Effects of Sunlight Intensity on Survival of Striped Bass X White Bass Fry

Robert A. Rees, *Georgia Department of Natural Resources, Richmond Hill, GA 31324*

Stanley F. Cook, *Georgia Department of Natural Resources, Richmond Hill, GA 31324*

Abstract: The effects of sunlight intensity on survival of *Morone saxatilis X Morone chrysops* hybrid fry were examined through studies performed in replicated aquaria and hatchery rearing ponds. The aquaria and ponds were exposed to direct sunlight and 2 types of sunlight reduction (overhead shading and decreased water clarity). Direct sunlight reduced fry survival in the aquaria and pond experiments. In aquaria, variations in overhead shade and water clarity significantly affected fry survival, and decreased water clarity was more effective than an increase in overhead shade in increasing survival. In ponds, overhead shading was more effective than water clarity in increasing fry-to-fingerling survival.

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Low, variable survival of young striped bass *(Marone saxatilis)* and striped bass X white bass *(Morone chrysops)* hybrids 7 to 45 days old) in hatchery rearing ponds has been a major problem confronting fish culturists in Georgia. Demand for *Marone* spp. fingerlings for stocking in Georgia has increased greatly, while available state hatchery pond acreage has decreased. As a result, efforts to improve fry survival and fingerling production in hatchery ponds have continued in Georgia in order to achieve maximum fingerling yield from available pond space.

In the past, poor *Marone* fry survival and low fingerling production in hatchery ponds were believed by Georgia biologists to be influenced by genetic and/or physiological factors more than by environmental factors. Because of this, in recent years *Morone* fry produced at Georgia's Richmond Hill Hatchery have been closely monitored for deformities, post hatching mortality, feeding ability, and mobility prior to stocking in rearing ponds. Monitoring has eliminated obviously inferior fry and has resulted in improved fingerling production. However, problems still exist that are believed to be environmentally related.

Water clarity in many rearing ponds is often high at the time of fry stocking and occasionally remains high throughout the spring fingerling rearing period. The effect of direct sunlight accentuated by relatively clear water conditions in hatchery rearing ponds has often been considered a possible cause of fry mortality and low fingerling production. Barahona-Fernandes (1979) performed experiments to determine the effects of light intensity on the growth and survival of sea bass larvae, *Dicentrarchus labrax.* He found that there was better growth but poorer survival at higher light intensities and that strong light intensities were lethal to newly hatched larvae (with no pigmentation). Past observations by Georgia biologists and hatcherymen have indicated that fry survival generally appeared higher in opaque ponds, regardless of whether the opaqueness resulted from colloidal particles, heavier than normal zooplankton blooms, good phytoplankton blooms, or application of potassium permanganate as a dye.

A preliminary aquaria experiment conducted at Richmond Hill Fish Hatchery in 1976 (R. Rees, unpub!. rept.) confirmed that exposure to direct sunlight could affect survival of striped bass fry. Subsequently, 2 studies were designed to investigate the effect of sunlight intensity in water of varying degrees of clarity on the survival of striped bass x white bass hybrid fry. The objective of the first study was to investigate the effects of variations in exposure to sunlight upon the survival of fry held in aquaria containing clear, turbid, or colored (dyed) water. The second study tested the effects of sunlight on fry and fingerling survival in earthen rearing ponds.

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Methods

Aquaria Experiment

The aquaria experiment was conducted at Richmond Hill Fish Hatchery, Richmond Hill, Georgia during April 1979. Three 3,785 liter circular fiberglass tanks were positioned outdoors to receive direct solar radiation. A wooden frame was constructed around the perimeter of 2 of the tanks to support materials used to shade the tanks. Tank # 1 was not covered and had 0.0% shading or received total available sunlight intensity. Tank #2 was covered on the top and sides by 2 layers of saran cloth (0.32 cm mesh) producing 66.6% (medium) shading. Tank #3 was covered on the top and sides with 1 layer of saran cloth and several layers of burlap cloth (0.16-cm mesh) to produce 99.1% (heavy) shading. This arrangement resulted in 3 different levels of sunlight intensity. The percent shading for tanks #2 and #3 was calculated from the ratio of light intensity above and below the overhead cover, based on measurements by a Weston Master V photometer.

Twelve 37.85 liter aquaria were placed in each of the 3 circular tanks and numbered 1 through 12 (Fig. 1). The aquaria were supported by a wooden framework that permitted chilled water to circulate around them to maintain a constant temperature of 22.4 C. All of the aquaria were filled to a depth of 25.4 cm with the appropriate test water and aerated using compressed air and airstones to maintain dissolved oxygen between 8 and 9 ppm. Clear plastic bags were placed over all aquaria during inclement weather to prevent contamination by rain water.

Four water clarity treatments (clear, dyed, lightly turbid, and heavily turbid) were tested in conjunction with each of the shade treatments. Aquaria for each water clarity treatment in each test tank were selected at random. Each tank contained 2 aquaria with clear well water, 4 aquaria with dyed water, 2 aquaria with lightly turbid water, and 4 aquaria with heavily turbid water. Unequal replications of aquaria were based on an initial assessment of the relative importance of each treatment and on how the data were to be analyzed.

Dyed and turbid waters utilized in the experiment were pre-mixed and standardized in 3 other 3,785 liter circular mixing tanks prior to filling test aquaria. Dyed water was produced by adding 0.5 ppm potassium permanganate to well water and neutralizing the permanganate through oxidation with cottonseed meal. The dyed water was then filtered and standardized at 12 color units (APHA Platinum-Cobalt Standard). The lightly and heavily turbid waters were produced by mixing fine clay with well water until standard levels of 7 and 25 JTU's (Jackson Turbidity Units-Formazin Standard) were obtained, respectively. Sunlight reduction through both lightly turbid and dyed water in the aquaria was identical (38.0% through 25.4 cm of water). Well water was used for the clear water aquaria. Light reduction through clear and heavily turbid water was 19% and 62%, respectively. A photometer was wrapped in clear plastic bag for water proofing and held under the aquaria to obtain the light penetration through the water in the aquaria. Water clarity during the mixing phase and in all aquaria during each test run of the experiment was determined using a Hach model DR-EL portable water engineer's laboratory.

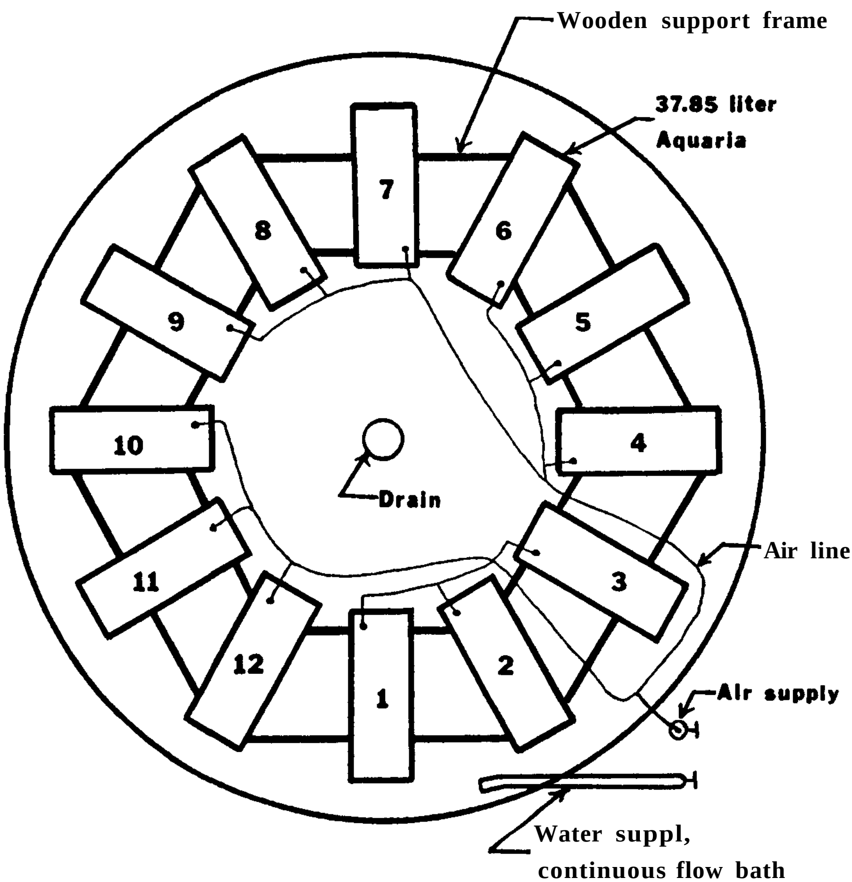

Figure 1. Axial-radiating arrangement of the 12 experimental aquaria containing clear, turbid, or dyed water supported on wooden frame in circular test tank.

Striped bass x white bass hybrid fry of 5 different broodfish were pooled to reduce the possibility of high mortality due to genetic and/or physiological factors. The pooled fry were individually counted into 100 ml beakers. One hundred 6½-day old fry were stocked simultaneously in each of the 36 aquaria 2 hours before sunrise. Fry were fed brine shrimp nauplii at 3-hour intervals from 0800 to 2300 hours each day of a test run.

All 36 aquaria were stirred every 2 hours between 0800 and 1600 hours to prevent settling and maintain turbidity levels originally set in the turbid aquaria. Stirring all aquaria reduced the possibility of variation in fry survival which might have resulted if only turbid aquaria had been stirred. At 0800 hours each morning, the turbid and dyed aquaria were checked against the initial standards before and after stirring. Sunlight intensity was also measured every 2 hours from 0800 to 1600 hours using a photometer held above an aquarium of each shade treatment. The light meter was sensitive only to visible light.

The test was repeated 3 times, and the duration of each of the 3 test runs was approximately 54 hours. On the advice of a statistician, the termination point for all runs was based on the length of time required for fry survival in any aquaria in the first run to fall below 20.0%. Aquaria were drained at the end of each run, and the live fry were counted and recorded.

Survival data were collected and analyzed by a split plot analysis of variance (ANOVA) with completely randomized subplots (Steel and Torrie 1960), using the least squares method. Additional regression analyses were applied to the data to determine if a reduction in water clarity was more effective in improving fry survival than a reduction in overhead shade.

Pond Culture Experiment

A pond culture experiment to test the results of the aquaria experiment in actual application was conducted at Richmond Hill Fish Hatchery the following year (spring 1980). Twelve small hatchery ponds (II 0.08 ha and 1 0.12 ha) were utilized in determining the effects of sunlight on striped bass x white bass hybrid fry survival through 4 different treatments involving shading and dyeing. The ponds were selected at random for each treatment. Treatment # 1 consisted of 3 ponds with no shade or dye (control). Treatment #2 consisted of 3 ponds with shade and no dye. Treatment # 3 consisted of 3 ponds with dye and no shade. Treatment # 4 consisted of 3 ponds with shade and dye.

Dyed ponds received 0.5 ppm of potassium permanganate 24 hours prior to stocking fry. Neutralization of permanganate occurred within 6 hours, giving the pond water a brown tint. Additional applications (0.2-0.3 ppm) were added throughout the test period when the pond visibility reached an estimated 0.46 m using a Secchi disc.

Shaded ponds were partially covered with black polyethylene plastic. Three polyethylene strips 3.66 m wide were stapled together resulting in a cover 10.97 m wide. The length of the cover varied according to the width of the respective pond. The covers were placed over the catch basin end (deeper end) and were held in place by ropes anchored to the pond banks on 3 sides and by concrete bottom weights on the open water side. Floats under the plastic cover held the cover on the surface while the anchor ropes prevented damage from wind action. Approximately 30.0% of the surface of each shaded pond was covered with the black plastic.

Striped bass x white bass hybrid fry (6½ days old) of 5 different broodfish were pooled in a fry holding trough and then transferred to 12 113.5 liter aquaria, each representing an experimental pond. The aquaria were subsampled for fry numbers, and the number of fry in each aquarium adjusted to the correct pond stocking rate of 74I,000/ha. Fry were removed from aquaria and transported in plastic garbage cans after dark to the respective ponds. All ponds were stocked simultaneously, and the fry were tempered for ½ hour prior to release in the ponds.

Standard *Morone* spp. culture practices used at Georgia hatcheries were followed during the experiment. Applications of algicides, fertilizers, and diesel fuel for aquatic insect control were applied equally to all experimental ponds to reduce variability between ponds. Water quality (temperature, dissolved oxygen, pH, carbon dioxide, total hardness, and total alkalinity) was monitored every 4 days throughout the rearing period to detect any problems that might cause mortality.

Fingerlings were harvested from the ponds at 44 days old and placed in separate holding vats containing a prophylactic treatment of 1.0% sodium chloride. After a 3-hour adjustment period to reduce fingerling stress, the total number and mean length of fingerlings from each pond were determined. Survival data were analyzed by a Model I, 2-way analysis of variance (Sokal and Rohlf 1973). A product-moment correlation coefficient was calculated to show the relationship between growth as measured by length and the number harvested per hectare.

Results

Aquaria Experiment

The highest survival of striped bass x white bass hybrid fry occurred in the heavily turbid/heavily shaded aquaria, while the lowest survival occurred in clear water aquaria with no shade (Table I). It was apparent that increased shade and decreased water clarity increased survival.

The analysis of variance was performed on transformed data, using the arcsin transformation equation arcsin $\sqrt{p} = Y$ where $p =$ survival expressed as a fraction and $y =$ transformed survival. There was no significant interaction ($P > 0.667$) between water clarity and overhead sunlight intensity, indicating that the treatments were independent and that the results of the ANOVA could be interpreted in a straightforward manner (Table 2). Direct sunlight did adversely affect the survival of 6½-day old hybrid fry ($P < 0.013$). Variations in overhead shading (0.0 to 99.I% shade) also affected fry survival ($P < 0.03I$); however, no significant difference ($P > 0.371$) could be detected between 66.6% (medium) and 99.1% (heavy) shading. Variations in water clarity had a significant effect ($P < 0.001$) on hybrid fry survival. However, it made no difference ($P > 0.226$) whether potassium permanganate dye

Table 1. Mean Percent Survival of Hybrid Bass Fry After 2½ Days at 3 Levels of Overhead Shade and 4 Levels of Water Clarity

	Water Clarity											
	Clear			Dyed			Light Turbidity			Heavy Turbidity		
	1st Run	2nd Run	3rd Run	1st Run	2nd Run	3rd Run	1st Run	2nd Run	3rd Run	1st Run	2nd Run	3rd Run
0.0% shade	29.5	0.0	16.5	40.8	19.8	30.0	21.0	2.0	31.5	60.5	55.0	51.5
66.6% shade	14.5	35.0	41.5	70.5	70.0	45.5	34.5	54.5	59.0	78.5	80.2	74.0
99.1% shade	27.0	58.0	31.0	67.2	77.8	53.5	61.5	63.0	79.0	79.0	83.5	82.8
Light reduction through 25.4 cm of water		19%			38%			38%			62%	
APHA platinum cobalt standard color units		0			12							
Jackson turbidity units (JTU)		0						7			25	

Table 2. Split Plot ANOVA for Testing the Effects of Overhead Shade and Water Clarity on the Survival of 6½-Day Old Hybrid Bass Fry in Experimental Aquaria.

Source	df	S5	MS	F	Significance Level
Runs	2	30.8	15.4		
Shading	2	9,546.0	4,773.0	9.30	*P<0.031*
o vs 66.6 & 99.1	1	9,462.0	9,462.0	18.44	<0.013
66.6 vs 99.1	1	519.0	519.0	1.01	>0.371
Error (a)	4	2,052.0	513.0		
Treatments[a]	3	11,202.0	3,734.0	25.93	<0.001
CvsK, L, H	1	6,563.0	6,563.0	45.58	<0.001
KvsL	1	226.0	226.0	1.57	>0.226
LvsH	1	5,651.0	5,651.0	39.24	<0.001
Treatment x shading	6	587.4	97.9	.68	>0.667
Error (b)	18	2,592.0	144.0		
Aquaria in treatment	72	6,984.0	97.0		

• C - Clear water
K - Potassium permanganate dyed water
L - Lightly turbid water (7.0 ITU)
H - Heavily turbid water (25.0 ITU)

or light clay turbidity was used to retard penetration through the water column; Le. equal levels of light transmission through dyed or turbid water appeared to produce equal survival.

Linear and curvilinear regressions were developed using data partitioned by the levels of overhead shade and for all levels of overhead shade combined. In these regressions, the quantitative light reduction produced through the 25.4 em of water (Table I) in the aquaria was used as the independent or x variable. Analysis was performed using arcsin transformed data. Linear regressions of form arcsin $\sqrt{p} = ax + b$, and curvilinear regressions of form arcsin $\sqrt{p} = ax^2 + bx + c$ were developed, where p is survival expressed as a fraction. These equations were developed to determine whether the effects of light reduction brought about by clear, dyed, or turbid water on fry survival were linear or curvilinear. The individual and overall linear equations were all significant ($P < 0.005$); none of the curvilinear equations were significant ($P > 0.189$), indicating that the effects of sunlight reduction on fry survival were linear in nature.

In order to determine whether water clarity was significantly more effective in improving fry survival than overhead shade, 2 linear arcsin regressions were developed. Percent effective sunlight was defined as the percent of direct sunlight striking the surface of the aquaria multiplied by the fraction of ambient sunlight at the surface which actually penetrated to a depth of 25.4 cm through the water. One of the equations expressed the relationship between effective sunlight and fry survival in clear, dyed, and turbid water with no

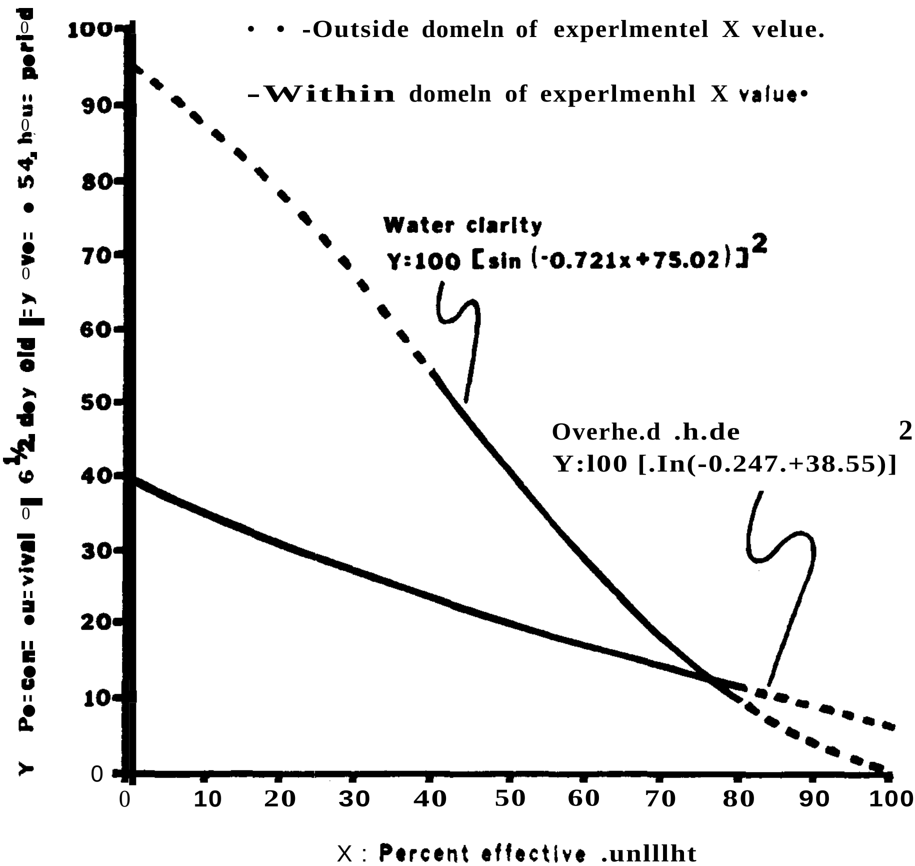

Figure 2. Percent survival as a function of percent effective sunlight.

overhead shade; the other equation expressed the relationship between effective sunlight and fry survival in clear water with overhead shade (Fig. 2).

The equation for overhead shade, rewritten in the original units of measure, was $y = 100\ [\sin\ (-.0247x + 38.55)]^2$, where $y =$ percent survival and $x =$ percent effective sunlight. The equation for turbid and dyed water was $y = 100\ [\sin\ (-0.721x + 75.02)]^2$ (Fig. 2). The slopes of the 2 regressions were found to differ significantly ($P < 0.025$); Le., the increase in survival per unit decrease in effective sunlight was significantly greater (P <

0.025) when the reduction in effective sunlight was brought about by turbid or dyed water than when brought about by overhead shade.

Pond Culture Experiment

Treatment #2 (shade-no dye) resulted in the highest striped bass x white bass hybrid fry survival rate of 13.8% (Table 3) followed by treatment #4 (shade-dye), treatment #1 (no shade-no dye), and treatment #3 (no shade-dye). Overall survival in the newly constructed (1st year in production) experimental ponds was considerably lower than the normal survival in the older *Morone* hybrid production ponds on the station that year.

The analysis of variance (Table 4) indicated that variations in pond shading had a significant effect ($P < 0.05$) on survival. Variations in water clarity did not have a significant effect ($P > 0.05$) on survival. There was a significant interaction ($P < 0.05$) between shade and water clarity.

A product-moment correlation coefficient ($r = 0.66$) was calculated to determine if there was a significant correlation between survival and growth

Table 3. Mean Hybrid Bass Harvest and Survival Rates in 4 Experimental Pond Treatments

Treatment	Pond Size (ha)	No. Fingerlings Harvested	No. Fingerlings Harvested Per ha	Percent Survival
No shade/No dye	0.081	4,093	50,530	6.82
Shade/No dye	0.095	9,211	96,958	13.81
No shade/Dye	0.081	3,171	39,148	5.29
Shade/Dye	0.081	6,580	81,236	10.97
Overall	0.084	5,764	68,616	9.22

Table 4. Model I, 2-Way ANOVA Evaluating the Effects of Variations in Water Clarity and Overhead Shade on the Survival of Hybrid Bass Fingerlings in Experimental Hatchery Ponds.

Source of Variation	df	SS	MS	F
Subgroups	3	49,005,886	16,335,289	
A (shade)	1	43,361,510	43,361,810	6.36 *
B (dye)	1	5,181,102	5,181,102	.82NS
A X B (interaction)	1	43,462,954	43,462,954	6.88 *
Within SUbgroups (error)	8	50,573,661	6,321,708	
Total	14	142,579,527	10,184,252	

• - significant ($P <$ .OS)
NS - nonsignificant ($P >$ .OS)

(total length) of hybrid bass fingerlings in the ponds. There was a significant correlation ($P < 0.02$) indicating that as survival increased, growth increased.

Discussion

The aquaria and pond experiments both indicated that direct sunlight affects *Morone* hybrid bass fry survival. However, there were some results which appeared to be in conflict. In the ponds, shading was more effective in improving survival than water clarity; the opposite was true in the aquaria tests. There was a significant interaction between the effects of shade and water clarity on survival in ponds, whereas none was present in aquaria. In ponds, the effect of shading on fry survival was dependent upon the level of water clarity of the pond water. Such an interaction may not occur using dyeing agents other than potassium permanganate to reduce water clarity.

There were differences in the aquaria and pond experiments which may have accounted for the conflicting results. In the aquaria experiment, the food supply was constant (all treatments received identical amounts of brine shrimp from an outside source), whereas in the pond experiment, zooplankton populations and concentrations could have varied significantly from pond to pond even though each pond received identical fertilizer applications. However, the positive correlation between survival and growth in the ponds would seem to rule out food supply as a limiting factor. Also, in the pond experiment, the fry or fingerling could escape direct sunlight by descending to a depth of 183 cm, whereas fry in the aquaria were restricted to a maximum depth of 25.4 cm. In addition, the duration of the pond experiment was many times longer (44 days) which may have introduced a long-term effect not present in the aquaria experiment. Finally, oxygen and temperature were maintained at constant levels in the aquaria experiment, but exhibited daily fluctuations in the pond experiment.

Efforts to increase *Morone* spp. fry-to-fingerling survival in pond culture has caused many Georgia biologists to conclude there are complex systems of genetic, physiological, and environmental factors which may affect fry independently or collectively through interaction of a combination of factors. Whether the increase in fry survival from reduced light in the aquaria and pond experiments was due to reduced ultraviolet radiation, reduced cannibalism, or some other factor or combination of factors is not clear. However, both experiments demonstrated that increased survival was related to a reduction in sunlight penetrating the water column.

Although it appears that shading the water is effective in improving fry survival in relatively clear hatchery rearing ponds, the method used in this particular study to reduce sunlight penetration may not be practical in all pond management applications. In the pond experiment, shading one-third of the pond surface area doubled survival, but the shade covers used were expensive, bulky, and difficult to fabricate and maintain. Modifications in design and construction, however, could reduce some of the cost and handling problems.

The percentage of shaded pond surface area which is needed for optimum fingerling survival may vary from the surface area used in this study and should be examined further. In addition, dyeing the pond water, which appears to be practical from a cost and labor standpoint in reducing sunlight penetration, should be investigated further to determine which dyeing agent or concentration level may result in increased survival.

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