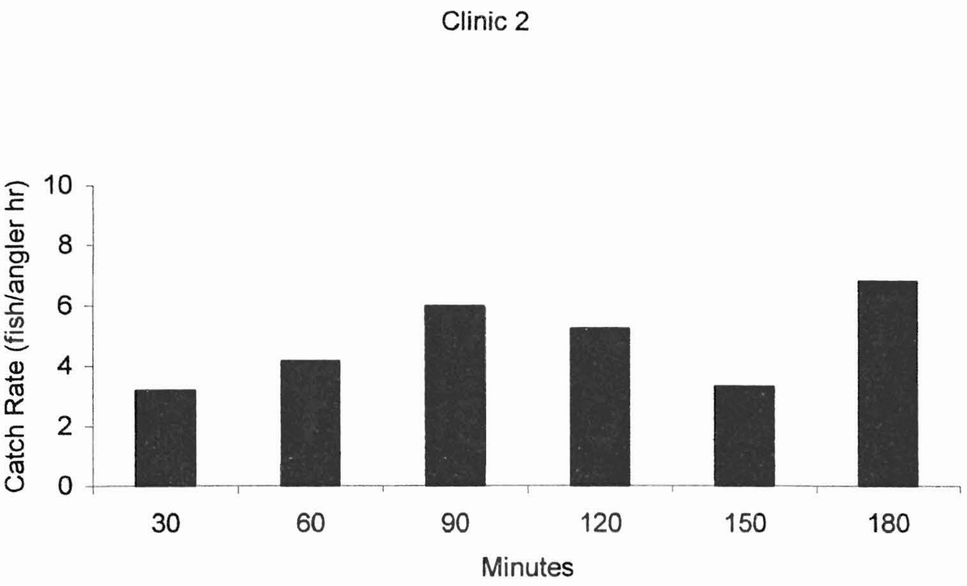


Figure 2. Catch rates over time for hybrid sunfish at Clinics 1 and 2.





EVALUATION OF CHANNEL CATFISH AS A PREDATOR FOR STOCKING WITH HYBRID BLUEGILL

ABSTRACT

Previous studies have shown that F_1 hybrid bluegill grow faster when stocked with a larger predatory species. However, little research has evaluated the efficiency of such predatory species or the proper species combinations to stock with hybrid bluegill. Our experiment evaluated reproductive success and growth of hybrid bluegill when stocked with channel catfish (*Ictularus punctatus*). Two treatments, hybrid bluegill only and hybrid bluegill/channel catfish, were replicated 5 times each, and evaluated in 0.1-ha ponds from 12 March 2001 to 19 February 2002. Reproduction by hybrid bluegill was unsuccessful in 3 of 5 ponds for each treatment and the numbers of F_2 hybrid bluegill were highly variable in ponds with reproductive success. Hybrid bluegill were significantly larger in ponds without channel catfish.

INTRODUCTION

Hybrid bluegill are fertile hybrids with approximately 10% of the population being female and there is a potential for reproduction, overpopulation, and ultimately slower growth and stunting. Hybrid bluegill grow faster in ponds containing one or more predator species (Heidinger and Lewis 1972; Ellison and Heidinger 1978), and current recommendations call for stocking largemouth bass (*Micropterus salmoides*) to control reproduction of hybrid bluegill in Oklahoma ponds (Dean and Gebhart 1995). However, stunting of largemouth bass has been observed in bass-bluegill ponds when bluegill populations are unable to support a growing bass population (Harders and Davies 1973). Reproduction of hybrid bluegill is far less than that of pure bluegill (Laarman 1979), which would result in less forage for bass, therefore, bass-hybrid bluegill combinations would probably lead to stunted bass populations.

Other predatory species have not been investigated for predator control of hybrid bluegill. Desired characteristics for a predator species are 1) reduced or no reproduction 2) no competition with other desired species 3) contribution to the fishery, and 4) control of reproductive success of desired species. Channel catfish (*Ictularus puntatus*) possess most of these characteristics. They are cavity spawners and have limited reproductive success in ponds devoid of artificial spawning structures (Prather 1959; Prather 1969; Powell 1976). In addition to being piscivorous, channel catfish readily accept supplemental feed, which could reduce competition for natural resources. Channel catfish are generally considered a desirable sport fish by anglers. Prather (1959) found that total biomass harvested from catfish ponds could be as much as eight times greater than harvest from bass-bluegill ponds. Ellison and Heidinger (1978) found that 9 of 13 pond owners were satisfied with channel catfish when stocked with hybrid sunfish. However, the ability of channel catfish to control reproductive success of hybrid bluegill is unknown. We hypothesized that channel catfish would provide population control of hybrid bluegill. The objective of our experiment was to evaluate channel catfish as a predator species for stocking with hybrid bluegill.

METHODS

During mid-March of 2001, 10 rectangular 0.1-ha ponds were stocked with 150 age-2 hybrid bluegill (1,500 fish/ha). Five of these ponds were also stocked with 100 channel catfish per pond (360-560 mm, 1,000 fish/ha) during early-April. Fish were fed a floating pellet diet (Rangen Inc., EXTR400, 4.8 mm) on a low intensity (1% biomass) feeding regime twice per week. Temperature, dissolved oxygen, and Secchi depth were monitored (YSI Model 57) at 0830 on feeding days. All feeding was suspended when dissolved oxygen levels dropped below 3.0 mg/L, or water temperatures dropped below 10 °C in any pond.

Baited minnow traps (42 cm x 23 cm; 6 mm mesh) were used every 56 d to determine relative abundance of F_2 hybrid bluegill. Each pond was divided into eight equal segments, and traps were randomly placed 1 or 5 meters from the shoreline in each segment. Traps were distributed 30 min before sunset and retrieved between 0830 and 1000 the following day. Total number of fish caught in each trap was recorded as well as minimum and maximum total lengths, and all fish were returned to the pond. Each pond was trapped twice (16 trap nights) during a sampling period. Once trapping was completed, ponds were seined and F_1 and F_2 hybrid bluegill and channel catfish were individually weighed and measured to estimate growth, size distribution, and mean biomass. The experiment was conducted from 12 March 2001 to 19 February 2002. Ponds were drained at the conclusion of the experiment to determine overall biomass and number of F_2 hybrid bluegill present. Growth of F_1 hybrid bluegill and number of F_2 hybrid bluegill was evaluated using analysis of variance. Water quality data were evaluated using repeated measures analysis of variance.

RESULTS

Only four ponds (two from each treatment) contained young-of-the-year (YOY) hybrid bluegill at the conclusion of the experiment, and reproduction was highly variable within these ponds (Table 1). Ponds without channel catfish that contained YOY hybrid bluegill had 24 and 2,543 individuals, whereas ponds containing channel catfish had 3 and 1,028 individuals. Minnow trap samples did not detect YOY hybrid bluegill in the remaining 6 ponds throughout the experiment.

At the conclusion of the experiment, mean lengths and weights of F_1 hybrid bluegill (SE) were 181 mm (0.84) and 149 g (2.42) for ponds with channel catfish, and 181 mm (0.81) and 161 g (2.28) for ponds without channel catfish. Hybrid bluegill from ponds without channel catfish weighed significantly more than those from ponds with channel catfish ($p < 0.001$). Mean survival of F_1 hybrid bluegill was 64% and 60% for ponds with and without channel catfish, respectively, and was not significantly different between treatments ($p = 0.478$). Mean dissolved oxygen level and Secchi depth differed significantly between treatment groups. Ponds without channel catfish had higher levels of dissolved oxygen ($p = 0.016$) and higher visibility ($p = 0.0001$).

DISCUSSION

Reproductive success of hybrid bluegill was highly variable which is common for this hybrid. Due to a low percentage of females in most populations of hybrid bluegill, reproductive success depends on a few individuals and a relatively low abundance of eggs. Our results are similar to the findings of Laarman (1979) in which only 3 out of 6 ponds contained YOY hybrid bluegill, and a high level of variability occurred in the numbers of F_2 hybrid bluegill each pond produced. The causes for such variability in reproductive success are not understood and might be attributable to a number of environmental and behavioral variables, including abnormal courtship or mistimed fertilization of eggs, interference by other aggressive males, loss of females to predation, or the destruction of nests containing eggs. However, this experiment demonstrates the capacity of hybrid bluegill, under certain conditions, to produce large numbers of offspring that could potentially lead to overpopulation.

We do not believe that stunting in hybrid bluegill populations can be avoided through simply manipulating stocking rates. We recommend that a predator species be stocked with hybrid bluegill to reduce the F_2 population and allow for faster growth of F_1 hybrids. Our sample sizes were not large enough to determine the effects of channel catfish as a predator species, but we feel that this species needs further evaluation as a candidate for stocking with hybrid bluegill.

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Table 1. Mean number of young-of-the-year hybrid bluegill per trap night and total number of young-of-the-year hybrid bluegill removed per pond at the conclusion of the experiment. Treatment HBG denotes ponds stocked with 150 F_1 hybrid bluegill, and CCF denotes ponds stocked with 150 F_1 hybrid bluegill and 100 channel catfish.

Pond #	Treatment	Fish/trap night					# Removed at conclusion of experiment
		May	July	Sept	Nov	Feb	
8	HBG	0	0	0	0	0	0
9	HBG	0	0	0	0	0	0
12	HBG	0	0	0	0	0	0
13	HBG	0	0.6	8.75	15	4.6	2543
15	HBG	0	0	0	0.13	0	24
5	CCF	0	0	0	0	0	0
7	CCF	0	0	0	0	0	0
10	CCF	0	0	0	0	0	0
14	CCF	0	0	0	0	0	3
16	CCF	0	0	15.4	12.1	0.7	1028

MANAGEMENT RECOMMENDATIONS

Hybrid bluegill are very popular and sought after sportfish. This study has evaluated the techniques used to produce these fish and answered questions that will be important to the management of hybrid bluegill fisheries. Our findings have lead to the following conclusions.

Fish fed using alternative feeding strategies in this study did not exceed the performance of control fish. The concept of using compensatory growth to increase growth rates of fish has been attempted with numerous species of commercial importance. However, for these feeding strategies to be useful for aquacultural production, compensatory growth must be easy to induce, practical in a production setting, and occur over a range of environmental conditions. Our results suggest that increasing growth rate using feeding schedules designed to elicit compensatory growth may not be practical when feeding an artificial pelleted diet, and feeding strategies of this type may be difficult to implement for large-scale hybrid bluegill production. However, our results suggest that hybrid bluegill do not need to be fed everyday to optimize growth and alternative feeding regimes could significantly reduce labor costs.

Feeding frequency had no significant effect on growth, food conversion efficiency, size variation, or percentage of harvestable sized hybrid bluegill reared in ponds. Feeding once daily requires less labor and reduced cost for automatic feeders. Because the overall growth performance did not differ between groups, we recommend feeding hybrid bluegill once per day when cultured in ponds. We estimated the cost of producing 2nd year hybrid bluegill to be \$5.76/Kg (\$2.62/lb).

The results of our angling experiments illustrate the need for intensive management of hybrid bluegill in urban fisheries. Mean catch rates for hybrid bluegill at two fishing clinics were 6.6 and 4.4 fish/hour. We estimated that 65% of stocked hybrid bluegill were captured during a two hour fishing period. Due to potentially high fishing pressure that urban fisheries can receive, populations could be rapidly decimated without the enforcement of strict fishing regulations. We estimated fishing mortality to be 1.3% for hybrid bluegill, making them a suitable candidate for catch and release fisheries.

Our channel catfish predator experiment illustrates the potential of hybrid bluegill to overpopulate under certain conditions. Although reproduction was highly variable, a predator species will still be needed to reduce the F_2 population and allow for faster growth of F_1 hybrids. Our sample sizes were not large enough to determine the effects of channel catfish as a predator species, but we feel that this species needs further evaluation as a candidate for stocking with hybrid bluegill.

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