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ABSTRACT

Experiments on the effects of stocking densities and feeding rates on growth and production of golden shiner were conducted under laboratory conditions. The stocking densities were 20, 28 and 36 fry per 60 gal of water. The fish in tanks with 28 fry were fed at 1, 3 and 5% feeding rates and the rest were fed at 5% feeding rate. A 5% feeding rate was found to be essential for good production. The stocking density of 20 fry (400 lb/acre production) with 5% feeding rate yielded better growth in weight and length and better production than the rest of the experimental conditions.

INTRODUCTION

The golden shiner is probably the most important of all bait fishes raised commercially. In Arkansas in 1969, 21,550 acres was devoted to the production of minnows, and of this area 20,200 acres was used for golden shiner production (Meyer et al., 1970).

Production, the product of growth rate and mean biomass, may be influenced by the environmental factors that affect growth rate or biomass. Growth rates of fishes are affected by such variables as temperature, light, chemcial factors, volume of water per fish and the quantity and quality of food (Brown, 1957). Of these the effects of feeding rates and stocking densities are important to the commercial fish grower. Forney (1957) obtained faster growth by providing supplemental food to the golden shiner. Prather (1957) stated that one of the problems in golden shiner culture was the overproduction of small fish.

This paper concerns the effects of feeding rates and stocking densities on growth and production of golden shiner.

MATERIALS AND METHODS

The experiments for this study were conducted in 63-gal capacity tanks filled with 60 gal of water, constructed of plywood with double walls and coated with fiberglass resin. Temperature in the tanks was maintained at 22.8 C by a mercury-column thermoregulator. All experiments were conducted under a 12-hr photoperiod. Two 20-watt Gro-Lux fluorescent lamps were used for the light source. The intensity at the surface of water was 30 ft-candles. The lights came on at 0800 hours and went out at 2000 hours and the changes from dark to light and vice versa were instantaneous.

The experiments were conducted for a period of 180 days (2 September 1971 - 29 February 1972). The golden shiner fry were procured from the Logan Spring Hatchery, Siloam Springs, Arkansas, and the fry that were 18-22 mm in total length were selected for the investigation. Six tanks were stocked with 28 fry per tank (about 600 lb/acre production or 150,000 fish/acre) and were fed daily with commercial minnow food in quantities of 1, 3 and 5% of body weight. For the study on the effects of stocking density on production, two tanks were stocked with 36 fry per tank (about 800 lb/acre production or 200,000 fish/acre) and two tanks were stocked with 20 fry per tank (about 400 lb/acre production or 100,000 fry/acre), and these fish were all fed at a rate of 5% of body weight. The commercial minnow food obtained from Montclaire Prime Quality Feed Supplies, Little Rock, Arkansas, contained 33% protein, 5% crude fat and 7% crude fiber. All experimental fish were fed within an hour after the lights came on.

At the beginning of the experiments, the fish in each of the experimental conditions were weighed and measured individually. At 30-day intervals, a random sample of five fish from each of the experimental conditions was weighed and measured individually. The average weight of the five fish was used in determining the amount of food to be given to the experimental fish. Mortalities were recorded as they occurred.

Production is expressed as pounds per acre-foot of water. The data were analyzed by IBM 360 computer and desk calculator. Significance levels are expressed at the 0.05 level, unless otherwise stated.

RESULTS

Growth in Weight. The initial weights of the fish in the experimental tanks were not significantly different ($F_{4,450}=0.38$). Therefore each of the tanks received the same size fish (0.06 g) at the beginning of the experiments.

Differences between the replicates were not significant during the experimental period and therefore the data for the replicates were combined for the remainder of the analyses. The growth in weight-time relationship was expressed by the formula:

$$\ln W_t = \ln W_o + bt$$

where

W_t = weight in grams at time t,

W_o = average weight at the beginning of the experiments,

b = instantaneous growth rate and

t = sampling period (one month).

Differences in growth rates among the experimental groups were tested (Sokal and Rohlf, 1969) and the results are shown in Table I.

The instantaneous growth of golden shiners at a population density of 20 fish (5% feeding rate) was significantly different

Table I. Instantaneous Growth Rates and Tests for Differences for Golden Shiner Under Experimental Conditions

Experimental Condition	Instantaneous Growth Rate		Final Average Weight	
Population density 20 (5%)	0.45078	N.S.	0.82	N.S.
Population density 28 (5%)	0.40226	N.S.	0.71	
Population density 36 (5%)	0.37570	N.S.	0.52	N.S.
Population density 28 (3%)	0.32592		0.42	
Population density 28 (1%)	0.22375		0.21	

N.S. = not significant.

from that at a population density of 28 fish with 1% and 3% feeding rates and at a population density of 36 fish (5% feeding rate), but was not significantly different from that at a population density of 28 fish with a 5% feeding rate. Also, a population density of 28 fish with a 5% feeding rate was significantly different from that with 1% and 3% feeding rates, but not from a population density of 36 fish (5% feeding rate). The instantaneous growth rate of fish at a population density of 36 fish (5% feeding rate) was significantly different from that at a population density of 28 fish with a 1% feeding rate, but was not significantly different from the instantaneous relative growth rate of fish at a population density of 28 fish with a 3% feeding rate. The 3% feeding rate (population density of 28 fish) was significantly different from the 1% feeding rate (population density of 28 fish).

The results of Duncan's multiple range test of unequal sample sizes on the final average weights (Table I) correspond with the foregoing, except the weights of fish in a population density of 36 fish (5% feeding rate) were significantly different from those of fish in a population density of 28 fish with a 5% feeding rate.

The weight gained by the fish in each experimental condition was calculated and expressed as percentage of the initial weight (Table II). The population density of 20 fish (5% feeding rate) showed the greatest gain, 12.67%.

Growth in Length. The initial lengths of the fish at the beginning of the study were not significantly different ($F_{4,270}$ = 0.55) and therefore the tanks received fish of the same average size (21.3 mm) at the beginning of the experiments.

The growth in length was expressed as:

$$\ln L_t = \ln L_o + bt$$

where

L_t = total length in millimeters at time t,
L_o = average total length at the beginning of the experiments,
b = regression coefficient and
t = sampling period (one month).

The regression equations for the different experimental conditions are given in Table III.

Table III. Total Length-Time Relationship and Test for Differences for Golden Shiner Under Experimental Conditions

Experimental condition	Slope*	Final Average Total Length (mm)	
Population density 20 (5%)	0.1380	47.6	
Population density 28 (5%)	0.1180	44.2	
Population density 36 (5%)	0.1043	40.1	N.S.
Population density 28 (3%)	0.1001	38.8	
Population density 28 (1%)	0.0609	30.6	

*Slope = b, the regression coefficient.

The differences in lengths between the experimental groups at the end of the experiment were highly significant ($F_{4,142}$ = 29.15). This result indicates that the lengths of the fish were influenced by different feeding rates and population densities. Duncan's multiple range test of unequal sample sizes was performed for comparisons of experimental conditions (Table III).

The differences in average lengths among the densities of 36 fish (5% feeding rate) and of 28 fish (3% feeding rate) were not significant. All other experimental conditions yielded significantly different average lengths.

Length-Weight Relationship. Length-weight relationships were calculated by the formula log W = a + b log L. Because the differences between the slopes of the regression lines of the replicates of each experimental condition were not significant

Table II. Details of Weight Gain and Standing Crop Estimates for Golden Shiner Under Experimental Conditions

Experimental Condition	Initial Weight (g)	Weight at 180 Days (g)	Gain in Weight (g)	% Gain	Number of fish in each tank Initial	Number of fish in each tank Final	Standing Crop (lbs/acre-ft)
Population density 28 (1%)	0.06	0.22	0.16	2.67	28	9	23.70
Population density 28 (3%)	0.06	0.41	0.35	5.83	28	12	58.90
Population density 28 (5%)	0.06	0.70	0.64	10.67	28	13	108.95
Population density 20 (5%)	0.06	0.82	0.76	12.67	20	18	176.64
Population density 36 (5%)	0.06	0.52	0.46	7.67	36	26	161.80

the replicates were combined, and the length-weight relationship for each experimental condition was calculated (Table IV). An analysis of covariance showed that there were no significant differences between the slopes of the regression lines of the different experimental conditions ($F_{3,185}$ = .077). It is surmised from this information that different feeding rates and population densities have no effect on body shape of golden shiners. The "b" value (slope) significantly exceeded the cube of the length (t_{675} = 16.90).

The average condition factor was calculated for each experimental group (Table IV) by the formula:

$$K = \frac{W10^5}{L^3}$$

where

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

Table IV. Details of Slopes and Intercepts Derived From Length-Weight Relationships and Condition Factors with Tests for Differences for Golden Shiner Under Experimental Conditions

Experimental Condition	Intercept (log a)	Slope (b)	Average Condition Factor	
Population density 28 (1%)	-5.4928	3.1852	0.588	
Population density 28 (3%)	-5.5032	3.2131	0.633	N.S.
Population density 20 (5%)	-5.5666	3.2495	0.649	
Population density 36 (5%)	-5.6831	3.3452	0.661	N.S.
Population density 28 (5%)	-5.6749	3.3383	0.664	

Duncan's multiple range test of unequal sample sizes showed the condition factor of fish at a population density of 28 fish with a 1% feeding rate was significantly different from all other conditions. All conditions with a 5% feeding rate (population densities of 36, 28 and 20 fish) were not significantly different. The fish at a 5% feeding rate had the highest value for "K" (condition factor) and are considered to be in the best condition of all the different experimental groups.

Production Estimates. In this study, net production is defined as the total growth in weight of fish including growth in the part of the population that dies before the termination of the experiment. The production estimates were made according to the model of Chapman (1968). Instantaneous growth rates were greater than the instantaneous mortality rates for all the experimental conditions with the exception of 1% and 3% feeding rates (Hickman, 1973). The production values for each experimental condition are shown in Table V.

A stocking density of 20 fish (5% feeding rate) gave the highest production value, followed by a stocking density of 36 fish (5% feeding rate), a population density of 28 fish with a 3% feeding rate and a population density of 28 fish with a 1% feeding rate. Standing crop estimates yielded similar results (Table II).

Behavioral Observations. Light was observed to affect the behavior of the experimental fish. During the lighted periods the fish were very active and fed well, whereas during the dark periods the fish were sluggish with a minimal amount of movement. They would not eat in the dark. This finding indicates that the optimal time for feeding golden shiners is when the fish become active in the morning.

The feeding rate and stocking density also affected the activity of the golden shiners. Those fish with low feeding rates and high population densities were more sluggish than those fish with higher feeding rates and lower population densities.

DISCUSSION

Growth and production of fishes are affected by several variables, such as temperature, light, chemical factors, volume of water per fish and the quantity and quality of food (Brown, 1957). Of these, feeding rates and stocking densities and their effects on growth and production of golden shiners are of primary importance to the commercial grower.

In this study, the temperature and photoperiod were kept constant throughout the experiments. The chemical factors were not allowed to change in significant amounts. These factors were always within the recommended ranges for warm-water fishes as prescribed by FWPCA (1968). The quality of the food remained the same during the experiments. Because stocking density and quantity of food were the only manipulated variables, the difference in growth and production of the experimental fish can be attributed to the combined effects of these two factors.

Growth - Condition. The most favorable condition for growth in weight was a stocking density of 20 fish with a feeding rate of 5% of the body weight (Tables I, II). Next was a population density of 28 fish with a 5% feeding rate, followed by a population density of 36 fish with a 5% feeding rate, a population density of 28 fish with a 3% feeding rate and a population density of 28 fish with a 1% feeding rate. Growth in length followed the same pattern as growth in weight with respect to the experimental condition.

Cooper (1937) noted a growth of 74 mm total length and 3.3 g in five months for golden shiners in a pond with largemouth bass. In the present study, the greatest growth was 47.6 mm and 0.82 g in six months and occurred at a stocking density of 20 fish (5% feeding rate). The golden shiners in Cooper's study had faster growth rates because of the reduced population density due to bass predation.

The highest condition factor was found in fish with a 5% feeding rate (population densities of 20, 28 and 36 fish) followed by the 3% and 1% feeding rates with a population density of 28 fish each (Table IV). Tarzwell (1938) noted a condition factor of 1.7 in fish 25-76 mm long. In the present study, the highest condition factor was 0.66 in fish 40-48 mm long. Tarzwell used a fish from a pond environment where there was a varied diet with an abundance of zooplankton and phytoplankton for the golden shiners to feed on.

Table V. Production Estimates for Golden Shiner Under Experimental Conditions

Experimental Condition		Production	
		P_1	P_2
Population Density	Feeding Rate (%)	(g/60 gal)	(lbs/acre)
28	1	1.72	20.61
28	3	5.03	60.24
28	5	10.78	129.07
20	5	14.32	171.57
36	5	13.46	161.15

Production. Production was highest with a stocking density of 20 fish and a feeding rate of 5% of the body weight (Table V). Under a 5% feeding rate, production was highest at the stocking density of 20 fish, followed by a density of 36 fish and by a density of 28 fish. A high mortality rate in the early part of the experiment in the experimental tank with a population density of 28 fish may have caused the production values to be lower than expected. These findings agree with the findings of Prather (1957, 1958), who found that the production was higher in ponds with lower stocking densities for golden shiners and fathead minnows.

Under conditions with a stocking density of 28 fish, the feeding rate of 5% yielded the highest production, followed by the 3% feeding rate and the 1% feeding rate. These findings agree with the findings of Prather (1958) that the production was higher in ponds with higher feeding rates. However, Prather (1957) reported that supplemental feeding at rates as high as 20-40 lb per acre per day may cause death of shiners during the fall and winter.

From this study, it is evident that a feeding rate of 5% of the body weight is essential to obtain good production. It is also apparent that this feeding rate (5%) with a low stocking density (100,000 fish/acre) results in the largest production.

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