# THE EFFECT OF MONOCHROMATIC LIGHT ON THE GROWTH, FOOD CONVERSION, AND SURVIVAL OF TWO STRAINS OF RAINBOW TROUT, *SALMO GAIRDNERI*

(PART I)

and

# CATFISH FARMING AS SUPPLEMENTAL INCOME IN RURAL VIRGINIA: USE OF CATFISH STRAINS

(PART II)

by

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# PART I

## The Effect of Monochromatic Light on the Growth, Food Conversion, and Survival of Two Strains of Rainbow Trout, *Salmo gairdneri*

## INTRODUCTION

The major problem faced by the fish culturist is to produce a product that can be sold at a reasonable profit. With the rapid increase in the cost of fish food, construction, labor, building materials, and equipment profits have shrunk to where small changes in the profit margin may mean the difference between success and failure. A simplistic analysis of the problem tells us that the culturist's profit margin is improved when his fish reach marketable size in the least amount of time with the least amount of feed. The problem then becomes the identification of means to maximize the growth rate and feed conversion efficiency of his fish.

The problem is basically the same problem faced by poultry growers. Poultry growers have found that the growth rate of poultry can be depressed or accelerated by providing specific segments of the spectrum as a light source in rearing houses. The light sources appeared to improve growth through behavioral and physiological changes, but the complete pathways or mechanisms have not been identified. The possibility presents itself that fish growth, like that of poultry, may be improved by rearing under specific wavelengths of light. Ability to control fish growth rate would allow the fish culturist to improve the profit margin of his operation.

Much similarity exists between the responses of fowl and of fish to different light conditions. Increased growth and production have been found in broiler chickens (Weaver and Seigel, 1968) as well as in brook trout (*Salvelinus fontinalis*) (Pyle, 1969), brown trout (*Salmo* trutta) (Brown, 1946), and green sunfish (Lepomis cyanellus) (Gross et al., 1965) with changes in photoperiod. Light intensity has been found to alter behavior and physiology in laying hens (Dorminey et al., 1970) and various salmonids (Eli, 1959). Some of these changes may be mediated through the pineal gland. The activity of this gland seems to affect behavior, growth, and survival. The function of the pineal gland is largely unknown. However, it is thought to be a photosensory receptor and/or a secretory organ (Fenwick, 1970). Pineal gland activity as estimated by the gland's release of hydroxyindole-o-methyl transferase, has been modified in broiler chickens (Machemer et al., 1971) and also rainbow trout (Dodt, 1963) by rearing under different wavebands within the 400 mu to 700 mu range. Fowl grew better under wavelengths from 500 mu to 600 mu (green light) (Foss et al., 1972; Foss and Arnold, 1969) where pineal gland activity is stimulated (Machemer et al., 1971). Generally, chickens responded to red light by early sexual maturity, increased egg production, and decreased aggressive behavior and excitability (Foss et al., 1972; Foss and Arnold, 1969; Peterson and Eppenshade, 1971; Woodard et al., 1969; Lauber and McGinnis, 1965; Benoit and Ott, 1944; Scott and Payne, 1937). Blue light has also been found to reduce excitability in fowl (Hansen, 1970).

Fish growth and production under colored light conditions have not been intensively studied, and studies of fish behavior under colored lights are still in the initial stages. However, Hamdorf (1960) found increased weight at hatching, increased survival, and increased weight of larval fish versus controls 1000 hours after hatching when the fish were incubated, hatched, and reared under colored lights.

This research was initiated to see if: 1) the growth rate of young rainbow trout can be affected by rearing under different wavebands of light, and 2) the growth parameters of two strains of rainbow trout would be affected by the colored lights in the same manner.

## MATERIALS AND METHODS

To test the growth response of fish to selected wavebands of light, the fish must be capable of detecting and responding to the experimental spectrum and all other wavelengths of light must be omitted from the fish's environment. Rainbow trout, *Salmo gairdneri*, were used as test fish because they possess the same visual pigments as fish that are known to discriminate colors (Bridges, 1956).

There are technical difficulties in eliminating unwanted wavelengths of light from entering the water. Light waves bend as they pass through the surface of the water. This phenomenon allows unfiltered light to emit other wavelengths of light depending on the angle at which it strikes the water surface. To overcome this problem, monochromatic light filters with the maximum intensity near the center of the color band were used. No overlap of color could take place because the filters emit only one band of light (Loh, VPI & SU Physics Department, personal communication).

Another problem is caused by the selective absorption of certain spectra of light by the water. Wavelengths below 400 mu and above 700 mu are absorbed in very shallow water and were therefore, not used in this study. From 400 mu to 700 mu the loss of transmissibility of light is approximately 40 percent per meter of water (Ruttner, 1970). A maximum water depth of two thirds of a meter was used to minimize the loss of transmissibility on the intensity of colors transmitted. The differences in intensity of the various colors under these circumstances can be considered negligible (Loh, VPI & SU Physics Department, personal communication).

Six hundred rainbow trout were exposed to three non-overlapping wavebands of light; 200 fish per light condition. Two hundred fish were also used as a control. Carolina Monochromatic Light Filters (Klein, 1964) were used to create spectral bands of light with intensities as follows: Blue (range 410 mu to 480 mu with the maximum intensity at 450 mu), Green (range 500 mu to 600 mu with the maximum intensity at 545 mu), and Red (range 600 mu to 710 mu with the maximum intensity at 650 mu). The control fish were exposed to incandescent lighting of intensity equal to that of the three spectral treatments (21.4 lux). A photometer was used to measure light intensities at the water surface and a rheostat was installed to control the lighting circuit. Adjustments were made via the rheostat until light intensities were equal in all tests. All fish were exposed to continuous light of the assigned experimental spectra for 53 days.

Strains of rainbow trout originating from Soap Lake, Washington, and from Wytheville, Virginia, were used to test for strain specific responses. The Soap Lake strain has been cultured at the Wytheville National Fish Hatchery for 5 years; the Wytheville strain has been cultured in this hatchery for 10 years. Immature Soap Lake trout from the Spring 1974 spawn were 3 months old at the beginning of the experiment. They ranged in weight from 4.3 to 6.1 grams. The Wytheville trout from the Fall 1973 spawn were 8 months old and ranged in weight from 10.1 to 14.0 grams.

Four raceways 9 m long, 1 m wide and .75 m deep with a flow rate of 152 l/min were divided into 4 equal sections by nylon screens. Test lots of 50 fish from a strain were stocked into 2 individual sections of each raceway (200 trout per raceway). Strains were placed in alternate sections within each raceway.

At the beginning of the experiment a sample of 10 fish from each section, 20 percent of each test lot, was measured and weighed. Initial within-strain weights of the stocked fish were compared using analysis of variance ($\alpha$= 0.50) to test for significant differences in size at the time of stocking.

Light conditions were created by three 300-watt incandescent bulbs shining through Carolina Monochromatic Light Filters located approximately 1-2/3 meter above each raceway. The bulbs were placed at equal intervals along each raceway and resulted in equal light intensities in each test section. A frame of galvanized tubing held the bulbs in place and supported a black plastic cover that excluded outside light. Water temperature was maintained at 12.7°C and the raceways were cleaned daily.

Fish were fed trout chow (PR 11-28) twice daily according to the feeding charts developed by Haskell (1959). In this study the hatchery constant was 12, the desired increase in length was 0.80 inches per month, and the present average weight was 5 grams for the Soap Lake fish and 12 grams for the Wytheville fish. Soap Lake trout were fed at an average rate of 4.3 percent of their body weight per day; the Wytheville strain at 3.2 percent. Strains were fed at different rates to adjust for the initial differences in size; 0.80 inch was chosen as the desired increase in length because Wytheville hatchery records indicated that rate to be the maximal growth rate per month that could be efficiently obtained for these fish at these particular hatchery conditions. A maximal increase in growth was desired to facilitate detecting any differences in growth due to the treatment. All feed was weighed prior to feeding. Fish were not fed 24 hours before each of the two sampling days. Absence of feed allowed complete digestion before handling, and lessened the chance of regurgitation. Regurgitation of feed by the fish could bias the feed conversion ratio as well as other parameters.

For the statistical analysis of growth the data from the two sections of each strain of a specific light treatment were pooled. Growth data were then analysed using the Kruskal-Wallis nonparametric test and Dunn's treatment versus control multiple comparisons test. The statistical analysis of the other parameters was carried out with each section within each raceway as a block. The Friedman rank sum test and treatment versus control multiple comparisons were used (Hollander and Wolfe, 1973). These tests account for known within-strain differences in growth, feed conversion, and survival, as well as differences in age, size, and position within a raceway. To obtain equal sample sizes for the calculations of growth, sample values were deleted using a random numbers table until a sample of 40 fish from each section was obtained.

## RESULTS

The project began on June 7, 1974, and was terminated on July 29, 1974. Although no detailed behavioral studies were carried out, test fish and control fish were observed to have no gross behavioral differences. Occasionally (9 times during the study period) a fish jumped from section to section within a raceway. Strain differences and, hence, jumping were easily discerned by the relative size of the two strains. When a fish was determined to have jumped into another section, data from that fish were eliminated from the calculation of growth, yield, and feed conversion.

On July 5, 1974, 10 fish from each section were weighed and measured. These data were used to adjust the daily feed ration. Analysis of the data using the Kruskal-Wallis nonparametric test showed no significant differences in growth between light conditions at this time ($\alpha = 0.05$).

The following parameters were calculated at the end of the project: growth, coefficient of condition, yield, feed conversion ratio, and survival. Because Bartlett's test showed significant differences in the homogeneity of variances ($\alpha = 0.0001$), analysis of variance was not used to test these parameters. Homogeneity of variance is not one of the assumptions of the Kruskal-Wallis and the Friedman rank sum tests.

Growth - Total length in centimeters (Table 1) and weight in grams (Table 2), were obtained for each fish at the end of the project. The Kruskal-Wallis nonparametric test was used to analyze the data.

Lack of similarity was found in the lengths and also weights of the different strains and test treatments when compared to control values ($\alpha = 0.001$). Multiple comparison test of treatment versus control fish indicated that lengths of Wytheville fish were greatest under green light conditions while lengths of Soap Lake fish were greatest under blue light conditions. Differences in the Wytheville strain were significantly greater than control values ($\alpha = 0.001$) in both green and blue treatments. All differences in Soap Lake strain were significantly different than the control values. Red light appeared to inhibit the growth in length and weight of both strains. These differences were significantly different than control values ($\alpha = 0.001$). In the Wytheville strain the fish reared under green light were heaviest whereas in the Soap Lake strain control fish were heaviest. The weight of all fish treated with the green light was significantly different than the weight of the control fish in each strain ($\alpha = 0.001$).

Coefficient of condition - The coefficient of condition (Table 3) is a measure of the relative robustness of a fish in numerical terms. This statistic was determined following Lagler (1952) as modified by Carlander (1969). Multiple comparison tests of treatment versus control fish showed that Soap Lake fish grown under blue light had the lowest coefficient of condition, whereas Wytheville fish grown under blue light had the highest coefficient of condition ($\alpha = 0.23$).

Yield - Yield (Table 4) was determined by adding the individual weights of all fish in each section. Multiple comparison of treatment versus control fish showed that yields of the Wytheville strain and

Table 1. Lengths in centimeters of strains of rainbow trout after 51 days of treatment.

| Light | Section | Soap Lake Sectional Mean Length | C.V.%* | Wytheville Sectional Mean Length | C.V.%* | Soap Lake Mean Length | C.V.%* | Wytheville Mean Length | C.V.%* |
|---|---|---|---|---|---|---|---|---|---|
| Blue | 1 | 10.87 | 11.9 | 14.66 | 21.1 | 10.58[a] | 19.0 | 14.65[b] | 21.0 |
| | 2 | 10.29 | 12.6 | 14.64 | 8.2 | | | | |
| Control | 1 | 10.54 | 15.9 | 14.08 | 13.3 | 10.29 | 19.0 | 14.29 | 15.5 |
| | 2 | 10.04 | 10.3 | 14.49 | 8.2 | | | | |
| Green | 1 | 10.01 | 10.2 | 15.19 | 6.3 | 9.95[a] | 13.9 | 15.10[b] | 9.6 |
| | 2 | 9.89 | 9.5 | 15.00 | 7.4 | | | | |
| Red | 1 | 9.57 | 10.5 | 13.48 | 17.3 | 9.60[a] | 14.6 | 13.96[b] | 19.3 |
| | 2 | 9.62 | 10.2 | 14.43 | 9.5 | | | | |

* Coefficient of Variation expressed in per cent

[a] significantly different from the control light condition of Soap Lake fish at = 0.001

[b] significantly different from the control light condition of the Wytheville fish at = 0.001

Table 2. Mean weight in grams of strains of rainbow trout after 51 days of treatment.

| Light | Section | Soap Lake Sectional Mean Length | C.V.%* | Wytheville Sectional Mean Length | C.V.%* | Soap Lake Mean Length | C.V.%* | Wytheville Mean Length | C.V.%* |
|---|---|---|---|---|---|---|---|---|---|
| Blue | 1 | 12.75 | 33.6 | 29.06 | 53.6 | 11.62[a] | 55.4 | 31.01[b] | 56.0 |
| | 2 | 10.49 | 45.6 | 32.95 | 23.4 | | | | |
| Control | 1 | 14.40 | 39.6 | 30.18 | 32.3 | 12.09 | 54.8 | 29.87 | 41.1 |
| | 2 | 9.79 | 34.7 | 29.55 | 25.4 | | | | |
| Green | 1 | 12.20 | 32.0 | 34.79 | 15.9 | 11.58[a] | 40.7 | 34.51[b] | 28.1 |
| | 2 | 10.96 | 24.1 | 34.22 | 23.2 | | | | |
| Red | 1 | 9.78 | 10.2 | 26.79 | 42.2 | 9.72[a] | 50.7 | 29.38[b] | 47.3 |
| | 2 | 9.65 | 31.5 | 31.97 | 25.4 | | | | |

* Coefficient of Variation expressed in per cent

[a] significantly different from the control light condition of Soap Lake fish at = 0.001

[b] significantly different from the control light condition of Wytheville fish at = 0.001

Table 3. Coefficient of condition for strains of rainbow trout.

| Light | Section | Mean coefficient of condition for each section | | Mean coefficient of condition for each section | |
|---|---|---|---|---|---|
| | | Soap Lake | Wytheville | Soap Lake | Wytheville |
| Blue | 1 | 1.018 | 1.022 | 0.961[a] | 1.033[b] |
| | 2 | 0.900 | 1.044 | | |
| Control | 1 | 1.246 | 0.992 | 1.093 | 0.971 |
| | 2 | 0.940 | 0.949 | | |
| Green | 1 | 1.207 | 0.988 | 1.171 | 0.986 |
| | 2 | 1.134 | 0.983 | | |
| Red | 1 | 1.074 | 1.008 | 1.064 | 1.014 |
| | 2 | 1.053 | 1.020 | | |

[a] not significantly different from the control light conditions of the Soap Lake fish. Significance level at $\alpha < 0.23$.

[b] not significantly different from the control light conditions of the Wytheville fish. Significance level at $\alpha < 0.37$.

Table 4. Yield in grams for strains of rainbow trout after 51 days of treatment.

| Light | Section | Yield for each section | | Mean yield | |
|---|---|---|---|---|---|
| | | Soap Lake | Wytheville | Soap Lake | Wytheville |
| Blue | 1 | 548.3 | 1453.0 | 484.0 | 1451.4 |
| | 2 | 419.6 | 1449.8 | | |
| Control | 1 | 720.0 | 1509.0 | 580.3 | 1493.3 |
| | 2 | 440.6 | 1477.5 | | |
| Green | 1 | 536.8 | 1356.8 | 526.0 | 1448.4 |
| | 2 | 515.1 | 1539.9 | | |
| Red | 1 | 449.9 | 1339.5 | 422.8[a] | 1293.2[b] |
| | 2 | 395.7 | 1246.8 | | |

[a] not significantly different from the control light conditions of the Soap Lake fish. Significance level at $\alpha = 0.09$.

[b] not significantly different from the control light conditions of the Wytheville fish. Significance level at $\alpha = 0.09$.

the Soap Lake strain were lowest under red light (significantly different than controls at $\alpha = 0.09$ for the Soap Lake strain, and the Wytheville strain and highest for the control). Adjusting the yield for mortalities showed that green may enhance the growth of the Wytheville strain (Table 5) but had no effect on Soap Lake fish.

Feed conversion ratio - The feed conversion ratio (Table 6) is an estimate of the weight of feed necessary to produce a pound of weight gain in fish. The feed conversion ratio for each section was determined by the equation FCR = TFC/TWG, where FCR is the feed conversion ratio, TFC is the total dry weight of feed given to each section, and TWG is the total weight gained in each section. TWG is equal to the total weight of live fish plus the weight of dead fish minus the initial weight of the stocked fish. Multiple comparison of treatment versus control fish indicated that the feed conversion ratio decreased for the Wytheville and Soap Lake strain under green light ($\alpha = 0.23$) whereas the feed conversion ratio for both strains increased under red light ($\alpha = 0.23$ for the Soap Lake strain; $\alpha = 0.37$ for the Wytheville strain) when compared to other treatments.

Survival - Survival (Table 7) for each section was determined by counting the number of fish in each section. This number was then divided by the initial number stocked in each section (5) to determine the percent survival. Multiple comparison of treatment versus control fish revealed that in the Soap Lake strain, fish grown under blue light had highest mortality ($\alpha = 0.23$), whereas in the Wytheville strain, fish grown under red and green lights had about equal mortality

Table 5. Adjusted yield* in grams for strains of rainbow trout after 51 days of treatment.

| Light | Section | Adjusted yield* for each section | | Mean adjusted yield | |
|---|---|---|---|---|---|
| | | Soap Lake | Wytheville | Soap Lake | Wytheville |
| Blue | 1 | 1275 | 2906 | 1162 | 3088 |
| | 2 | 1049 | 3295 | | |
| Control | 1 | 1440 | 3018 | 1209 | 2986 |
| | 2 | 979 | 2955 | | |
| Green | 1 | 1220 | 3479 | 1156 | 3449[b] |
| | 2 | 1096 | 3422 | | |
| Red | 1 | 978 | 2679 | 971[a] | 2906 |
| | 2 | 965 | 3197 | | |

* 2(yield/% survival ÷ 100) = adjusted yield (estimated yield of 100 fish).

[a] not significantly different from the control light conditions of the Soap Lake fish. Significance level at $\alpha = 0.23$.

[b] not significantly different from the control light conditions of the Wytheville fish. Significance level at $\alpha = 0.23$.

Table 6. Feed conversion ratio of strains of rainbow trout after 51 days of treatment.

| Light | Section | Mean conversion ratio for each section | | Mean feed conversion ratio | |
|---|---|---|---|---|---|
| | | Soap Lake | Wytheville | Soap Lake | Wytheville |
| Blue | 1 | 1.42 | 1.62 | 1.83 | 1.51 |
| | 2 | 2.23 | 1.39 | | |
| Control | 1 | 1.23 | 1.43 | 1.80 | 1.47 |
| | 2 | 2.36 | 1.50 | | |
| Green | 1 | 1.50 | 1.32 | 1.63 | 1.31[b] |
| | 2 | 1.76 | 1.30 | | |
| Red | 1 | 2.12 | 2.23 | 2.30[a] | 1.84 |
| | 2 | 2.48 | 1.44 | | |

[a] not significantly different from the control light conditions of Soap Lake fish. Significance level at $\alpha = 0.23$.

[b] not significantly different from the control light condition of Wytheville fish. Significance level at $\alpha = 0.23$.

Table 7. Survival of strains of rainbow trout after 51 days of treatment.

| Light | Section | Survival for each section by strain (percent) | | Mean survival (percent) | |
|---|---|---|---|---|---|
| | | Soap Lake | Wytheville | Soap Lake | Wytheville |
| Blue | 1 | 86 | 100 | 83[a] | 94 |
| | 2 | 80 | 88 | | |
| Control | 1 | 100 | 100 | 95 | 100 |
| | 2 | 80 | 100 | | |
| Green | 1 | 88 | 78 | 91 | 84[b] |
| | 2 | 94 | 90 | | |
| Red | 1 | 94 | 100 | 88 | 89[b] |
| | 2 | 82 | 78 | | |

[a] not significantly different from the control light conditions of the Soap Lake fish. Significance level at $\alpha < 0.23$.

[b] not significantly different from the control light conditions of the Wytheville fish. Significance level at $\alpha < 0.37$.

($\alpha$ = 0.37). Mortality was highest for this strain under these treatments. Differences were not statistically significant.

# DISCUSSION

Light intensities of the treatments varied slightly (± 2 lux) during the project. Measurements of intensity taken throughout the study indicated that blue and green light treatments had virtually the same intensities during the project but were slightly different than the red light and the control. The red light intensity and the control intensity were virtually the same. Differences in the wavebands of light to which the animals were exposed may be responsible for all the effects encountered in my study or as suggested by Buikema (1973), there may be a wavelength-intensity interaction.

Hamdorf (1960) found increases in the growth rate and weight at hatching of fish exposed to different colored light from the egg until 1000 hours after hatching. In my study fish exposed to red light had the lowest mean weight, the lowest mean length, the lowest yield, and the highest feed conversion ratio of the treatments tested. However, only length and weight differences were statistically significant at $\alpha = 0.01$. One possible reason that yield did not show statistically significant differences was that it was calculated on the basis of data pooled for a strain. These statistics suggest that more energy was used per pound of growth under red light or food consumption was less (more food wasted). Several other authors have also reported retarded growth of test animals exposed to red light (Buikema, 1973; Foss et al., 1972; Foss and Arnold, 1969). In addition, Foss et al. (1972) have shown that fowl exposed to red light also exhibited increased gonado-trophin levels, shorter times to achieve sexual maturity, increased weight of the pituitary glands, and increased egg production. One possible explanation for the above phenomenon is that in fish, as well as some other test animals, red light may divert energy from somatic growth toward reproductive growth.

One can speculate from my data that exposure to green light led to greater fish growth in the Wytheville strain than did any of the other treatments tested. Data from the literature also support the conclusion that exposure to green light can increase growth. Foss et al. (1972) and Foss and Arnold (1969) found increased growth and yield in fowl reared under green light. They state that generally green light stimulates somatic growth in fowl while red light is used to stimulate reproductive growth. Differences in age or strain may be responsible for the different responses of the Soap Lake fish and the Wytheville fish.

The coefficients of condition in my study were near unity for all treatments. Apparent differences are probably experimental artifacts. Likewise, differences in survival are probably experimental artifacts. The possibility exists that differences in survival could result from strain or age differences. However, my data do not show any statistically significant differences in mortality at $\alpha = 0.01$.

Experimental design did not allow partitioning of the variability in data between strain or age differences. A comparison of my results with Hamdorf's (1960) might initially lead one to conclude the age of the fish when exposed to light determines the response to the treatment. However, since the strains and light intensity used by Hamdorf (1960) and me were not the same, this hypothesis remains to be tested. Between-strain differences do exist in the growth parameters of the strains used in this study. Analysis of hatchery records shows that the Soap Lake fish have a slower growth rate, lower survival, a lower coefficient of condition, and a higher feed conversion ratio than the Wytheville strain. Additional study of the various age fish of a single strain under these light conditions tested in this study would allow evaluation of age specific responses. Comparison of these data with similar studies using different strains would allow partitioning of variability and clarify and verify the results found in this study.

One should be careful when one tries to implement the use of specific wavebands of light to modify a fish growth response in a hatchery situation. Much controversy has arisen among poultry scientists as to the effects of colored lights on the growth parameters of poultry. Conflicting results have been obtained between different studies using colored lights and also with studies monochromatic light filters. Discrepancies are likely caused because colored lights emit the full spectrum of light. Test animals may be affected or not, depending on the spectral properties of the bulbs used and the spectral sensitivity of the animals tested. Use of monochromatic light filters ensures that no overlap of wavelengths takes place between treatments and that the sensitivity of the test animals is the only variable.

Although high variability and small sample size limit interpretation, this study suggests that certain light treatments used in conjunction with certain strains of fish could improve hatchery production.

Significant differences were found in growth during this study ($\alpha$ = 0.001). Fish of both the Soap Lake and the Wytheville strain grew less well under the red light treatment than under other treatments. Fish of the Wytheville strain grown under green light showed the greatest increase in length and weight, whereas fish of the Soap Lake strain grown under blue light showed the greatest increase in length and condition. Therefore, green and possibly blue light treatments would appear to be the most promising for further study. The severe financial pinch which hatcheries are facing makes any technique which shows promise of increasing growth and yield without additional feed a high priority for further study. Since differences in the growth parameters of salmonids have been found with differences in photoperiod (Brown, 1946), intensity (Eisler, 1957), and with wavelength, studies should be initiated involving these three variables of light on growth, reproduction, and physiology.

Part I

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# PART II

# Catfish Farming as Supplemental Income in Rural Virginia: Use of Catfish Strains

# INTRODUCTION

The farming of channel catfish has grown into a multimillion dollar enterprise in the United States within the last 10 years. More than 45 million pounds of farm-raised catfish (Dillin, 1973) valued at nearly 25 million dollars were harvested from more than 65,000 acres of ponds, raceways, cages, and tanks during 1972 (Anonymous, 1973a). These figures compare favorably with 1970 figures of 34 million pounds and 40,000 commercial acres. While most of the channel catfish production is in the south-central states, the growth and expansion of the industry have also been experienced in other neighboring states.

The opportunities for domestic aquaculture are pointed up by statistics compiled by the National Marine Fisheries Service which show that over 2.5 billion pounds of fishery products were consumed in the United States in 1972. The per capita consumption was 12.2 pounds, the highest per capita consumption of fishery products since 1927. This trend is expected to continue so that an additional 3 billion pounds of fish and shellfish will be needed over the next 14 years (Anonymous, 1973b). Domestic aquaculture could fill much of this demand without having the problems of pollution and foreign harvesting faced by "wild-fish" commercial fisheries.

Virginia presently does not have an aquacultural channel catfish industry. During the late 1960's serious consideration was given to developing such an industry in the state (Smith, 1972). Preliminary studies indicated that channel catfish production in the state was economically and biologically feasible. It was estimated that Virginia could produce over 3.4 million pounds of marketable fish per year (Pfeiffer, 1971; Douglass and Lackey, 1973). Markets existed in Lynchburg, Danville, Richmond, and Washington, D.C. Beland (1969) and Douglass and Lackey (1973a) maintained that the climate in the southeastern area of the state compared favorably with that in the Mississippi Delta Region. Further, research showed that many Virginia ponds already in use for tobacco irrigation or the waterings of livestock are suitable for the production of channel catfish.

In a feasibility survey, Smith (1972) estimated that of the 1500 farm ponds in Pittsylvania County, Virginia, 790 were suitable for catfish culture. Use of these ponds could result in the establishment of a limited catfish industry producing an estimated 860,000 kg of marketable fish per year. Field trials indicated that it was biologically and economically feasible to raise channel catfish in at least some Pittsylvania County ponds (Holmes, 1971, Holmes et al., 1973, Douglass and Lackey, 1973b), but due to the relatively short growing season, Holmes et al. (1973) recommended a stocking size of at least 150 mm. Douglass and Lackey (1973a) found that stocked at this size, 90 percent of the channel catfish would reach marketable size in 140 days. However, some technical problems developed in the Douglass study that must be solved before cage culture in Virginia is feasible.

Pittsylvania County has a relatively short growing season (139 days) when compared with southeastern Virginia (Beland, 1969). Therefore, it was believed that fish farming in southeastern Virginia would be a more feasible and lucrative venture due to the longer growing season (180 days).

In an attempt to further refine cage culture techniques in Virginia, strains of channel catfish from different southeastern regions were grown in cages during the 1973 growing season. Cage culture was used because most Virginia farm ponds cannot be easily drained or have irregular bottoms making conventional harvest methods difficult. Specific objectives of this research were:

(1) To evaluate three strains of channel catfish in terms of yield;

(2) To evaluate the feasibility of growing channel catfish in cages moored in small farm ponds in southeastern Virginia.

## STUDY AREA

The ponds used in this study were selected based on their suitability for cage culture. Dr. Louis Martin, Extension Specialist, Virginia State University, through county extension agents, was contacted by farmers interested in catfish farming. After a preliminary evaluation by Dr. Martin, final evaluation was determined using the evaluation forms developed by Smith (1972). The two ponds found to be most suitable were:

(1) Wall Pond - The Wall Pond was a 1.5 acre mill pond located in Central Brunswick County. The pond was constructed by the damming of Reedy Creek, a narrow (100 ft.), slow moving (average velocity = 11 inches per minute) stream. The stream meandered largely through forest land. Logging operations keep the creek fairly turbid (Seechi disk 18 in.). The pond had a maximum depth of 12 ft. and a mean depth of 6 ft. Springs and an intermittent stream also supplied the pond with water.

(2) Joyner Pond - The Joyner Pond, a 17-acre pond located in South-Central Southampton County, lies in a depression surrounded by woods on two sides. However, due to its large size, wind causes considerable surface agitation and aeration. The pond has a maximum depth of 10 ft. and a mean depth of 4 ft. This pond was less turbid than the Wall Pond (Secchi disk 3 ft.) since the water sources, i.e., springs and run-off, were from forested land.

## MATERIALS AND METHODS

Three strains of 4 - 6 inch channel catfish were obtained for this study; The Harrison Lake National Fish Hatchery provided a Virginia strain; a Kansas strain was purchased from Four Courners Fish Farm, Topeka, Kansas, and a Mississippi strain was acquired from Twin Lakes Minnow Farm, Dickson, Tennessee. The latter strain is native to Missi-ssippi but is now being propagated in Tennessee. The Kansas strain was considered to be the control since this same strain was used by Douglass and Lackey (1973a).

The same cages used in the Douglass and Lackey (1973a) study were utilized for this project. Cages were placed at least 20-feet from each other and/or from the shore. The widest part of the cage was positioned so as to receive the greatest exposure to the wind and/or current. Cages were held in position by cement block anchors in the Joyner Pond and ropes tied to stakes and trees in the Wall Pond.

Three hundred thirty channel catfish of each strain were randomly assigned to separate cages. Each pond was stocked with 12 cages, 4 replicates of 330 fish from a strain. Prior to stocking three 100-fish samples from each strain were weighed. This statistic was used to estimate the weight of fish in each cage, which must be known for effi-cient feeding.

Six days a week, fish were fed Purine Catfish Chow at 3 percent of their body weight. All feed was placed into the feeding well to mini-mize waste. The fish were not sampled during the growing season because the practice has been found to cause the fish to temporarily cease feeding. However, mortalities were used to estimate growth and adjust the feed ration.

## RESULTS

On May 12, 1973, the three strains of channel catfish were stocked into the Joyner and Wall Ponds. Feeding was initiated immediately after stocking and continued for 169 days.

Pond water temperatures throughout the growing season can be seen in Table 1. Temperatures in the Joyner Pond ranged from 14°C to 29°C while the range of temperature for the Wall Pond was somewhat cooler, 14°C to 27°C.

Three weeks after stocking the Joyner pond was vandalized. One cage of fish was pulled up on the shore and evident attempts were made to remove two others. All fish in the stranded cage were lost.

In late May, an aquatic weed problem developed in the Joyner Pond. This condition was caused by a hot dry spell which lowered the water level 18 in. The clarity of the water enabled sunlight to reach the bottom permitting rooted aquatics to grow. No weed treatment was used for fear of lowering the dissolved oxygen concentration (D.O.). During the second week of June a plankton kill occurred that lowered the D.O. Low D.O. and other factors caused 80 percent of the fish in the pond to die. The D.O. problem persisted periodically throughout the summer. As has been previously reported (Davis, 1965) it was found that feeding fish resulted in a further reduction in the D.O., further increasing mortality. Therefore, the fish were fed irregularly during the summer, when the D.O. was high enough that no mortalities occurred as the result of feeding.

Fish in the Wall Pond appeared to look and act normally until mid-

Table 1. Temperature (Centigrade) extremes and means for the channel catfish growing season in two southeastern Virginia ponds.

| Pond | High | Low | Mean |
|---|---|---|---|
| Joyner | | | |
| March | 18° | 14° | 17° |
| April | 26° | 16° | 23° |
| May | 28° | 25° | 26° |
| June | 29° | 27° | 27° |
| July | 29° | 28° | 28° |
| August | 29° | 26° | 27° |
| September | 28° | 23° | 23° |
| October | 25° | 23° | 23° |
| Wall | | | |
| March | 16° | 14° | 14° |
| April | 19° | 15° | 17° |
| May | 26° | 18° | 23° |
| June | 28° | 22° | 26° |
| July | 28° | 25° | 27° |
| August | 29° | 24° | 26° |
| September | 26° | 20° | 24° |
| October | 22° | 19° | 21° |

July. Mortalities increased at that time. Nutritional experts determined that a nutritional deficiency was causing the mortalities. The producer who had sold the feed was contacted and replacement feed promised. This feed was never received due to feed shortages.

Data from the study were gathered on October 6, the harvest date. The data were compared, using ANOVA and regression-correlation analysis on the following parameters of the three strains:

(1) Mean weight - The mean weight of the fish for each cage and strain was determined from weights of individual fish (Table 2). Significant differences were found between strains ($\alpha = 0.05$) but there was little correlation between mean weight and strain of fish ($r^2 = 0.063$) for strains in the Joyner Pond; 0.0246 for those in Wall Pond). Mean weight was lower than that found in other studies at this station (Douglass, 1973; Holmes, 1971).

(2) Yield - The yield (total weight) of fish in each cage was obtained by summing the weight of the individual surviving fish (Table 3). Significant differences ($\alpha = 0.05$) were found in both ponds, the Kansas strain having the higher yield in the Wall Pond and the Virginia strain in the Joyner Pond.

(3) Survival - Survival (Table 4) was determined on a percentage basis by dividing the number of fish harvested per cage by the number of fish stocked into that cage. The Kansas strain appears to have the highest survival in both ponds, but

Table 2. Mean weight in grams and survival of strains of channel catfish from 2 southeastern Virginia ponds.

| Strain | Cage | Mean weight | | Average mean weight | |
|---|---|---|---|---|---|
| | | Wall | Joyner | Wall | Joyner |
| Virginia | 1 | 60.8 ( 8) | 7.8 ( 63) | | |
| | 2 | 42.5 ( 13) | 15.5 ( 49) | | |
| | 3 | 51.4 ( 24) | 18.7 ( 33) | 47.5 | 12.7* |
| | 4 | 42.7 ( 29) | | | |
| | 5 | 93.1 ( 6) | | | |
| | 6 | 20.8 ( 27) | | | |
| Kansas | 1 | 50.7 ( 78) | 26.8 ( 6) | | |
| | 2 | 51.5 (107) | 8.6 ( 62) | | |
| | 3 | 58.7 ( 91) | 10.1 ( 32) | 55.9 | 9.8 |
| | 4 | 60.3 (139) | 9.1 ( 53) | | |
| Mississippi | 1 | 32.1 ( 18) | 16.3 ( 33) | | |
| | 2 | 44.8 ( 24) | 12.0 ( 22) | | |
| | 3 | 105.3 ( 4) | 17.5 ( 13) | 41.8 | 12.9* |
| | 4 | 51.4 ( 19) | 9.1 ( 43) | | |

* Values not statistically significant at = 0.05. ( ) indicates # fish per cage.

Table 3. Yield in grams of channel catfish from 2 southeastern Virginia ponds.

| Strain | Cage | Yield | | Mean yield per strain | |
|---|---|---|---|---|---|
| | | Wall | Joyner | Wall | Joyner |
| Virginia | 1 | 487 | 537 | | |
| | 2 | 553 | 743 | 771.8[a] | 622.7 |
| | 3 | 1234 | 618 | | |
| | 4 | 1239 | | | |
| | 5 | 559 | | | |
| | 6 | 563 | | | |
| Kansas | 1 | 3957 | 161 | | |
| | 2 | 5512 | 531 | | |
| | 3 | 5344 | 322 | 5797.1 | 373 |
| | 4 | 8384 | 481 | | |
| Mississippi | 1 | 577 | 541 | | |
| | 2 | 1074 | 263 | | 355[a] |
| | 3 | 421 | 226 | 876[a] | |
| | 4 | 976 | 391 | | |

a = not significant at $\alpha = 0.05$ in Wall Pond

b = not significant at $\alpha = 0.05$ in Joyner Pond

Table 4. Survival (%) of channel catfish from two southeastern Virginia ponds.

| Strain | Cage | Survival | | Mean survival | |
|---|---|---|---|---|---|
| | | Wall | Joyner | Wall | Joyner |
| Virginia | 1 | 5.3 | 20.7 | | |
| | 2 | 8.7 | 14.8 | 5.6* | 15.1* |
| | 3 | 7.3 | 9.8 | | |
| | 4 | 8.8 | | | |
| | 5 | 1.8 | | | |
| | 6 | 8.2 | | | |
| Kansas | 1 | 23.6 | 1.8 | | |
| | 2 | 32.5 | 18.8 | 31.7 | 11.5* |
| | 3 | 27.6 | 9.7 | | |
| | 4 | 42.2 | 16.0 | | |
| Mississippi | 1 | 5.5 | 9.7 | | |
| | 2 | 7.3 | 6.7 | | |
| | 3 | 1.2 | 3.9 | 6.5* | 8.3* |
| | 4 | 5.8 | 13.0 | | |

* no significant differences at $\alpha = 0.05$.

For Wall Strain - Survival = ($R^2 = 0.8740$).

Significance was found only in the Wall Pond ($\alpha = 0.001$).

(4) Food conversion - Food conversion was not determined by the usual method of dividing the amount of food consumed per cage by the total weight gained per cage. Instead the following formula was used:

$$F.C. = \frac{\text{Total food fed}}{\text{Total weight gain}} = \frac{\text{mean weight of food consumed by fish}}{\text{mean weight gain by the fish}}$$

Since the ration of food per cage was adjusted by the number of fish in that cage, it was assumed that all fish received the same amount of food. Therefore, any difference in feed conversion would be reflected in the mean weight of the fish (Table 2). On that basis, the Kansas strain had the highest feed conversion ratio in the Joyner Pond, but the lowest feed conversion ratio in the Wall Pond.

(5) Coefficient of Condition (C.O.C.) - The coefficient of condition was calculated by the same method used by Douglass and Lackey (1973a). The coefficient of condition is a measure of the robustness or "well being" of a fish. There is no significant statistical differences in the coefficient of condition among strains although differences between ponds are apparent (Table 5).

(6) Percent Marketable Fish - Due to the small stocking size, the lack of a nutritionally acceptable source of food, and the harshness of conditions in the Joyner Pond, no fish reached marketable size.

Table 5. Coefficient of condition of channel catfish from two southeastern Virginia ponds.

| Strain | Cage | COC | | Mean COC | |
|---|---|---|---|---|---|
| | | Wall | Joyner | Wall | Joyner |
| Virginia | 1 | 0.729 | 0.810 | | |
| | 2 | 0.603 | 0.971 | | |
| | 3 | 0.934 | 0.384 | 0.808 | 0.644 |
| | 4 | 0.690 | 0.599 | | |
| | 5 | 0.621 | 0.416 | | |
| | 6 | 0.753 | 0.572 | | |
| Kansas | 1 | 0.862 | 0.633 | | |
| | 2 | 0.914 | 0.608 | 0.863 | 0.666 |
| | 3 | 0.854 | 0.510 | | |
| | 4 | 0.735 | 0.749 | | |
| Mississippi | 1 | 1.214 | 0.703 | | |
| | 2 | 0.836 | 0.553 | | |
| | 3 | 0.953 | 0.339 | 0.943 | 0.526 |
| | 4 | 0.693 | 0.428 | | |

No significant differences $\alpha = 0.05$.

(7) Financial Analysis - Because there were no marketable-size fish at the completion of this study, an analysis was made for a 1.5 acre suitable, theoretical pond in southeastern Virginia using the following assumptions:

(a) A nutritionally-complete food is available at $300/ton

(b) Fish are stocked at 175 mm, weight 150 grams, and cost 10¢ each

(c) It takes 186 days for the fish to reach marketable size

(d) Feed conversion of the fish is 2.0

(e) 100% of the stocked fish are marketed; at 500 grams/fish

(f) Fish are marketed at 50¢/lb; $1.10/kg

(g) Labor costs are $2.00/hr; interest on loan is 12%.

## DISCUSSION

The two ponds were significantly different in every statistic. Therefore, the results from each pond will be discussed separately. The differences can be explained largely by the difference in physical conditions found between the ponds. The Wall Pond is smaller, more turbid, cooler, and has a more steady flow of water than the Joyner Pond. All fish were exposed to the stress of incomplete feed, but fish in the Joyner Pond were also stressed by low oxygen. (This dual stress is reflected by the lower survival, growth, yield and coefficient of condition for all three strains in the Joyner Pond.)

The Kansas strain had the highest yield, survival, and mean weight, and the lowest overall feed conversion rate in the Wall Pond and the best survival in the Joyner Pond. The major factor affecting the yield was survival. There was little correlation between strain and mean weight, and feed conversion, thereby, indicating a large variance in growth within a strain. The high correlation between strain and survival indicates a small within-strain variance in survival. Therefore, consistently high growth variance resulted in both very large fish and very small fish. This conclusion differs from the Douglass and Lackey (1973) where the factor affecting yield most was food conversion.

The Mississippi and Virginia strains exhibited equal growth in the Joyner Pond, but due to better survival, the Virginia strain produced the highest yield. As stated above, there is little correlation between mean weight or yield with either strain. It also can be seen from Tables 2 and 3 that the Mississippi strain had the highest mean weight but the lowest yield. Therefore, the highest survival combined with high mean weight resulted in the greatest yield of the Virginia strain in the Joyner Pond.

There were no significant differences ($\alpha = 0.05$) in C.O.C. among strains within each pond. Length-weight relationship is known to vary between strains and between different environmental conditions. Therefore, to get a true estimate of how well a strain did under a new set of conditions one must first know the C.O.C. for the strain under normal conditions. An increase in C.O.C. from this normal state would indicate robustness. This comparison was not done. Therefore, the existing C.O.C. in this study can be used as a comparison of robustness between strains, or as a comparison of healthiness between ponds (assuming the same initial C.O.C. for a strain in both ponds), but not as a measure of relative "healthiness" between strains in a particular pond.

Differences in pond conditions would explain why the Kansas strain had the highest yield in the Wall Pond but the lowest yield in the Joyner Pond. From these findings it appears likely that a particular strain may produce the highest yield, survival, etc. for a given set of pond conditions. A large variance in pond conditions, such as that found in Virginia, makes it very unlikely that one strain is "best" for the whole state.

None of the fish in this study reached marketable size for several reasons: 1) the fish were stocked at 100 mm while Holmes (1971) and Holmes et al. (1973) recommended that fish be at least 150 mm when stocked in Virginia, (150 mm fish were unavailable); 2) the food was nutritionally incomplete; 3) the low oxygen in the Joyner Pond posed an additional critical stress.

The importance of pond selection and evaluation during the worst conditions for culture in that pond cannot be overemphasized. Conditions in a pond can vary radically from month to month and season to season. Because the fish must be grown in the pond for at least 6 months, conditions in the pond must be possible for culture every day of the 6-month period. Evaluating the pond on the best day of the growing season does not truly evaluate the fitness of the pond for culture.

While the mean monthly temperature of the ponds in this study never reached that of maximum growth and food conversion of channel catfish the ponds remained above the critical low temperature at which catfish have been observed to cease feeding.

Table 6. Financial analysis of channel catfish cage production in a theoretical 1.5 acre Virginia pond excluding pond construction costs and transportation charges. Location southeastern Virginia.

| | |
|---|---|
| ANNUAL EXPENSES | |
| Fingerlings (2,000, 175 mm, @ $.10 each) | $ 200.00 |
| Food (1,400 kg, @ $0.33/kg) $300/ton | 462.00 |
| Labor | |
| Daily checking and feeding (69.3 hrs @ $2.00/hr) | 186.00 |
| Harvesting (3.0 hrs @ $2.00/hr) | 6.00 |
| Equipment | |
| Cages (amortized at 8% for 3 years)(6 cages @ 312 x .415) | 129.48 |
| Feed scale (amortized at 8% for 3 years) ($22.00 x .415) | 9.13 |
| Oxygen kit (amortized at 8% for 3 years) ($14.00 x .415) | 5.81 |
| Rope (amortized at 8% for 3 years) (550 m @ $12.00 x .415) | 4.98 |
| Interest on borrowed capital (fingerlings @ 12%) | 24.00 |
| (food and labor @ 8%) | 52.32 |
| TOTAL | 1,079.72 |
| Returns (expected) | |
| 1000 kg fish @ $0.66/kg ($0.30/lb) | 547.14 |
| @ $0.88/kg ($0.40/lb) | 728.52 |
| @ $1.10/kg (50 lb) | 1,100.00 |
| Less expenses | -1,079.72 |

Table 6. Financial analysis of channel catfish cage production in a theoretical 1.5 acre Virginia pond excluding pond construction costs and transportation charges. Location southeastern Virginia. (Continued)

| | |
|---|---|
| Net returns to land management and other fixed costs before taxes/year/0.6 ha pond | |
| @ $0.50/lb | 20.28 |
| Break Even = (49.04¢/lb) | |

PART II

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## VITA

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Gary L. Misko

THE EFFECT OF MONOCHROMATIC LIGHT ON THE GROWTH,

FOOD CONVERSION, AND SURVIVAL OF TWO STRAINS OF RAINBOW

TROUT, SALMO GAIRDNERI

by

Gary L. Misko

(ABSTRACT)

Three hundred rainbow trout from each of two strains (Wytheville and the Soap Lake) were exposed in equal numbers to three non-overlapping wavebands of light (red, green, blue). One hundred fish from each strain were used as a control. These fish were exposed to unfiltered light of intensity equal to that of the three spectral treatments (21.4 lux). All fish were exposed to continuous light of the assigned experimental spectra for 53 days.

Fish were fed trout chow twice daily at a rate previously found to maximize growth and efficiency. This feeding rate was determined by consulting hatchery records and the feeding charts developed by Haskell (1959).

Mean length and mean weight of test animals may be affected by the rearing of individuals under specific wavebands of light ($\alpha$ = .001). Fish grown under blue or green light had the greatest mean length and fish grown under control or green light had the greatest mean weight while those reared under red light had the lowest mean length and mean weight. Although differences in coefficient of condition, yield, feed

conversion ratio, and survival were not significant between light treatments ($\alpha = 0.05$) in my study, significant differences may possibly be found in studies with a larger sample size.

Although high variability and small sample size limit interpretation, this study suggests that certain light treatments used in conjunction with certain strains of fish could improve hatchery production.