The larvae collected in the meter nets had characteristics which indicate that they progressed beyond 150 hours of development at 60-62 F.

LITERATURE CITED

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EFFECT OF TEMPERATURE CHANGES UPON DEVELOPING STRIPED BASS EGGS AND FRY

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ABSTRACT

A comparison study was made to determine the effects of temperature upon the percent hatch of striped bass eggs and upon fry survival. No significant difference for percent hatch was found at incubation temperatures between 60°F. and 75°F. at 5° increments. Temperature shock between 65°F. and higher temperatures appears to have a more deleterious effect on freshly fertilized eggs than eggs incubated for 16 or 44 hours at 65°F. before transfer to the same higher test temperatures.

Fry produced at 65°F. and transferred to the various test temperatures two days after hatching showed an apparent difference in survival as temperatures exceeded 65°F. A significant difference in fry survival was observed only for those eggs hatched at the various test temperatures and then exposed to 80°F. temperature.

BACKGROUND

Much interest has been generated during recent years towards the use of striped bass to fill the need for a powerful predator that is also a highly prized game fish. The need for the striped bass seems far more widespread than is habitat meeting the rather specialized spawning requirements of this species. Realization of the full potential will be predicated upon successful relocation rather than upon successful natural reproduction.

Relocation with some species is most feasibly accomplished through the transfer of eggs for hatching in the new environment. It is essential, therefore, to know the approximate tolerance limits of both striped bass eggs and fry toward the major environmental factors to which they may be exposed during relocation. Research in the effects of incubation temperature on striped bass eggs or fry, either in a natural or an experimental environment, has been limited.

Worth (1884b) took sexually mature striped bass from the Roanoke River at Weldon, North Carolina, between April 19 and May 17 during which period water temperatures increased from 58 to 71°F. During hatchery operations at Weldon in 1931, ripe fish were taken by Pearson (1938: p. 830) between May 5 and 21 as the water temperature increased from 61 to 71°F. Tresselt (1952) found eggs in the lower reaches of Virginia Rivers from April 4 to May 20 when the water temperatures were 54 to 70°F. Freshly deposited eggs were found by Pearson (1938: p. 830) in the Lower Susquehanna River, Maryland, from May 16 to June 8, 1931 when the water temperature increased from 60 to 70°F. Woodhull (1947: p. 99) noted that the water temperature was 67°F. when striped bass were spawning in the vicinity of Venice Island, San Joaquin River, California. In the Lower Sacramento River System, according to Calhoun, Woodhull and Johnson (1950: p. 143), spawning does not begin until the water temperatures reach about 60°F. Spawning ceased during storms when water temperatures declined and resumed when temperatures increased with clear weather. Erkkila, *et. al.* (1950: p. 29) also pointed out that water temperatures appear to exert an important influence in determining both time of spawning and rate of development of larval and post-larval bass in the Sacramento Delta. As reflected by the egg collections, spawning occurred in temperatures of 58°F. and higher, with a peak developing between 60 and 67°F.

The duration of egg incubation, as given by Pearson (1938: p. 831) is 48 hours at water temperatures averaging 64.2°F. Bigelow and Welsh (1925) gave 74 hours as the hatching time at a water temperature of 58°F. and 48 hours at 67°F. Merriman (1941: p. 9) gave about 30 hours at 71-72°F. and 70-74 hours at 58-60°F. Mansueti (1958) reported eggs incubated at 62-63°F. hatched in 36 and 48 hours. He also presented the following table:

Incubation Period	Average Water Temperature	Locality from which Adult
Hours	°F.	Fish Originated
30	72	North Carolina
72	59	North Carolina
48	64	North Carolina
72	?	California
74	58	Unknown
48	67	Unknown
80	54	California
74	58	Unknown
48	66-67	North Carolina
36	71	North Carolina
64	65	North Carolina

OBJECTIVES

The objectives of this study are to determine the threshold points at which various incubation temperatures—both in shock and in continuous exposure—adversely affect the development of striped bass eggs and fry.

PROCEDURES

The following successive steps briefly describe the procedures for a test run: (1) Obtain freshly fertilized striped bass eggs; (2) Inoculate egg-incubation tubes with approximately equal numbers of eggs; (3) Maintain agitation of the eggs with water of the specific temperature desired; (4) Remove the dead, injured, and unfertilized eggs from the tubes after water-hardening; (5) Transfer the egg tubes or the fry containers from the control group being maintained at 65°F, to the

experimental temperature at the predetermined intervals; and (6) Make observational notations at four-hour intervals throughout the test.

Four experimental tests were conducted at temperatures of 60°F. through 80°F. at 5°F. intervals. Eggs used in the experiments were taken from naturally-maturing females collected from the Roanoke River in the act of spawning. Male striped bass utilized for fertilizing the eggs also were collected from the river during the spawning act.

Eggs were maintained in 150-ml. test tubes modified with a spout enabling fry to swim into the fry container. Egg agitation was accomplished with a flow of test water ranging from 50 to 60 cc per minute through a glass pipe extending to within ½-inch of the tube bottom. Fry containers were 500-ml. plastic bottles placed on their side and modified with a 2″ × 4″ rectangular opening on the upper side. In this position, a volume of approximately 200 ml. each was maintained. Fry escapement was prevented by welding a 3″ × 3″ sheet of saran screen into an incision one inch from the neck outlet.

Water used for egg incubation was obtained from the Weldon Municipal water supply. The 60, 65, and 70°F. test temperatures were controlled by water baths consisting of "living stream" units with ¼-HP cooling units capable of constant temperature and continuous circulation. In these units, four-foot sections of ½″ glass tubing connected with rubber tubing were used as heat-exchangers. Elevation of water temperature to 75 and 80°F. was accomplished by passage of the incoming water through a series of ½″ glass tubes each two feet in length connected with rubber tubing. These units were submerged in constant temperature baths heated with 200-watt incandescent light bulbs controlled by thermo-switches and agitated with electric stirring devices. All water bath units were insulated with polyurethane sheeting and chips.

The ambient temperature was regulated in an insulated room by balancing a 50,000-BTU portable mini-furnace for heat against a 19,000 BTU air conditioner for cooling.

Immediately after egg fertilization, an aliquot of eggs approximating 0.6 ml. by displacement was injected into each egg incubation tube for water-hardening and incubation. Similar volumes of eggs also were placed into tubes supplied with water of each test temperature to determine the initial temperature shock effects. Following 12 hours of incubation, egg agitation was briefly terminated and the dead, injured and unfertilized eggs removed from the tubes. Egg agitation then was continued until melanophore formation was apparent, or after approximately 16 hours of incubation had elapsed. At this time, the appropriate tubes containing eggs were transferred from the control temperature of 65°F. to the various experimental temperatures. Another transfer was made at 44 hours after fertilization, or approximately five hours prior to hatching. The third transfer employed fry from eggs incubated, hatched and the fry maintained for two days at 65°F. before transfer to the successive test temperatures. The temperature shocks were induced by transferring fry containers from one water source to another not by handling the eggs or fry.

After transfer of eggs to a higher temperature, changes in egg bouyancy necessitated a decrease in water flow to maintain egg equilibrium. The reverse was necessary upon transfer of eggs to a lower temperature.

FINDINGS

Data gathered at the Weldon Striped Bass Hatchery, Weldon, North Carolina, during the years 1960-67 indicated the optimum spawning temperature range for striped bass in the Roanoke River was between 62 and 67°F. The minimum recorded temperature at which spawning has occurred during this period was 55°F. and the maximum was 71°F. Gross screening bioassays conducted at the hatchery during the 1967 spawning season (Shannon, Smith-1967) substantiated this opti-

mum temperature range. Also noted were the following observations (Tables 1 & 2): (1) Increases in water temperature decreased the time of incubation; (2) The percentage of eggs hatched decreased as incubation temperatures increased above the optimum range; and (3) The percentage of normal fry produced likewise decreased with each increase in test temperature.

During the 1968 striped bass spawning season in the Roanoke River, preliminary bioassays of temperature were conducted at the Weldon Hatchery. Incubation temperatures of 60 to 85°F.—in progressive 5°F. intervals—were tested in comparison with a control temperature maintained at 65°F. These experiments were conducted to determine the points at which temperatures, both in shock and in continuous exposure, adversely affected the development of striped bass eggs and fry. Stages of egg development chosen for inoculation into, and for transfer between, the constant control temperature and the various test temperature were designated as follows: (1) Stage I—freshly fertilized egg; (2) Stage E—eyed stage, or about 16 hours after fertilization and incubation at 65°F.; (3) Stage V—about five hours before hatching at the control temperature, or approximately 44 hours after fertilization; and (4) Stage II—eggs incubated, hatched, and maintained at 65°F. until two days following hatch. These tests revealed the following (Table 3): (1) Hatching percentage for freshly fertilized eggs decreased as water temperature exceeded 70°F.; (2) The greatest percentage of normal fry developed in the 60°F. test presumably due to decreased metabolism at this low temperature; (3) Mortality in 65°F. test increased 72 hours after hatch (Shannon: 1968); (4) Mortality in 70°F. test was heavy 60 hours after hatch, (5) Mortality in 75°F. test was heavy 45 hours after hatch for Stages I, E, V and 60 hours after hatch for Stage II; and (6) Mortality of fry appears to be associated with the developmental stage rather than age.

Recommendations from these preliminary conclusions were: (1) Delete the 85°F. test from future experiments because of no evidence of survival; (2) Remove dead eggs from tubes after 12 hours incubation; (3) Transfers to coincide with the melanophore formation in fry should be made at 16 hours after fertilization for eggs held at 65°F; (4) Transfer of eggs at five hours before hatch should be made at 44 hours after fertilization when incubated at 65°F; (5) Terminate all fry tests after 144 hours at 60°F, 72 hours at 65°F, 40 hours at 70°F, and 28 hours at 80°F.

Final testing during the 1969 season utilized four test series with eggs from different naturally-maturing females, and the recommendations from experiments of the preceding years were applied.

Discussion of results will be in terms of the previously mentioned stages of development.

Stage I: In general, the preliminary results of 1968 were corroborated by the current 1969 data (Figure 1). The apparent variance observed for hatch between the same test temperatures in 1968 and in 1969 is attributed to the lack of sufficiently accurate control over the ambient temperature during the 1968 test. Ambient temperature in 1968 fluctuated through the range of 50°F. to 80°F. in 1969, it was observed that a very significant difference appeared between the percent hatch at 80°F. and the percent hatch obtained at the lower test temperatures (12 percent at 80°F., 67 percent at 60°F., 75 percent at 65°F., 72 percent at 70 and 75°F.).

Stage E: In comparing the percent hatch of the eyed stage at 80°F. with the lower temperatures, a difference is apparent although, statistically, it is not significant. Deletion of one test series, composed of eggs that seemed extremely sensitive to manipulation, would place the mean hatch for this group at 76 percent and more closely align it with the other results for the stage. Utilization of this series, however, indicates a critical period of development exists which affected the hatch of eggs exposed to 80°F. This evidence is substantiated by the wide

standard error. It appears that early development of the egg (Stage I) cannot withstand the effects of 80°F., but a more advanced stage of development at the lower control temperature increases egg tolerance to higher temperatures.

Stage V: Eggs transferred from the control temperature and incubated at the various test temperatures until five hours before hatch show no significant difference in terms of percent hatch.

There was no significant difference in the percentage of eggs hatched between 60°F. and 75°F. in the various stages.

In 1968, Stage II eggs were hatched and resulting fry maintained at 65°F. for two days before transfer to the test temperatures. After transfer, the fry were maintained at the test temperatures for five days or until complete mortality. The same procedure was followed in 1969, but test were terminated three days after transfer, or when fry were five days old because of the extensive mortality from undetermined causes following this stage of development (Figure 2).

Stages I and E for 1968 show an apparent decrease in fry survival as test temperatures were increased. The 1969 data, however, show no significant difference for temperatures between 60 and 75°F. The change in detention time after hatch favored the 1969 data as the resulting fry were held for only three days after hatch rather than five thus allowing less time for other factors to adversely affect the results.

Stages V and II for 1968 show no difference between fry survival at 60°F. and 80°F., while the 1969 data show the 80°F. temperature highly unsuccessful for fry survival. This lack of conformity can be attributed to the uncontrolled ambient temperature of 1968 and the extended length of fry detention time.

As shock temperatures to which eggs were exposed increased, the time required for hatching decreased (Figure 3). Although hatching occurred at 80°F., survival as stated earlier, was very low.

Experimental procedural factors were quite variable in 1968. The 1969 variables however, were controlled to the extent that they were considered to have a negligible effect upon the test results (Table 4).

CONCLUSIONS

1. The optimum spawning temperatures for striped bass in the Roanoke River ranged between 62°F. and 67°F. during the period 1960 to 1967.

2. Spawning has been recorded in the Roanoke River at a minimum temperature of 55°F. and a miximum of 71°F.

3. There is a significant difference between percent hatch at 80°F. and at lower temperatures to 60°F. with results at 80°F. being very low.

4. The longer egg development is maintained at 65°F., the more tolerant the eggs become to shock exposure to higher temperatures.

5. No significant difference in hatch success was observed among the various stages of development or between test temperatures from 60 to 75°F.

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TABLE I. Results of temperature bioassays using striped bass eggs and sac fry as test organisms (1967)

	Temperature (°F.)			
Data	70°	74°	75°	80°
Percent Egg Hatch	68	80	71	60
Percent Normal Fry	60	52	35	0
Percent Dead and Malformed Fry at Hatch	40	48	65	100
Percent Fry Survival to 70 Hours Following Hatching	100	0	0	0

TABLE II. The effect of increased water temperature upon incubation of triped bass eggs (1967)

Temperature (°F.)	Incubation Time Hours
60	58
70	34
74	30
75	28
80	25

TABLE III. *Comparison of egg hatching success and fry survival for striped bass after temperature shock at different stages of development* * (1968)

Incubation Temp. (°F)	SAMPLE SIZE I	E	V	II	PERCENTAGE HATCH I	E	V	II	PERCENT NORMAL FRY FIVE DAYS AFTER HATCH I	E	V	II
FEMALE INDUCED TO OVULATE WITH HORMONE (HCG)												
60	561	317	313	235	58.5	55.2	50.8	67.7	66.2	5.1	9.4	0.0
65	280	196	301	419	64.3	27.6	27.9	8.8	61.7	0.0	1.2	0.0
70	536	246	146	223	4.7	38.6	52.7	39.5	36.0	0.0	0.0	0.0
75	747	188	511	234	2.5	25.0	11.4	39.3	0.0	2.1	0.0	37.0
80	683	643	281	190	0.0	19.3	44.1	65.0	. . .	3.2	0.0	0.0
85	697	338	424	218	0.0	34.6	38.2	54.1	. . .	0.0	0.0	0.0
FEMALE NATURALLY MATURING												
60	317	384	347	335	78.9	77.9	66.6	64.8	58.0	56.9	63.6	12.9
65	460	473	442	412	66.2	71.0	64.0	82.8	4.6	11.6	10.6	38.7
70	352	421	407	382	70.2	71.5	76.7	68.3	7.3	6.0	0.0	0.0
75	481	390	400	481	69.4	72.6	72.0	79.8	1.8	2.1	2.4	1.0
80	505	346	278	347	0.0	43.4	60.4	67.7	. . .	0.0	0.0	71.1
85	488	319	512	403	0.0	69.3	72.9	68.2	. . .	0.0	0.0	0.0
FEMALE INDUCED TO OVULATE WITH HORMONES (HCG)												
60	482	557	452	551	66.6	67.7	50.0	61.9	1.6	76.0	44.7	0.6
65	517	576	534	626	52.8	57.8	52.6	61.0	9.2	20.1	0.0	5.0
70	706	603	584	452	60.3	57.9	61.6	53.1	0.2	0.3	0.0	0.0
75	609	568	503	470	60.6	63.9	61.2	53.8	0.0	0.0	0.6	0.4
80	576	564	523	582	36.6	61.7	50.0	57.2	1.4	0.0	44.4	0.0
85	623	564	469	623	0.0	58.3	42.6	61.6	. . .	0.0	0.0	0.0

TABLE IV. Effluent temperature average and range during testing—1968 and 1969

Test Temperature (°F)	TEST NUMBER (1) 1968	(1) 1969	(2) 1968	(2) 1969	(3) 1968	(3) 1969	(4) 1969
60	60.7	60.4	61.4	60.1	60.5	60.0	61.4
	60-62	58-64	60-65	56-62	58-62	58-62	59-65
65	64.4	65.3	65.4	65.2	65.0	65.0	65.4
	62-66	64-67	65-66	64-67	63-68	64-67	64-67
70	69.2	70.0	70.9	69.4	71.0	70.3	70.4
	67-71	68-71	68-75	68-70	70-73	69-72	68-71
75	75.7	75.3	75.1	75.1	75.6	75.2	75.4
	73-81	74-78	71-81	72-76	78-80	72-78	73-77
80	79.8	80.0	79.9	80.0	81.4	79.6	79.0
	77-81	78-80	77-85	77-81	73-87	75-82	78-81
Ambient Temperature Average and Range During Testing in °F.—1969							
		71.8		70.2		72.1	72.2
		69-84		67-75		69-75	68-77

Chemical Analysis of Test Water (Average for 20 Days—1969)			
Dissolved Oxygen	Hardness	Alkalinity	pH
8.8 ppm	41.7 ppm	45.5 ppm	7.1

* Developmental stages exposed to shock were:
I—*Immediately after fertilization.*
E—Eyed stage at melanophore formation.
V—Five hours before hatch.
II—Two day old fry.

FIGURE 1

MEANS AND STANDARD ERROR OF THE MEANS FOR PERCENT HATCH OF STRIPED BASS EGGS FOR TWO YEARS

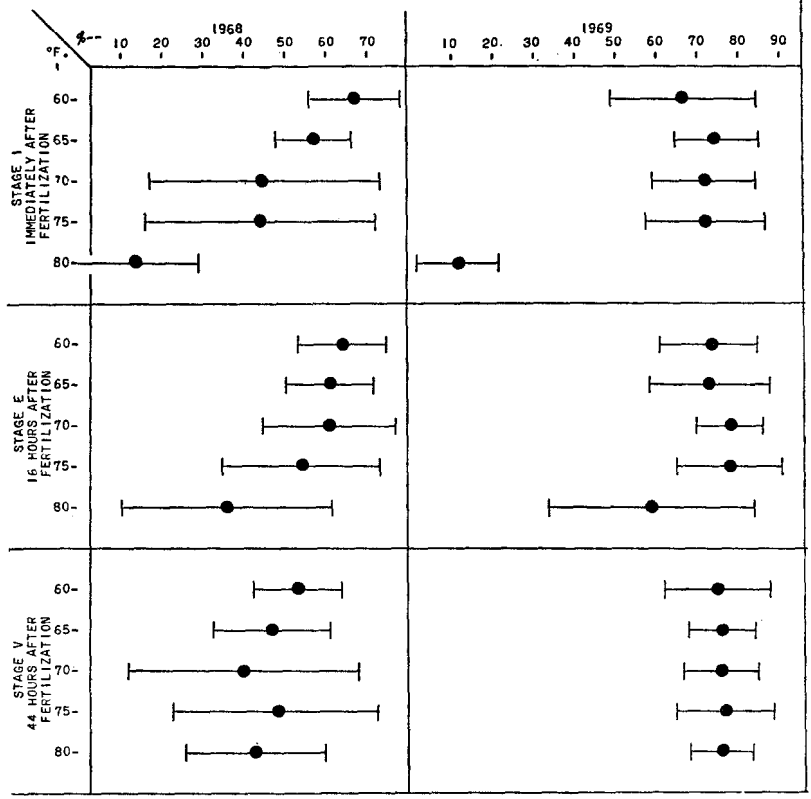

FIGURE 2

MEANS AND STANDARD ERROR OF THE MEANS FOR PERCENT NORMAL STRIPED BASS FRY AT TEST TERMINATION FOR FRY HELD FOR FIVE DAYS AFTER HATCHING (1968) AND FOR FRY HELD FOR THREE DAYS AFTER HATCHING (1969)

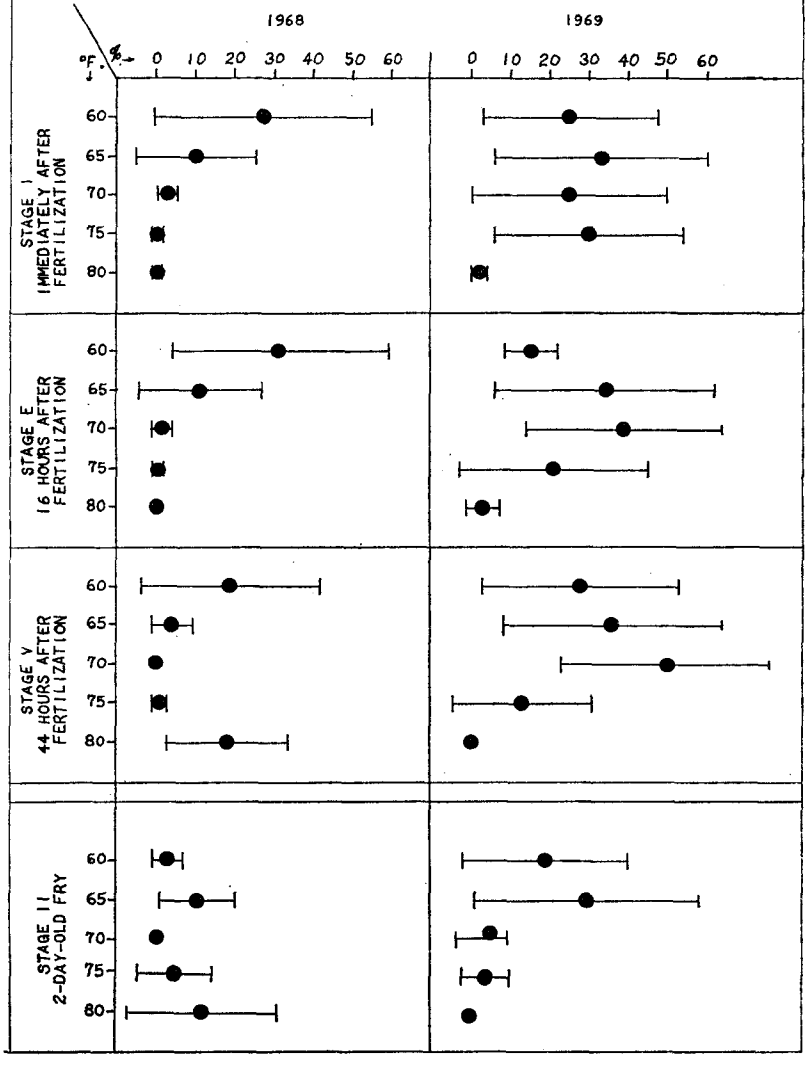

FIGURE 3

RANGE AND AVERAGE NUMBER OF HOURS REQUIRED FOR STRIPED BASS EGGS TO HATCH AT THREE TEST STAGES (1969)