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Fungal Control Methods, Diets and Water Temperatures Used to Culture Paddlefish, Polydon spathula

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FUNGAL CONTROL METHODS, DIETS AND WATER TEMPERATURES USED TO CULTURE PADDLEFISH, *Polyodon spathula*

BY

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FUNGAL CONTROL METHODS, DIETS AND WATER TEMPERATURES USED TO CULTURE PADDLEFISH, *Polyodon spathula*

This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree, but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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FUNGAL CONTROL METHODS, DIETS AND WATER TEMPERATURES USED TO CULTURE PADDLEFISH, *Polyodon spathula*

Abstract

Ronald L. Brandt

Studies were conducted at Gavins Point National Fish Hatchery, South Dakota, in 1976 and 1977, to evaluate the effects of diet and water temperature on growth and survival of paddlefish, *Polyodon spathula*, young, and the effects that fungicides have on hatching success and fry survival.

The W-7 cool water diet was fed hourly and three times daily while the Liv commercial diet was fed hourly to paddlefish young for 40 days after swim-up. Average survival rate and total length of paddlefish fed W-7 hourly were 16.0% and 30 mm, those fed W-7 three times daily were 10.0% and 23 mm, and those fed Liv hourly were 7.5% and 23 mm. The W-7 diet fed hourly was significantly better in terms of survival ($P<0.1$) and growth ($P<0.005$).

Paddlefish fry were fed the W-7 diet hourly for 40 days after swim-up at water temperatures of 16±1.6°C and 21±1.6°C. The average survival rate and total length of paddlefish reared at the lower temperature were 6.8% and 52 mm, and those reared at the higher temperature were 27.5% and 118 mm.

Survival rate and growth were significantly higher ($P<0.005$) for paddlefish reared at 21±1.6°C.

Paddlefish eggs were treated with formalin, for 15 min daily, first at 1667 mg/1 and later at 833 mg/l; and with malachite green, for 2 min daily at 65 mg/1, to control fungus. Hatching success, determined by estimating numbers of fry at swim-up, was 16.6% for the eggs treated with formalin and 21.8% for the eggs treated with malachite green. Hatching success was significantly higher for eggs treated with malachite green ($P<0.005$). The average survival rate and total length of paddlefish after a 23-day feeding period were 32.2% and 43 mm for fish hatched from formalin treated eggs, and 47.5% and 45 mm for fish hatched from malachite green treated eggs. Fry survival was significantly higher for fry hatched from malachite green treated eggs ($P<0.05$). No significant difference was found in total lengths of paddlefish hatched from eggs treated with formalin or malachite green ($P>0.1$).

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INTRODUCTION

The paddlefish, *Polyodon spathula*, a species native to the Missouri River (Bailey and Allum 1962), has been adversely affected by dam construction. Paddlefish were infrequently taken by anglers prior to impoundment. The construction of dams, and the resultant blockage to upstream movement by paddlefish, concentrated paddlefish in the tailwater areas and made them vulnerable to a snagging-type fishery. Sport fisheries for paddlefish developed in four areas of South Dakota; (1) Oahe Dam tailwaters, (2) Big Bend Dam tailwaters, (3) Fort Randall Dam tailwaters, and (4) the Missouri River below Gavins Point Dam. Generally, these fisheries lasted for only a few years before abrupt catch declines (Friberg 1973, Unkenholz 1976).

Paddlefish spawning requires rock or gravel areas with swift current, rising water levels, and water temperatures near 12^{0}C (Stockard 1907; Purkett 1961). The transformation of a large portion of the Missouri River from a free-flowing river to a series of large reservoirs has reduced the availability of paddlefish spawning habitat. Artificial propagation and stocking will be necessary in some cases if a sport fishery is to be maintained. Stocking will be necessary to maintain paddlefish populations over much of their native range.

The first attempt to artificially propagate paddlefish was in the early part of this century, but was unsuccessful (Alexander 1915). Purkett (1961) successfully fertilized eggs of paddlefish in 1960, but all were lost due to fungal infection. Meyer and Stevenson (1962) attempted unsuccessfully to induce maturation of paddlefish with injections of gonadotropins. Purkett (1963) was able to hatch eggs that were taken from ripe females and fertilized with milt from ripe males. In 1963 and 1964, the maturation of paddlefish was successfully induced with intraperitoneal injections of paddlefish and carp, *Cyprinus carpio*, pituitaries (Needham 1965).

Extensive work on the artificial propagation of paddlefish has been carried on in Missouri (Russell 1973). In 1972 South Dakota biologists began work on this aspect. Ovulation of paddlefish was successfully induced with paddlefish pituitaries and hatching of eggs and rearing of fry were partially successful. Fungal infections on incubating eggs have caused extensive mortality and attempts to rear fry intensively on artificial diets have been unsuccessful in South Dakota. In 1976 and 1977, I conducted studies to evaluate diets suitable for rearing paddlefish young intensively, to determine the optimum water temperature for rearing paddlefish young, and to measure the effects of different fungal control methods on hatching success and fry survival.

MATERIALS AND METHODS

Studies were conducted at Gavins Point National Fish Hatchery, Yankton, South Dakota. Paddlefish young were reared in 115 1, fiberglass, flow-through tanks (18.9 x 6.7 x 4.7 cm deep).

Each tank was supplied with a constant flow of well water. Water was heated in an elevated tank with four 1000 watt immersable heating elements and two 1200 watt livestock watering tank heaters. Temperature was regulated by adjusting water flow rate through the heating tank.

Automatic feeders, constructed from electric wall clocks, were used to feed the fish. The minute and second hands were removed from the clocks and paddles were placed on the ends of the hour hands. Holes were drilled through the faces of the clocks at one-hour intervals. The clocks were horizontally placed over the tanks and feed that was placed between the holes in the faces of the clocks was pushed through the holes by the paddles on the hour hands (Figure 1).

Survival data were analyzed with one-way analysis of variance. Growth data were analyzed with least-squares analysis of variance.

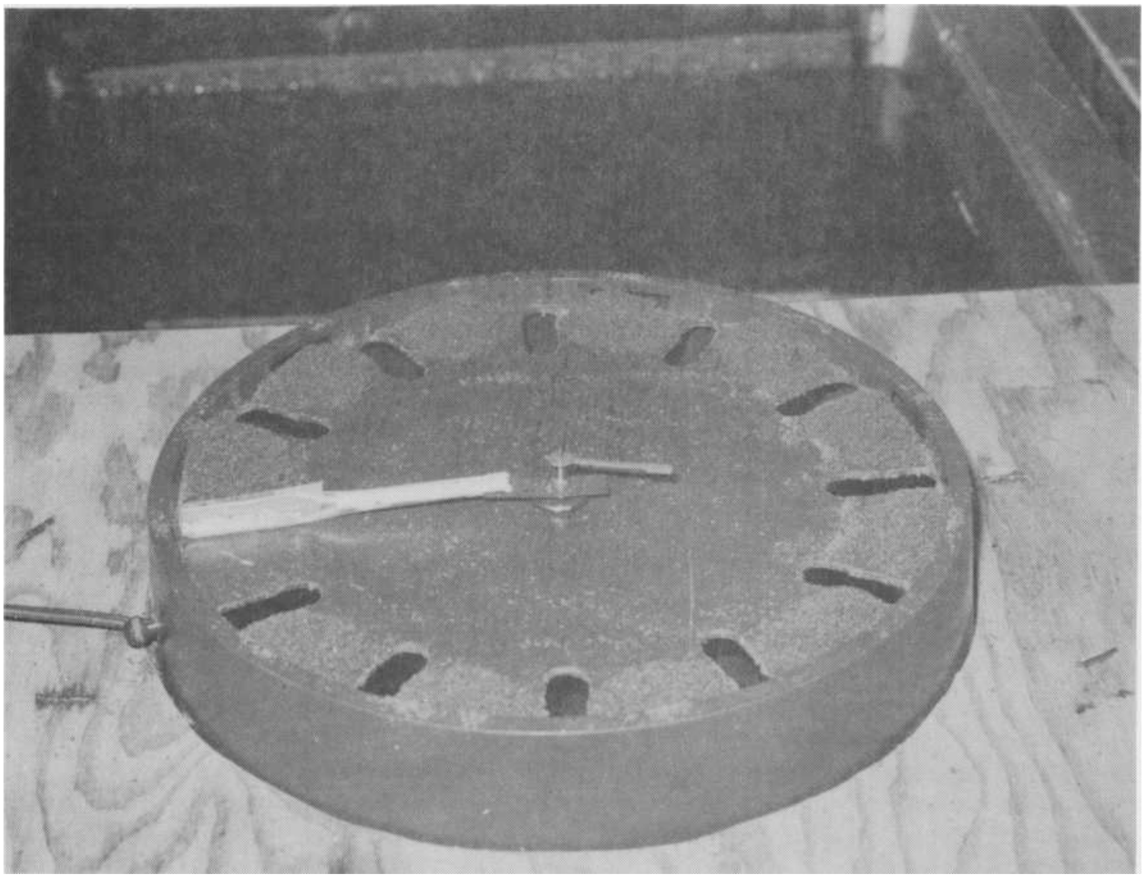

Figure 1. Automatic feeder constructed from electric wall clock and used to feed paddlefish during intensive culture studies, Gavins Point National Fish Hatchery, South Dakota, 1976-77.

Diet evaluation

Two diets, W-7 cool water diet formulated by the U. S. Fish and Wildlife Service (Table 1) and Liv, a commercial diet, were tested in 1976 with paddlefish fry obtained from the Missouri Conservation Commission. The W-7 diet was fed hourly and three times daily, and the Liv diet was fed hourly (Table 2). Each feeding treatment was replicated with four groups of 100 fish.

Feeding began on 26 April and continued for 40 days. The fry were five to six days old at the beginning of the feeding period and averaged 14 mm total length. Yolk sac absorption was almost complete and mouth parts were developed. This stage of development will later be referred to as swim-up.

The water temperature was 15.5±1°C and the water exchange rate was approximately once every hour in all tanks throughout the 40-day feeding period. Tanks were cleaned daily by siphoning wastes from the bottom. Dead fish were removed and their numbers recorded. The total lengths of surviving paddlefish were recorded at the end of the 40-day feeding period.

Water temperature evaluation

Two water temperatures, 16±1.6°C (hereafter referred to as the lower temperature) and 21±1.6°C (hereafter

Table 1. Composition and nutritional characteristics of the W-7 diet.

Composition of diet	
Herring meal	50.0%
Blood flour	5.0%
Soybean flour	10.0%
Dried whey	5.0%
Brewer's yeast	5.0%
Fish solubles	10.0%
Fish oil	9.0%
Vitamin permix #27	6.0%
Proximate analysis of diet	
Protein	51.0%
Fat	15.0%
Moisture	7.8%
Ash	9.0%
Carbohydrate	17.2%
Available kilocalories/100 g	346.0 kcal
Composition of Vitamin Premix #27 (potency)	
D. Calcium pantothenate	408.2 mg/kg
Pyridoxine (Pyridoxine HC1)	226.8 mg/kg
Riboflavin	272.2 mg/kg
Niacin	2,835.0 mg/kg
Folic acid	45.4 mg/kg
Thiamin (Thiamine mononitrate)	226.8 mg/kg
Biotin	2.3 mg/kg
Vitamin B-12	0.1 mg/kg
Menadione sodium bisulfate	56.7 mg/kg
Vitamin E	3,000.0 IU
Vitamin D-3	5,000.0 IU
Vitamin A	75,000.0 IU
Ethoxyquin	272.2 mg/kg
Choline chloride	1,814.4 mg/kg
Ascorbic acid	2,268.0 mg/kg

Table 2. Feeding treatments used to evaluate the effects of diet on survival and growth of paddlefish young, Gavins Point National Fish Hatchery, South Dakota, 1976.

Treatment	Days of Experiment	Food* Size	Feeding Time	Grams Per Feeding	Grams Per Day
W-7 hourly	1 - 8	starter	0800-1700, hourly	0.13	1.17
	9 - 29	starter	hourly	0.13	3.12
	30 - 40	#1	hourly	0.13	3.12
W-7 three time daily	1 - 29	starter	0800, 1200, 1700	0.26	0.78
	30 - 40	#1	0800, 1200, 1700	0.26	0.78
Liv	1 - 8		0800-1700, hourly	0.13	1.17
	9 - 40		hourly	0.13	3.12

*Size of food particles is as follows: starter = 420 to 595 p, number 1 = 595 to 841 p, and number 2 = 841 p to 1.19 mm.

referred to as the higher temperature), were used to rear paddlefish fry that were hatched at Gavins Point Hatchery in 1976. A 5°C difference between the two temperature treatments was maintained by raising the temperature of a constant flow of well water 5°C. Fluctuations in water temperature were due to fluctuations in the temperature of the well water. Each temperature treatment was replicated with four groups of 100, five to six day old paddlefish fry.

The paddlefish in all tanks were fed the W-7 diet hourly for a period of 40 days beginning 10 June (Table 3). A water exchange rate of approximately once every two hours was maintained in all tanks. Tanks were cleaned daily and dead fish were removed and their numbers recorded. The total lengths of surviving paddlefish were recorded at the end of the 40-day feeding period.

Fungal control evaluation

Two agents, formalin and malachite green, were used for controlling the fungus *Saprolegnia* on incubating paddlefish eggs in 1977. Eggs were taken on 25 and 26 May and placed in 6 l hatching jars for incubation. All eggs were mixed and divided into eight equal groups of 37,762 eggs each on 28 May. The eggs were again placed in jars for the duration of the incubation period. Well water at a temperature of 14.4°C was used for incubation and a flow rate of 10 l/min

Table 3. W-7 diet feeding rates used during evaluation of water temperatures of 16±1.6°C or 21±1.6°C for rearing paddlefish young, Gavins Point National Fish Hatchery, South Dakota, 1976.

Days of Experiment	Food Size	Grams Per Hourly Feeding	Grams Per Day
1 - 6	starter	0.5	12
7 - 9	1/2 starter, 1/2 #1	0.5	12
10 - 14	1/2 #1, 1/2 #2	0.5	12
15 - 21	1/2 #1, 1/2 #2	1.0	24
22 - 40	1/2 #1, 1/2 #2	1.5	36

to each jar vigorously rolled the eggs as recommended by Russell (1971).

Formalin treatments were administered to the eggs in four jars using the constant flow siphon method (Burrows 1949). A siphon from a poultry waterer was used to treat the water with formalin prior to its flowing into the four jars. Formalin concentrations of 1667 mg/1 were maintained for 15 min daily on 29-31 May and 833 mg/l was maintained for 15 min on 1 June (Kallemeyn 1974).

The malachite green treatment, administered to the eggs in the other four jars, consisted of a daily 2 min flush of malachite green at a concentration of 67 mg/1 on 29-31 May and 1 June (Russell 1971; Kallemeyn 1975). This treatment was accomplished by injecting a known volume of malachite green into the top of the stand pipe in a hatching jar with a syringe. When malachite green reached the top of the jar and appeared to be of a uniform concentration throughout the jar, the water coming into the jar was shut off. After two minutes, the malachite green was flushed from the jar and the water flow was returned to normal.

Fry that hatched and swam out of the overflow of each jar were kept separate by running the overflows into individual fiberglass tanks that had their outlets screened. On 9 June, the number of surviving fry that hatched from each jar of eggs was estimated. A water displacement method is normally used to estimate fry numbers in production hatcheries. In this study, a different method of estimating fry numbers was devised because of the need for more accurate estimations. Several hundred fry were placed in a 35 x 21 cm glass cake pan with approximately 2 cm of water. The pan was placed over a numbered grid and photographed with a 35 mm camera containing Kodak Plus X film. Grid size was 2.5 cm square. Counting was done directly from the negative with the aid of a 10 X dissecting microscope. All fry were counted in 10 squares that were randomly selected from the 77 squares making up the central portion of the pan. The total number of fry in the central portion of the pan was estimated from this count. All fry in the border around the 77 central squares were counted. The number of fry counted in the border plus the number of fry estimated in the central portion was used as the number of fry per exposure (Figure 2).

One-hundred fry that had hatched from each jar were placed in separate tanks for feeding. Feeding began on 10 May. The W-7 diet was fed to the fish in all eight tanks (Table 4).

The water temperature throughout the feeding period was 19±2°C. A water exchange rate of approximately once every two hours was maintained in all tanks. Tanks were

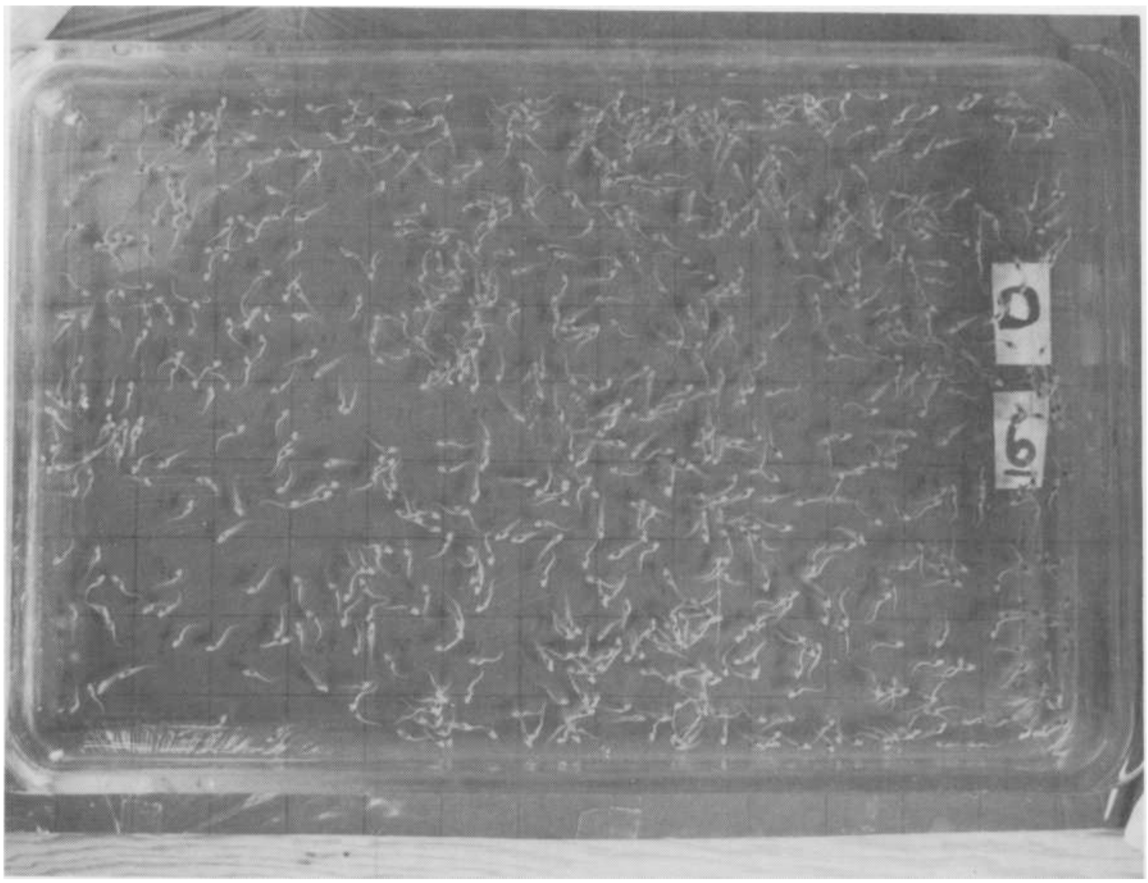

Figure 2. Photograph of paddlefish fry over grid used to estimate numbers of paddlefish fry, Gavins Point National Fish Hatchery, South Dakota, 1977.

Table 4. W-7 diet feeding rates used during evaluation of the effects of malachite green and formalin (used as fungicides on incubating eggs) on the survival and growth of paddlefish young, Gavins Point National Fish Hatchery, South Dakota, 1977.

Days of Experiment	Food Size z	Grams Per Hourly Feeding	Grams Per Day
1 - 4	1/2 starter, 1/2 #1	0.5	12
5	1/3 starter, 2/3 #1	0.5	12
6 - 9	1/3 starter, 2/3 #1	1.5	36
10 - 23	#1	1.5	36

cleaned daily, dead fish removed and their numbers recorded. At the end of the 23-day feeding period, the total lengths of surviving paddlefish were recorded.

RESULTS AND DISCUSSION

Diet evaluation

The average survivial rate and length of paddlefish, after 40 days, that had been fed W-7 hourly were 16.0% and 30 mm (range 19-44 mm), that had been fed W-7 three times daily were 10.0% and 23 mm (20-30 mm), and that had been fed Liv hourly were 7.5% and 23 mm (19-26 mm) (Table 5). Significant differences in survival ($P<0.1$) (Table 6) and growth ($P<0.005$) (Table 7) existed between treatments. Survival and growth were highest for those fish that were fed W-7 hourly.

The paddlefish fry were all in good condition at the beginning of the feeding period. Swimming was constant, and for the first few days nearly always at the surface. Gradually, the fish began to swim at all depths.

Fish in all tanks were feeding. Most feeding occurred as the food settled through the water column. Limited feeding took place at the surface, where fish were observed turning over to take food. Food was rarely taken from the bottom.

Most feeding did not appear to be deliberate. By constantly swimming, the fish would run into the food. Occasionally, when a fish swam through a concentration of food, it would turn around and pass through that area again.

Table 5. Percent survival and mean length of paddlefish fed the W-7 diet hourly, the W-7 diet three times daily, or the Liv diet hourly for 40 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1976.

Treatment	Replication	Percent Survival by Replication	Mean Percent Survival by Treatment	Mean Length (mm) by Replication	Mean Length (mm) by Treatment
W-7 Hourly	1	22	16.0	28	30
	2	13		31	
	3	11		33	
	4	18		29	
W-7 Three Times Daily	1	15	10.0	23	23
	2	11		22	
	3	3		22	
	4	11		24	
Liv	1	9	7.5	23	23
	2	5		22	
	3	11		22	
	4	5		23	

Table 6. One-way analysis of variance of percent survival of paddlefish fed the W-7 diet hourly, the W-7 diet three times daily, or the Liv diet hourly for 40 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1976.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	11	329.67		
Treatment	2	152.67	76.33	3.88*
Within	9	177.00	19.67	

*$F_{2,9}$ at the 0.1 level = 3.01.

Table 7. Least-squares analysis of variance of lengths of paddlefish fed the W-7 diet hourly, the W-7 diet three times daily, or the Liv diet hourly for 40 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1976.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	133	3781.04		
Treatment	2	1647.45	823.72	31.86*
Replication	3	22.89	7.63	
Treatment x Replication	6	155.09	25.85	
Remainder	122	1955.61	16.03	

*$F_{2,6}$ at the 0.005 level = 14.54

Swimming activity increased with increasing amounts of food in the water column. No difference in feeding behavior was noted between treatments.

After approximately one week of feeding, high mortality began to occur in all tanks (Figure 3). Some fish began to swim in a disoriented, corkscrew fashion before dying, the same swimming manner described by Friberg (1973) and Russell (1971). Dying fish would gradually weaken and settle to the bottom, unable to maintain constant swimming activity.

Attempted cannabilism was noted to a limited degree. On several occassions, a fish was observed with its mouth closed on another fish, usually on the tail. No fish were observed to be ingested in this manner.

After the 40-day feeding period, most of the surviving fish that had received the W-7 diet three times daily or the Liv Diet hourly were in poor condition. Several of the fish that had been fed the W-7 diet hourly were also in poor condition.

Kallemeyn (1975) and Friberg (1974) reported total mortality within three weeks in their attempts to intensively culture paddlefish. Although the results of this experiment were encouraging, they were not satisfactory. The growth potential is much greater than the 0.4 mm/day achieved by the fish fed the W-7 diet hourly. Unkenholz

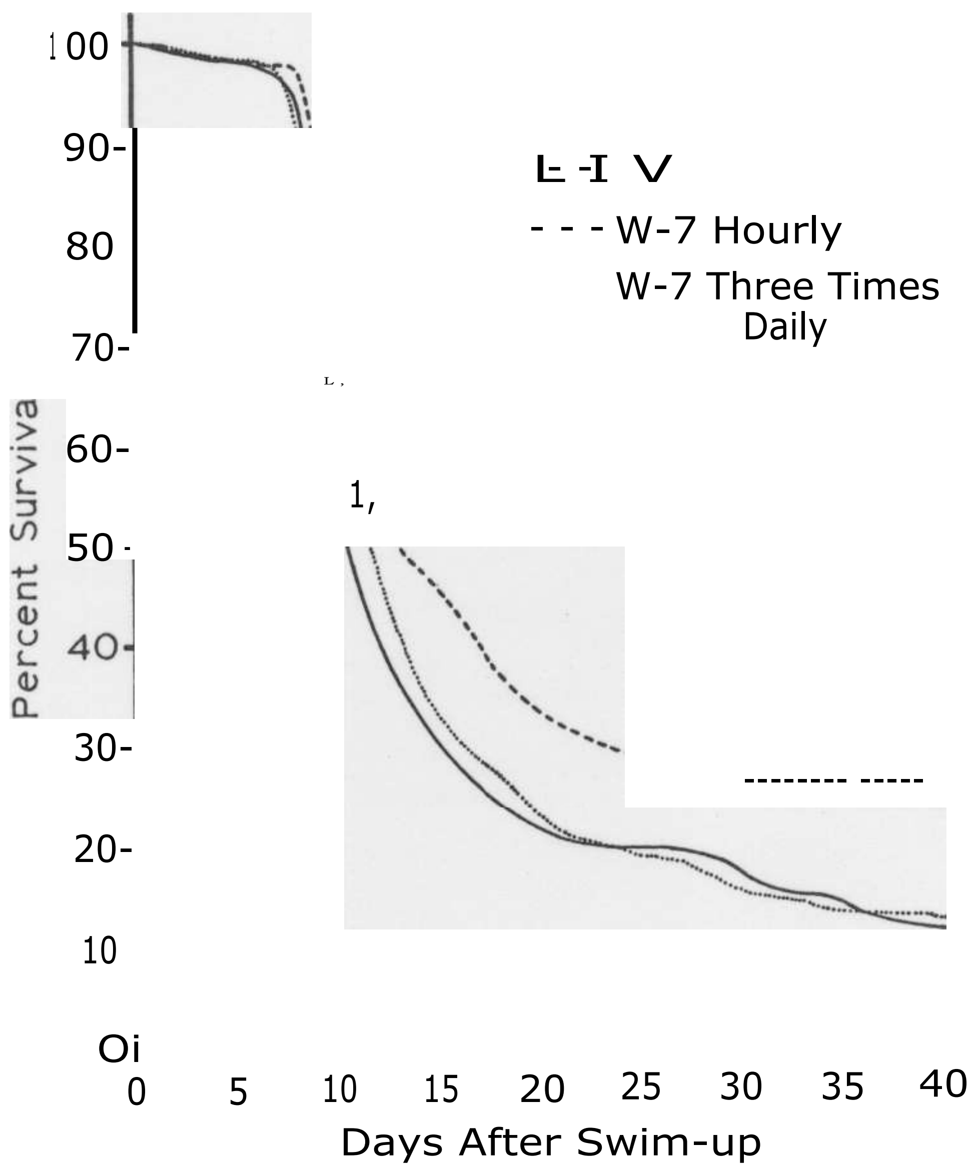

Figure 3. Survival of paddlefish fed the W-7 diet hourly, the W-7 diet three times daily, or the Liv diet hourly for 40 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1976.

(1976) reported growth of nearly 5 mm/day during a 52-day pond culture experiment. In that study, only 30 fish survived in a 3.3 hectare pond thus competition for natural food was probably low. Ruelle and Hudson (1977) observed an average growth rate of 2.7 mm/day for young-of-the-year paddlefish in Lewis and Clark Lake on the Nebraska-South Dakota border.

A comparison between the survival and growth of fish fed the W-7 diet hourly and those fed the W-7 diet three times daily indicated that those fish fed three times daily were either fed insufficient amounts, fed too infrequently, or both. Paddlefish young swim constantly. If food is present, they will feed. If food is not present, or is present in insufficient quantities, energy is wasted by their constant activity.

The survival and growth rates of paddlefish fed the Liv diet hourly were similar to those of fish fed the W-7 diet three times daily, even though the Liv diet was fed in the same amounts and at the same frequency as the W-7 diet hourly. Several explanations for this inferior survival and growth were possible. The Liv diet was possibly not as complete a diet as the W-7 diet. Liv contents and food value data were not available from the manufacturer. Another possible explanation was that the Liv Diet, being a fine powder, may not have been ingested as readily as the W-7 diet.

A large amount of food in all treatments was wasted because it settled to the bottom and was not utilized. The larger the particle size of the food, the more rapidly it settled. The development of a diet that would settle more slowly or remain suspended would be desirable. Increasing the depth of the tanks would also increase the length of time that the food remained in the water column, and a larger number of fry in the tanks may prevent excessive amounts of food from reaching the bottom and being wasted. Reducing the amount of wasted food would reduce food costs. Less wasted food would reduce tank cleaning labor.

Water temperature evaluation

The average survivial rate and length of paddlefish, after 40 days, that had been reared at the lower water temperature were 6.8% and 52 mm (range 23-92 mm), and that had been reared at the higher temperature were 27.5% and 118 mm (59-168 mm) (Table 8). Survival and growth rates were significantly higher ($P<0.005$) (Tables 9, 10) for paddlefish reared at the higher water temperature.

The feeding and swimming behavior observed during approximately the first 25 days of this experiment were much like those observed during the diet experiment. Swimming was constant and food was taken as it settled through the water column by fish in both treatments. During

Table 8. Percent survival and mean length of paddlefish reared at 16±1.6°C or 21±1.6°C for 40 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1976.

Treatment	Replication	Percent Survival by Replication	Mean Percent Survival by Treatment	Mean Length (mm) by Replication	Mean Length (mm) by Treatment
16±1.6°C	1	8	6.8	44	52
	2	6		46	
	3	6		61	
	4	7		56	
21±1. 6°C	1	17	27.5	90	118
	2	38		129	
	3	25		128	
	4	30		125	

Table 9. One-way analysis of variance of percent survival of paddlefish reared at 16±1.6°C or 21+1.6°C for 40 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1976.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	7	1096.88		
Treatment	1	861.12	861.12	21.92*
Within	6	235.75	39.29	

*$F_{1,6}$ at the 0.005 level = 18.63.

Table 10. Least-squares analysis of variance of lengths of paddlefish reared at 16±1.6°C or 21±1.6°C for 40 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1977.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	136	156311.24		
Treatment	1	92265.04	92265.04	69.60*
Replication	3	9783.33	3261.11	
Treatment x Replication	3	3976.69	1325.56	
Remainder	129	50286.18	389.82	

*F1,3 at the 0.005 level = 55.55

the latter part of the experiment, several of the fish reared at the higher temperature began swimming with their rostrum raised, breaking the surface. This may have been due to crowding and may have prevented the fish from swimming into one another during their constant activity.

Heavy mortality began early in both treatments (Figure 4). After approximately ten days of feeding, the mortality in the higher temperature treatment decreased. Mortality in the lower temperature treatment continued at a high rate for 20 days and then decreased. On day 19, 25 of 51 fish in one replication of the higher temperature treatment were inadvertently killed while attempting to treat for a suspected gill disease. This may have decreased overall survival in this treatment.

A difference in growth of fish between the treatments was evident by the end of the first week of feeding. Fish at the higher temperature were growing faster. This superior growth by fish at the higher temperature continued throughout the 40-day feeding period.

Fish reared at the higher temperature were in better condition after 40 days of feeding. However, several of the fish reared at the higher temperature had the ends of their rostrums damaged from swimming into the side of the tank. This indicated that they had probably outgrown the tanks.

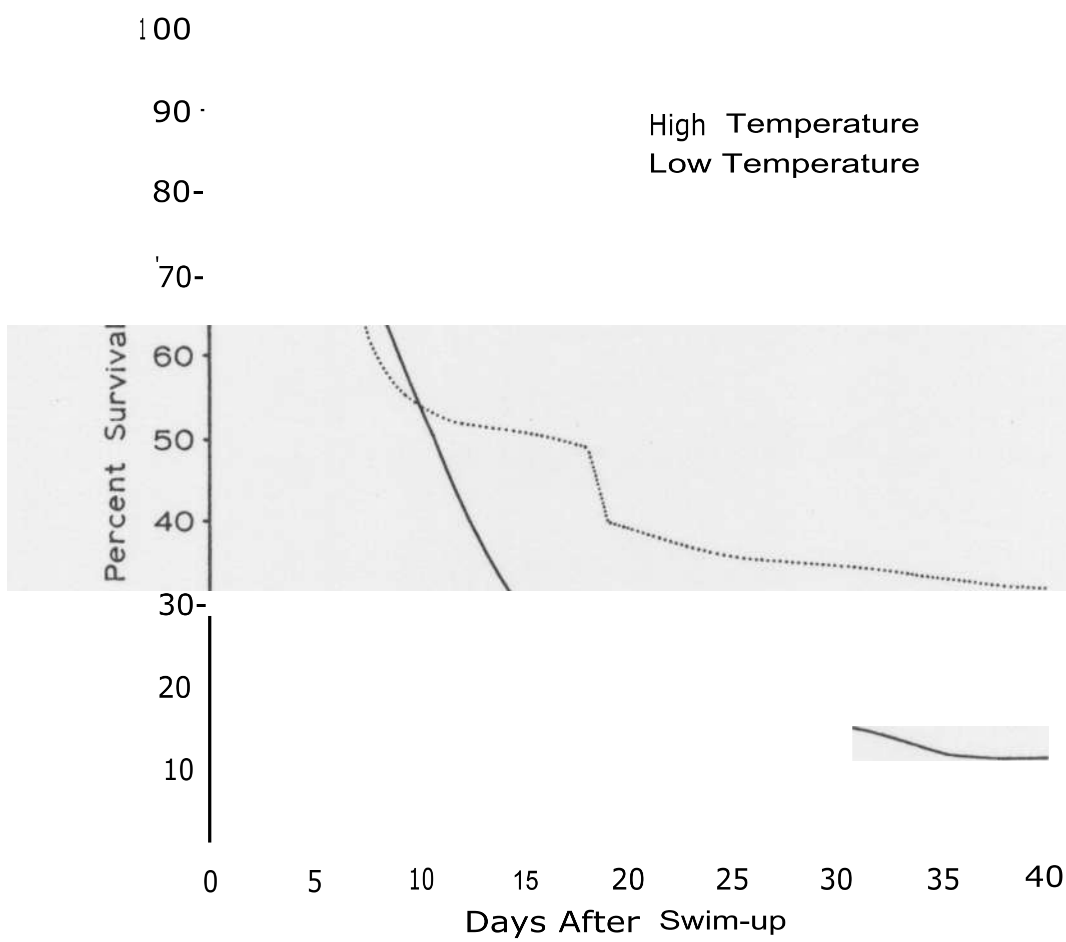

Figure 4. Survival of paddlefish reared at water temperatures of 16±1.6°C or 21±1.6°C for 40 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1976.

An increase in water temperature can cause increased maintenance requirements and food intake, and thus effects the growth of fish (Phillips 1969). Changes in growth rates with changes in water temperature have been noted for many species. Huh et al. (1976) found that walleye (*Stizostedion vitreum*) and yellow perch (*Perca flavescens*) displayed better growth rates at 22°C than at 16°C when cultured intensively. Andrews and Stickney (1972) reported better growth for channel catfish (*Ictalurus punctatus*) reared at 30°C than at 18, 22, 26, or 34°C.

An explanation for the higher growth rate of paddlefish reared at the higher temperature is difficult without data on food intake and metabolism. Fish may have eaten more at the higher temperature and/or food conversion efficiency may have been higher.

The optimal temperature for paddlefish young growth may be higher than the 21±1.6°C at which paddlefish exhibited an average growth rate of 2.6 mm/day. Unkenholz (1976) reported growth near 5 mm/day for paddlefish reared in a pond. Water temperatures were not recorded in that pond, however, temperatures in a similar pond under similar conditions ranged from 20 to 29°C (Unkenholz 1977). As previously stated, competition for food in the pond was probably low.

Fungal control evaluation

The number of fry surviving to swim-up was 16.6% for fry hatched from formalin treated eggs and 21.3% for fry hatched from malachite green treated eggs (Table 11). A significant difference ($P<0.005$) (Table 12) in fry survival to swim-up existed between the fungal control methods.

The average survival rate and length of paddlefish after a 23-day feeding period was 32.2% and 43 mm (range 29-63 mm) for those hatched from formalin treated eggs, and 47.5% and 4F mm (28-63 mm) for those hatched from malachite green treated eggs (Table 13). A significant difference ($P<0.05$) existed for fry survival between treatments (Table 14), but no significant difference ($P>0.1$) was detected for growth (Table 15).

Both the formalin and malachite green treatments controlled fungus on the incubating eggs. The number of fungal infected eggs was not excessive in either treatment.

Eggs treated with malachite green began hatching a few hours earlier than eggs treated with formalin. Perhaps the formalin treatment stressed the eggs and slowed development. Initial hatching occurred on 2 June, approximately six days after the beginning of incubation. Most of the hatching occurred on 4 and 5 June and by 7 June, hatching was complete.

Table 11. Number of paddlefish fry and percent survival at swim-up from formalin and malachite green treated eggs, Gavins Point National Fish Hatchery, South Dakota, 1977.

Treatment	Replication	Number of Fry Per Replication	Number of Fry Per Treatment	Percent Survival at Swim-up by Replication	Percent Survival at Swim-up by Treatment
Formalin	1	6057	25168	16.0	16.6
	2	5346		14.2	
	3	6730		17.8	
	4	7035		18.6	
Malachite Green	1	7970	32989	21.1	21.8
	2	8144		21.6	
	3	8829		23.4	
	4	8046		21.3	

Table 12. One-way analysis of variance of the number of paddlefish surviving at swim-up from eggs treated with formalin or malachite green, Gavins Point National Fish Hatchery, South Dakota, 1977.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	7	9806080.00		
Treatment	1	7645952.00	7645952.00	21.24*
Within	6	2160128.00	360021.31	

*$F_{1,6}$ at the 0.005 level = 18.63

Table 13. Percent survival and mean length of paddlefish hatched from formalin or malachite green treated eggs and reared for 23 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1977.

Treatment	Replication	Percent Survival by Replication	Mean Percent Survival by Treatment	Mean Length (mm) by Replication	Mean Length (mm) by Treatment
Formalin	1	30	32.2	41	43
	2	28		42	
	3	28		45	
	4	43		45	
Malachite Green	1	57	47.5	45	45
	2	50		44	
	3	40		46	
	4	43		45	

Table 14. One-way analysis of variance of percent survival of paddlefish hatched from formalin or malachite green treated eggs and reared for 23 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1977.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	7	794.88		
Treatment	1	465.12	465.12	8.46*
Within	6	329.75	54.96	

* $F_{1,6}$ at the 0.05 level = 5.99

Table 15. Least-squares analysis of variance of lengths of paddlefish hatched from formalin or malachite green treated eggs and reared for 23 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1977.

Source	Degrees of Freedom	Sum of Squares	Mean Square	F
Total	318	16477.49		
Treatment	1	186.30	186.30	2.76*
Replication	3	327.21	109.07	
Treatment x Replication	3	202.58	67.53	
Remainder	311	15761.40	50.68	

* $F_{13\ 3}$ at the 0.1 level = 5.54

For one or two days after hatching, the fry alternately swam up several centimeters and settled back down. Purkett (1961) stated that this type of swimming was probably due to the large yolk sac that existed for the first few days after hatching. Gradually this activity changed to constant horizontal swimming.

Fry that hatched from the formalin treated eggs appeared to suffer somewhat higher, although limited, mortality during the first few days after hatching. It is not known whether the difference in the number of fry surviving at swim-up resulted mainly from greater mortality in the formalin treatment than in the malachite green treatment prior to or after hatching.

Fry that hatched from the malachite green treated eggs were more active than fry that hatched from formalin treated eggs. This was noted during counting, and also during the first few days of feeding. In all replications of fish hatched from formalin treated eggs, there were from one to several fish that were weak and rested on the bottom at times. Almost all fish hatched from malachite green treated eggs were active during this time. Mortality of fry hatched from formalin treated eggs was higher throughout the entire feeding period than those that hatched from malachite green treated eggs (Figure 5).

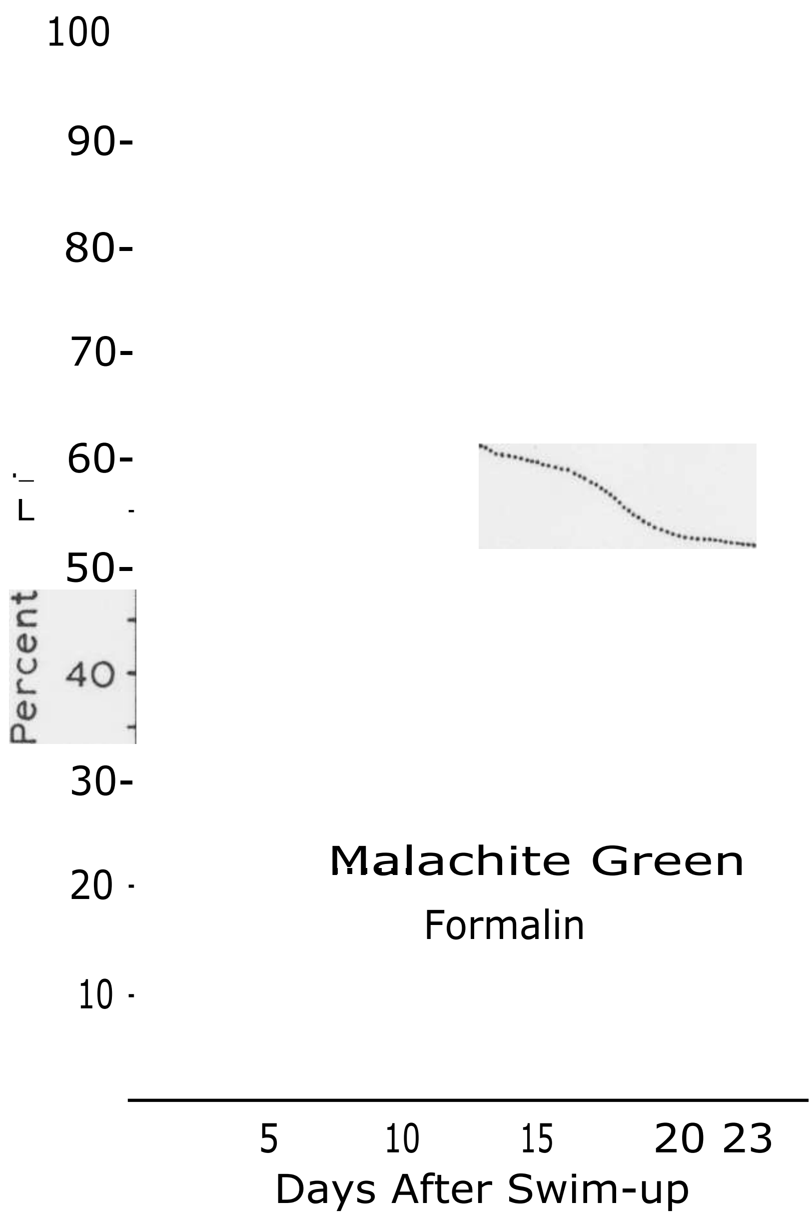

Figure 5. Survival of paddlefish hatched from formalin or malachite gree treated eggs and reared for 23 days after swim-up, Gavins Point National Fish Hatchery, South Dakota, 1977.

During the first portion of the feeding period, it appeared that the paddlefish hatched from malachite green treated eggs were growing at a faster rate than those hatched from formalin treated eggs. But, the lengths of fish in both treatments were similar at the end of the feeding period. The smaller, slower growing individuals in the formalin treatment had died.

The malachite green treatment resulted in higher survival than the formalin treatment both from the beginning of incubation to swim-up and during the 23-day feeding period after swim-up. Cline and Post (1972) discussed criteria that fungal control methods must satisfy. The method must effectively eliminate or inhibit fungi and there must be a wide margin of safety between fungicidal concentrations and concentrations that are toxic to the eggs being treated. Both the formalin and malachite green treatments controlled fungus on the incubating paddlefish eggs. The formalin treatment, however, was toxic to the eggs as evidenced by the lower survival of eggs and young from that treatment.

Cline and Post (1972) compared the effectiveness of formalin and malachite green as fungal control agents on trout eggs and found that malachite green was superior in controlling fungus with the widest margin between levels that controlled fungus and levels toxic to eggs. Malachite green was also a better fungal control agent when used on the eggs of fathead minnows, *Pimephales promelas* (Guest 1977).

CONCLUSIONS

The W-7 cool water diet was suitable for the intensive culture of paddlefish young. The feeding behavior of paddlefish young dictates that food be present at all times. Survival and growth might be improved by feeding more frequently than the hourly feeding schedule used in these studies. Feeding rates will depend on fry densities, the sinking rate of the food particles, and the dimensions of the tank in which the fish are held. Studies to evaluate these factors are needed.

Water temperatures near 21 ^{o}C, or possibly higher, are optimal for growth and survival of paddlefish young. Additional study may reveal that growth and survival can be improved by raising the water temperature as the fish grow.

Malachite green was superior to formalin as a fungicide on paddlefish eggs, both in terms of hatching success and fry survival. At the present time, formalin is registered for use on fishes. Malachite green is not. It may be necessary to test lower concentrations or shorten exposure to formalin. Other methods of controlling fungus on fish eggs could also be tested on paddlefish eggs.

The maintenance of paddlefish populations in areas where recruitment is limited or lacking may be possible when refinements in artificial propagation techniques for paddlefish are made.

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