Docket File

MAR 1 5 1973 ENVIRON

Docket No. 50-247

D. R. Muller, Assistant Director for Environmental Projects, L
Thru: G. W. Knighton, Chief, Environmental Projects Branch No. 1, L

CONSOLIDATED EDISON INDIAN POINT UNIT NO. 2 - FISH HATCHERY AND REPLACEMENT PROPOSAL

As you well know, Con Ed has taken the position of offering to the New York State Department of Environmental Conservation to build a fish hatchery to replace fish unavoidably killed at Indian Point. A letter to the Editor of New York Times by Charles F. Luce, Chairman of the Board, on November 13, 1972 reconfirmed that position.

Mr. Harry Woodbury, Executive Vice President for Environmental Affairs for Con Ed, testified at the March 8, 1973 hearing (Tr. 10,133) that the Hudson River Policy Committee composed of representatives of State and Federal fishery agencies "has taken the position that until there was a need shown to replace the striped bass in the river, that any study of how to do it was pointless, and they saw no point in being a part of it."

Woodbury further testified that although the record of success of plantings of striped bass was rather meager until recently, the Hudson River Policy Committee advised him that they became aware of Dr. Shell of Auburn University in Auburn, Alabama, who has successfully planted striped bass in Mobile Bay and has been able to demonstrate survivability.

He also stated that more recently Dr. J. Barkvloo in Florida attempted to stock the Choctowahtchee River with about a 1.5 million striped bass fingerlings from 1 1/2 to 6 inches long in 1968 and in 1971 found 200 of these fish had been harvested by sports fishermen.

Woodbury is planning to propose before the next meeting of the H. R. Policy Committee an organization for a study of the feasibility of the stocking of striped bass particularly in regards to the question of survivability of the striped bass and whether a hatchery would be developed on the river or fish hatched elsewhere and brought to the river.

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Last summer when the subject of stocking came up, P. Goodyear, ecologist at ORNL, provided an enclosed copy of preliminary information on the subject and concluded that to replace the striped bass killed by plant operation, a hatchery operation would have to replace about half the number spawned (about 2 billion eggs). At an average of 500,000 viable eggs per spawning female, this would be the equivalent of some 2,000, 8-12 pound female bass. Such an operation is considerable larger than any past effort, and its success is highly questionable.

Tom Cain, ESB, also contacted the Virginia Institute of Marine Science, Gloucester Point, Virginia, to discuss this question. A project entitled "Feasibility of Increasing Striped Bass Population by Stocking of Underutilized Nursery Grounds" is being financed through the Department of Interior Bureau of Sport Fisheries and Wildlife under the Andramous Fish Act. Tom talked with J. Merriner who told him that approximately 98-99% mortality occurs in nature with the yolk -sac fry stage. The greatest success, is apparently with transplanting fingerlings up to one inch in length. Most of the striped bass stocking in the Southeastern states has occurred in fresh water reservoirs. Cannabalism of young bass by the older bass is quite common as is the case for the bass in the Sacramento-San Jaoquin estuary in California. Apparently the fish undergoing stocking grow at a slower rate. The survival of the fish is unknown. Although the fish can be raised in the ponds under controlled conditions, when they are removed and placed in open-end bays or lakes, they can't be found after a specified period of time. Whether they die off or mix in with the wild variety, it is very difficult to determine. Tagging of the young fish used for stocking purposes has not always been successful.

From discussions with Goodyear, it appears that a striped bass hatchery of striped bass is feasible with success of stocking only in fresh water reservoirs (closed end); however, apparently, the stocked bass have limited ability to spawn later in life since the conditions in the reservoirs are not conducive to spawning. The replacement of large numbers of fish which would have been developed from eggs and larvae that could survive by natural means but could not because of plant operation of Indian Point does not appear to be a practical solution to the problem of maintaining the fish population in the Hudson at the present levels. Thus Con Ed's proposal may be quite noble but we have no way of knowing with any degree of confidence if the

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replenishment of sufficient magnitude would prove to be successful to replace all of the fish we expect the plant will kill during its lifetime. In addition the costs of the hatchery and planting may be prohibitively higher in the long term than the costs for the cooling towers.

/s/ Original signed by
M. J. Oestmann

M. J. Oestmann,
Project Manager
Indian Point

cc: Enclosure as stated
A. Giambusso

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NOTES ON FISH CULTURE

Both from a theoretical and from a practical point of view, the artificial propagation of fishes to replace those killed by entrainment and impingment at Indian Point cannot be expected to maintain fish populations. This conclusion results from consideration of two factors, i.e., the availability of culture techniques and the efficiency of these techniques. Techniques for mass culture are not available for those fish which spawn in salt water and move into the Indian Point area from downstream. This category includes the American eel, Atlantic menhaden, Bay anchovy, tidewater silverside, Hogchocker, Atlantic tomcod and many others.

Culture techniques are available for a few species. However, these have been of little value for maintaining or increasing population levels and in many cases could have a negative effect on the population because the hatchery operation itself is less efficient than natural spawning. This is the situation with American shad, striped bass and smelt, and would probably be the case for alewives and blueback herring as well. Example discussions of American shad and striped bass follow:

American Shad (extract from Talbot 1951)

For many years a shad hatchery was operated on the Hudson River in the vicinity of Catskill. In addition to the shad hatched at this station, the U. S. Fish and Fisheries Commission furnished shad fry for distribution in the Hudson River during the years between 1882 and 1904. More recently the practice of artificially hatching shad eggs has not received support, and the Hudson River shad hatchery, along with many others on the Atlantic coast, has ceased operations.

Many fishermen and others associated with the fishing industry have insisted that the closure of the Hudson River hatchery has been the cause of the present decline in the Hudson River shad fishery. To examine this possibility, the records of shad eggs hatched or fry stocked each year have been compiled from available records (New York Fisheries Commission; New York Forests, Fish and Game Commission; New York Conservation Department; U. S. Fish Commission). These show that artificially hatched fry were stocked in the Hudson almost every year from 1869 through 1944.

The greatest hatchery production occurred between 1887 and 1903. What part the hatchery played in shad production during early years is hard to assess at present, but it can be stated definitely that the peak hatchery production in 1899, 1900, and 1901 did not maintain the runs, for the shad catch dropped from 3,432,472 pounds in 1901 (the peak year of hatchery production) to 573,399 pounds in 1904 (U. S. Bureau of Fisheries, 1907) and did not recover to anywhere near its former abundance until 32 years later, beginning in 1936.

To determine whether hatchery production affects the size of runs in later years, a multiple-regression analysis was calculated between the size of the run each year from 1915 through 1946 and hatchery production 4 and 5 years before each year's run. No significant correlation was found.

It is not surprising that no correlation exists between the hatchery output and the size of subsequent runs. The average number of eggs obtained per female shad by fish culturists is between 20,000 and 30,000 (New York Fish. Comm. Rept. for 1899; Brice, 1898) but recently it has been shown (Lehman, 1953) that the actual number of eggs per female spawned naturally each season is between 100,000 and 5,000,000, depending on the age of the fish. Some of the eggs may be spawned in advance of stripping, but many are not ripe when the fish are stripped, and since the fish are usually killed in the process many of the eggs are lost. Since 1914, the number of eggs hatched artificially in the Hudson River hatchery each year has usually been between 1 and 3 million. From 40 to 120 female shad were stripped to obtain these eggs (at 25,000 per female), and if each of the female contained an average of 250,000 eggs, it is possible that between 10 million and 30 million eggs were wasted in the process. The added protection given artificially hatched eggs can hardly be expected to compensate for the waste of eggs inherent in the process.

In some cases, the eggs for hatchery operations were obtained from commercial fishermen who stripped ripe eggs from the fish before killing them. In these cases no wastage occurs, but in any event the number of eggs handled each year is comparatively very small. For instance, the eggs handled in 1914 are equivalent to the total production of only 4 or 5 averaged-sized female shad, and the greatest hatchery output in 1901 of almost 18 million eggs is equivalent to the total egg production of only about 72 fish. Furthermore, the lowest calculated escapement shown in Table 8 was 58,000 pounds in 1917. If females make up half the poundage, there were 29,000 pounds of female shad, and converting pounds to fish by a factor of 4 pounds to the female gives a figure of over 7,000 female shad spawning naturally each year. The hatchery production in the same year was only about half that produced by 1 average-sized fish. Similarly, the greatest hatchery production in recent years was in 1933 and is equivalent to the production of approximately 15 female shad. In that same year the calculated natural escapement was 602,000 pounds which, on the basis of a fifty-fifty sex ratio, and an average weight of 4 pounds, amounts to more than 75,000 females spawning naturally. Obviously, the number of eggs that it has been possible to obtain for hatchery operations is only an extremely small fraction of the amount spawned naturally, and the increased survival rate, if any, resulting from current shad-hatchery practices has not produced, and cannot be expected to produce, an increase in shad production.

Striped Bass (extract from Talbot, 1967)

The hope of increasing the abundance of striped bass prompted fish culturists to attempt propagation of this species even before the turn of the century (Worth, 1882, 1884). Striped bass hatcheries were established at Weldon, North Carolina, and Havre de Grace and several other localities in Maryland (Mansueti and Hollis, 1963). Many thousands of striped bass were hatched and stocked as yolk-sac fry from these installations. Attempts to propagate striped bass on the west coast have been described by Scofield and Coleman (1910).

The eggs used at these hatcheries were usually obtained from fishermen who caught striped bass near the hatchery site. Some of the fish were already partially spawned when caught, or not yet ready to spawn; consequently most fish taken to the hatchery did not produce a full complement of eggs. During the season the number of eggs handled at the hatcheries usually amounted to that produced by only a few large females. The advantage, if any, of the hatchery over natural production was 3 or 4 days of protection, since the yolk-sac fry were released into the river soon after hatching. No benefits to the commercial fishery were ever shown from the operation of the hatcheries, and because of this, and in some cases the inability to obtain ripe spawn, operations of all striped bass hatcheries except the one at Weldon, North Carolina, were discontinued.

The successful fishery for striped bass introduced into several reservoirs where it was found that the inlet streams were not adequate for successful reproduction, has led to a renewed interest in artificial propagation as a means of supplying fish for stocking. In 1961, a hatchery was constructed at Moncks Corner in South Carolina in an attempt to obtain striped bass for this purpose. Here again, it proved impossible to obtain sufficient ripe female striped bass from a spawning area in a nearby river.

In order to replace the striped bass killed by plant operation, a hatchery operation would have to replace about half the number spawned (about 2,000,000,000 eggs). At an average of 500,000 viable eggs per spawning female, this would be the equivalent of some 2000, 8-12 pound female bass. Such an operation is considerably larger than any past effort, and its success is highly questionable.

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An Evaluation of Striped Bass Fingerling Culture

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ABSTRACT

This paper presents a synopsis of investigations concerned with culture of striped bass (*Morone saxatilis*, Walbaum) fingerlings. An historical review of significant events includes the development of hatcheries and rearing techniques. Changes in food habits and feeding behavior occur with early development of the fish. Early instars of copepods and cladocerans are preferred natural foods until the fish are about 10 mm in total length. The diet of fish in the 10–30 mm size group consists mainly of adult copepods supplemented with some cladocerans and insect larvae. Fish in the 30–80 mm size group utilize fewer copepods while cladocerans and insect larvae make up the major portion of the diet. Insect larvae are the most important foods of fish in the 80–100 mm size group.

A comparison of first year growth rates of pond-reared striped bass with those sampled from natural waters on the mid-Atlantic Coast indicates that both groups of fish grow at approximately the same rate for the first 30 days, after which the pond-reared fish grow much faster. Striped bass reared in ponds are approximately 170 mm in length at the end of the first year while those in natural waters are about 110 mm long.

Factors affecting growth and survival of young striped bass include predation, handling, stress, and various water quality factors. The future outlook for fingerling culture includes the development of hatcheries, nursery ponds, and intensive culture techniques.

INTRODUCTION

The problem of establishing reproducing striped bass (*Morone saxatilis* Walbaum) populations in most landlocked waters has not been solved; thus, consideration has been given to maintenance stocking. The techniques for propagating and transporting millions of fry have been developed to the point where various states have attempted to establish striped bass populations in reservoirs, but fry stocking usually has failed because larval mortality has been high even under the best conditions. Attempts to establish this fish in inland waters in several states by stocking adults in spawning condition were also unsuccessful. One solution is to rear the fry to fingerling size before they are stocked. This should increase survival since fingerlings can better compete with smaller fish species and escape excessive predation from large carnivores.

Several agencies have attempted to rear striped bass but success has been highly variable. This paper interrelates the findings of several investigators (including the doctoral dissertation of the senior author) in the continuing effort to establish sound management procedures and to determine areas which need additional research in the development of suitable culture techniques.

HISTORICAL BACKGROUND

Fertilized striped bass eggs for artificial propagation were collected from the Roanoke River at Weldon, North Carolina (principal spawning grounds of striped bass from Albemarle Sound) at irregular intervals for several years beginning in 1874 (Raney, 1952). After these early experiments demonstrated that striped bass could be artificially propagated, a hatchery was established at Weldon in 1906 and its operation has continued with minor interruption since then. The hatchery depends on sport and commercial fishermen who bring ripe male and female fish from the river. The eggs are removed and fertilized by sperm manually stripped from the males. The eggs are then incubated in McDonald hatching jars which receive a constant supply of fresh water. The newly-hatched fry swim into aquaria and are soon stocked or transported elsewhere.

Initially, fishermen supported the Weldon hatchery, hoping to perpetuate the run of striped bass in the Roanoke River and to re-establish the fish in rivers where successful reproduction was unlikely. The operation salvaged some eggs which would otherwise be

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taken from the river by fishermen, but the contribution of river stocking with newly-hatched fry was doubtful.

In several important areas on the Atlantic Coast drastic declines and fluctuations in abundance in striped bass populations occurred in the early 1930's. Since the striped bass was an important sport and commercial fish, studies on its life history and the effects of the fishery on abundance were initiated (Pearson, 1938; Merriman, 1941; Truitt and Vladykov, 1937; Vladykov and Wallace, 1952). Much of the present knowledge of striped bass biology resulted from these studies.

Interest in striped bass as a reservoir species began when the Santee-Cooper Reservoir was created in November 1941 by impoundment of the Santee River in South Carolina (Stevens, 1969). Runs of striped bass occurred in the Santee and Cooper Rivers before impoundment. Access from the Cooper River to the reservoir was provided by a navigation lock in a dam. During the 1940's sport fishermen made occasional catches of adult bass in the reservoir. By the early 1950's a creel census indicated that the striped bass population in the reservoir had increased greatly (Scruggs, 1955). Then it was believed that striped bass were compelled by some physiological need to spend part of their annual activities in salt water to reproduce successfully (Stevens, 1969). To reach salt water from the reservoir, the fish had to pass through a navigation lock. The large number of spawning adults in the reservoir coupled with the limited lock operation indicated that most fish had not returned to salt water. Studies in the mid and late 1950's confirmed this and showed that striped bass were able to complete their full life cycle in fresh water (Scruggs and Fuller, 1954; Scruggs, 1955; Stevens, 1957).

The ability of striped bass to utilize gizzard shad through predation in the Santee-Cooper Reservoir attracted the interest of fishery workers throughout the USA. In many large reservoirs, especially in the southeastern states, a predatory fish which would fill the pelagic niche and control the usually overabundant shad populations was being sought. It was also evident that the striped bass, if established, would serve as an excellent game and food fish. Interest was heightened in the late 1950's when it was discovered that another landlocked population of striped bass had been established in the Kerr Reservoir, Va. –N. C. by annual stocking of 1 million fry for 3 years (1953–1955).

Many states initiated lake and reservoir stocking programs in the 1950's. Some attempts involved transplanting adult or subadult fish taken from established populations (Surber, 1957). In many cases these fish survived and reproduced, but most reservoirs did not provide the essential spawning requirements, and so self-sustaining populations were not established. The spawning requirement dictates that the eggs remain suspended in a current until hatching. Otherwise, they settle to the bottom and suffocate (Stevens, 1964). A current within the reservoir or its tributary streams is necessary to keep the eggs suspended.

Since few reservoirs satisfied the spawning requirements of striped bass, the South Carolina Wildlife Resources Commission established a hatchery at Moncks Corner to provide fish for stocking reservoirs on a put, grow, and take basis (Stevens, 1969). The hatchery, patterned after the Weldon hatchery, was constructed in 1961. Over 900 female striped bass were examined at the hatchery in 1961 but none was ripe and no fry were produced.

In 1962 and 1963 hormones were used to induce ovulation in females kept in a temporary holding pond (Stevens, 1964). Millions of eggs were taken but high egg mortality limited production. A major breakthrough occurred when the role of immature eggs and over-ripeness as major causes of egg mortality was learned. In-vivo sampling of ovaries with a small glass catheter indicated that females with immature eggs could be induced to ovulate with hormones, but no hatch would result. Also, eggs which were not taken within an hour after ovulation would not produce viable fry. Refinement of techniques and renovations to the hatchery resulted in production of millions of striped bass fry for reservoir stocking in the following seasons (Stevens, 1966).

Temporary hatchery facilities were set up in

1963 at Brookneal, Virginia on the Roanoke (Staunton) River, a tributary of Kerr Reservoir. Previous egg sampling studies indicated that this was a primary spawning area for the landlocked striped bass from Kerr Reservoir. Techniques for taking eggs and producing fry which were developed at Moncks Corner were used at this hatchery in the following seasons.

Development and refinement of techniques for producing and transporting millions of fry at the three striped bass hatcheries (Weldon, Moncks Corner and Brookneal) allowed several states to stock reservoirs in the 1960's Generally, fry stocking was not worthwhile in establishing a put, grow, and take fishery in most reservoirs since larval mortality was high even under the best conditions. The major breakthrough in rearing striped bass fry to fingerling size in earthen ponds occurred in 1964 at the Edenton National Fish Hatchery, N. C. (Anderson, 1966). Striped bass fry from the Weldon hatchery were stocked in a standard hatchery pond which was fertilized to produce a heavy zooplankton bloom, and approximately 30,000 fingerlings were reared. Since then many agencies have participated in rearing experiments (Stevens, 1967). Major areas of study have included food habits and growth of bass under various conditions so that suitable culture techniques can be determined. Much progress has been made but many problems remain unsolved.

DEVELOPMENT, FOOD HABITS AND FEEDING BEHAVIOR

Newly-hatched striped bass prolarvae (2.5–3.7 mm TL) have no mouth opening, an enlarged yolk sac, and a large oil globule projecting beyond the head (Mansueti, 1958). At 4 to 6 days of age the yolk sac and oil globule are assimilated and mouth parts of the postlarvae (5.0–6.0 mm TL) became functional. Ingestion of food begins when the postlarvae are 5 to 8 days old (6.0–8.0 mm TL). According to Sandoz and Johnston (1965), early instars of copepods and cladocerans are preferred natural foods until the fish are about 15 days old (10.0 mm TL). The spasmodic movements of these organisms, especially the copepod nauplii, apparently attract the striped bass postlarvae. Fish in this size group can also be reared on a diet of brine shrimp (*Artemia salina*) nauplii. Feeding behavior consists of a careful approach to the prey and a sudden push forward from an S-shaped position in an attempt to seize it. These fish examine adult copepods (especially *Cyclops*) and cladocerans but pass them up because mouth parts of the fish are too small to capture these organisms.

The diet of fish in the 10–30 mm size group consists mainly of adult copepods supplemented with some cladocerans and insect larvae (Harper et al., 1968). These fish exhibit a strong preference for copepods and an especially high positive selectivity for *Cyclops* (Meshaw, 1969). The size of the copepods and their spasmodic swimming and jumping movements apparently intensify the feeding instincts of the fish. Fish in the 30–80 mm size group utilize fewer copepods, while cladocerans and insect larvae make up the major portion of the diet (Harper et al., 1968). These fish have undergone complete transformation from postlarvae to young and they have a full complement of meristic structures in all fins. Swimming speed and range of these fish increases and their food preference changes to larger, faster moving prey. Insect larvae make up the major portion of the diet of fish in the 80–100 mm size group. Fish and insect larvae are the most important foods of striped bass larger than 100 mm.

Food selection by striped bass indicates a positive correlation between fish sizes and sizes and types of organisms eaten. Generally, larger fish feed on larger organisms, but the relative abundance and availability of various sizes and types of food organisms often causes much variation. Behavior of prey organisms also influnces food selection by fish, especially those in early stages of development.

Young striped bass in culture ponds congregate in small schools, and members of a school usually feed simultaneously. But the number, types, and sizes of food organisms in stomachs of fish taken from a single school at the same time often reveal striking differences. In some cases, a patchy distribution of zooplank-

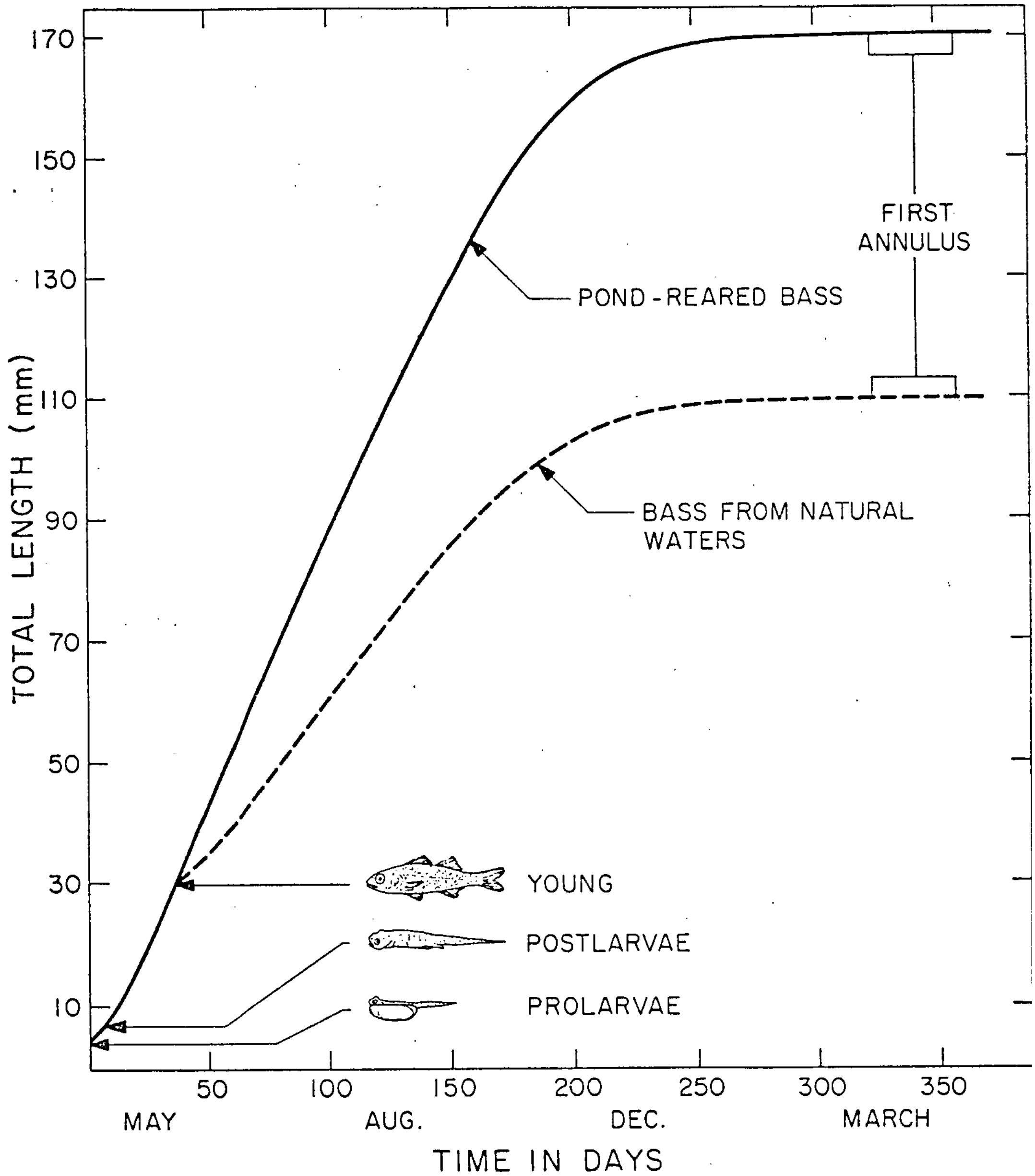


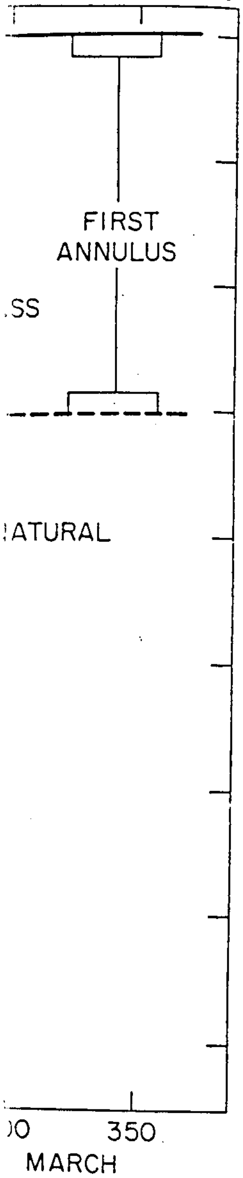
FIGURE 1.—Comparison of first year growth rates of pond-reared striped bass with those from natura waters (rivers and estuaries).

ton and opportunistic feeding by the fish are apparent, but more research on factors affecting food selection is needed.

Young striped bass sometimes ingest small amounts of phytoplankton and nonliving material. In culture ponds with a good crop of zooplankton, supplemental food is apparently of limited value. But striped bass approximately 30 days old can be trained to eat ar tificial food and they can be reared to ad vanced fingerling size on this food.

GROWTH PATTERNS

A comparison of first-year growth rates c pond-reared striped bass with those sample from natural waters (rivers and estuaries



on the mid-Atlantic Coast is presented in Figure 1. These curves were fitted by eye to data taken from studies in several states (Truitt and Vladykov, 1937; Pearson, 1938; Merriman, 1941; Vladykov and Wallace, 1952; Raney, 1952; Rathjen and Miller, 1957; Trent, 1962; Sandoz and Johnston, 1965; Stevens, 1965, 1967; Tatum et al., 1965; Bayless, 1968). Although growth rates are highly variable because of such factors as differences in years, spawning periods, and growing seasons, these curves probably give reasonable approximations of general growth patterns of these fish.

Growth rates of both the pond-reared fish and fish from natural waters are approximately the same for the first 30 days, after which the pond-reared fish grow much faster. Generally, the growth period for striped bass in the mid-Atlantic region extends from mid-April or early May (depending on date spawned) through October. Growth is almost linear during this period, but there is little indication of linear growth from November through March when low water temperatures apparently inhibit growth. Annulus formation occurs in March or early April in fish from natural waters. No data on annulus formation in pond-reared fish were available since these fish are usually stocked in reservoirs between July and September of their first year. But annulus formation in these fish would coincide closely with that of fish in natural waters since the growing season is approximately the same.

Striped bass reared in ponds are approximately 170 mm in length at the end of the first year, while those in natural waters are about 110 mm long. The major difference between growth rates of these fish is probably accounted for by increased food supply in ponds resulting from the artificial fertilization. Although the density of fish in ponds may be greater than that in natural waters, competition for food in ponds is decreased since most facilities eliminate undesirable organisms in the culture ponds before the striped bass are stocked. Also, supplemental food is usually supplied to the ponds when the fish are 30–60 days old.

Little information is available on first year growth of striped bass in reservoirs. But data from Santee-Cooper Reservoir, S. C. in the 1950's indicated that average lengths of bass (1 year old) ranged from 180 to 216 mm (Scruggs, 1955; Stevens, 1957). In 1968 a few striped bass (6–8 months old) from Keystone Reservoir in Oklahoma were 356 mm long (Bayless, 1968). These limited data indicate that first year growth rates of striped bass in reservoirs are higher than those in fertilized culture ponds. This is probably related to food supply since most reservoirs contain large populations of shad which are especially desirable forage fish for striped bass. Also, young striped bass usually occupy the pelagic zones in reservoirs; thus there is little competition for food from other predaceous fish which generally inhabit other areas.

FACTORS AFFECTING GROWTH AND SURVIVAL

Predation

Newly-hatched striped bass fry are especially vulnerable to predation since they are unable to swim continuously. Aquatic insects especially back swimmers and phantom midge larvae, and several species of fish including bluegill, green sunfish, crappie, flathead minnow and mosquitofish have been reported as predators on young striped bass in culture ponds (Stevens, 1965; Tatum et al., 1965). But these organisms are relatively easy to control or eliminate in ponds, so they should not cause much concern in future rearing efforts. Also, the practice of holding striped bass in troughs until they are swimming strongly and actively feeding reduces their vulnerability to predation when stocked in ponds.

Handling and Stress

Sensitivity to handling or other stress is especially pronounced in striped bass larvae. Stress may induce shock in the fish which usually causes death. Even abrupt contact with light or loud noises can induce shock. In many cases handling increases the incidence of bacterial infections, especially Columnaris disease. Elimination of unnecessary handling and stress at striped bass rearing facilities

TABLE 1.—*Favorable ranges and lethal limits of various water quality factors for larval striped bass (dashes indicate that limits are not known)*

Parameter	Favorable Range		Lethal Limits	
	Lower	Upper	Lower	Upper
Temperature (*C*)	16.0[1]	19.0[2]	14.0[2]	24.0[3]
Dissolved oxygen (*ppm*)	5.0[1]	—	1.7[1]	—
pH	7.5[2]	7.9[2]	5.3[4]	10.0[5]
Sulfates (*ppm*)	—	200.0[6]	—	250.0[6]
Chlorides (*ppm*)	—	950.0[7]	—	1000.0[6]
Dissolved solids (*ppm*)	100.0[2]	900.0[2]	—	—
Zinc (*ppm*)	—	—	—	0.28[6]
Copper (*ppm*)	—	—	—	0.05[6]
Aluminum (*ppm*)	—	—	—	0.02[5]

[1] Bogdanov et al. (1967).
[2] Davies (1970).
[3] Stevens (1969).
[4] Tatum et al. (1965).
[5] Bonn (1970).
[6] Hughes (1968).
[7] Albrecht (1964).

should increase survival. Also, a 1% salt solution apparently reduces sensitivity of young striped bass to handling and stress.

Water Quality Factors

Generally, little correlation has been found between production of striped bass fingerlings and water quality at most striped bass rearing facilities. The effects of many individual water quality factors on striped bass have been tested in the laboratory, but results have been variable due to different methodology and different ages of fish. Sensitivity to changes in water quality apparently decreases with age of the fish but few studies have been made to elucidate this matter. Davies (1970) reported that striped bass fry demonstrated a more restricted range of survival than fingerlings in water with variable pH, temperature, and dissolved solids.

Rapid or drastic changes in temperature, pH, and hardness of water and the lack of sufficient dissolved oxygen have been implicated as causes of mortality in young striped bass at various facilities. Also, certain metals including aluminum, zinc, and copper can be toxic to striped bass. On the other hand, survival of striped bass larvae has been enhanced by slightly saline water. In an attempt to define the best conditions for rearing larval striped bass, I summarize the data from several studies in Table 1. This table indicates generally favorable ranges and lethal limits of different water quality factors for larval striped bass. The tolerance limits usually increase with fish age, but these figures for larval striped bass should serve as general guidelines for striped bass rearing. The favorable ranges indicate only the known values for waters in which striped bass have been reared. In many cases these ranges probably are more extensive than indicated. The blanks in Table 1 indicate that further research is needed before optimum water conditions for striped bass rearing can be determined. Other water quality factors including iron, nitrogen, and ammonia have significant effects on growth and survival of striped bass, but specific tolerance limits have not been determined. Research on the effects of various metabolites on growth and survival is indicated if striped bass are to be reared in closed systems.

Some management procedures that can prevent or alleviate harmful water quality conditions in aquaria or troughs include control of water temperature, aeration, recirculation, and filtration of the water. The use of pipe or containers made of galvanized iron, copper, or aluminum should be avoided. In ponds, aeration along with a carefully controlled fertilization program and periodic monitoring of important parameters could prevent water quality deterioration.

FUTURE OUTLOOK

In areas where an adequate water supply is available, warmwater hatcheries with large holding ponds for rearing striped bass fry to fingerling size can be used to increase production. Several states including Kentucky and Virginia are developing hatcheries for this purpose. Use of nursery ponds built adjacent to reservoirs can also be used to rear striped bass fingerlings. The fish can then be drained directly into the reservoir, thus reducing handling and stress which often results in high mortality.

Intensive culture of striped bass fry has promise as a useful management technique. Generally, it has been necessary to stock 5 to 8 day old fry in culture ponds regardless of pond conditions due to absence of sufficient food in holding troughs. Nauplii of brine

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shrimp provide sufficient food to maintain fry in troughs or aquaria for 15–21 days. This procedure allows time to manipulate fertilization of ponds to produce a desirable crop of zooplankton. One rearing station employed this technique during the 1970 season and a fivefold increase in production of fingerlings resulted (Bonn, 1970). Thus, it is a highly recommended procedure for use at other striped bass rearing facilities.

Further research in nutrition must be accomplished before striped bass fry can be reared to fingerling size on a large scale in aquaria or troughs. Nutrition is a problem for fry held on a brine shrimp diet after they reach a certain stage of development. Generally, these fish begin to die in large numbers during the transformation from postlarvae to young (21–30 days old). Further research on physiological changes taking place at this time and the resulting nutritional requirements of the fish is indicated.

Since mass rearing of zooplankton as larval fish food is presently difficult and unreliable, rearing striped bass on laboratory plankton is not feasible. But the feasibility of mass rearing striped bass in floating cages in fertilized ponds should be tested. This method would eliminate the need to grow or collect food organisms and simplify harvesting the fish. After the critical period of metamorphosis (about 30 days), the young fish could be transferred to troughs or raceways and raised to stockable size on artificial food. This would allow close observation of the fish and decrease chances of loss due to diseases, oxygen deficiencies and other unfavorable factors.

If a proper diet is formulated, the feasibility of rearing striped bass fry to advanced fingerling size in closed system environments with precise control over chemical and physical factors in the water which affect the normal physiology of the fish should be tested. This intensive culture technique with new methods of water filtration and purification for control of water quality, diseases, and parasites should eliminate much of the variability in striped bass production while eliminating the need for large culture ponds. Control of water temperature and photoperiod would allow manipulation of the growing season which could possibly result in rearing of catchable size striped bass within 1 year for reservoir stocking on a put and take basis.

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