SPAWNING GROUNDS OF THE STRIPED BASS, *Roccus saxatilis* (Walbaum), IN THE TAR RIVER, NORTH CAROLINA

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by

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ABSTRACT

Earl Terry Humphries. SPAWNING GROUNDS OF THE STRIPED BASS, Roccus saxatilis (Walbaum), IN THE TAR RIVER, NORTH CAROLINA. (Under the direction of Joseph G. Boyette) Department of Biology, June 1966.

The purpose of this study was to investigate spawning of the striped bass, Roccus saxatilis (Walbaum), in the Tar River, North Carolina in 1965. Sampling for striped bass eggs was conducted on the Tar River from March 29 to May 24, 1965. Samples were taken at seven permanently located stations using a 15 inch plankton net having 30 meshes per inch. Eggs were collected at six of the stations during the period from April 14 to May 18. Quantitative estimates of the flow of striped bass eggs past Station 2 (near U. S. Highway 64 Bridge at River Mile 46.2) were made with estimates of up to 445,000 eggs per hour being determined. Based on egg collections and estimates of eggs flowing past Station 2, it was evident that significant striped bass spawning had occurred in the Tar River.

The period of spawning was considered to be correlated with striped bass egg collections, which were taken periodically from April 14 to May 18. The peak spawning period, as reflected by large egg collections, occurred from May 3 to May 11.

Estimates of the distribution of spawning were based on aging eggs and determining their approximate rate of transport downstream. According to these estimates, spawning occurred over a 50 mile stretch of river upstream from Station 4 (near the bridge on County Road 1400 at River Mile 30.0). Approximately 75% of the spawning occured over a 20 mile span of river centered near Station 1 (near Bells Bridge at River Mile 57.0).

Surface water temperatures ranged from 59 to 72°F (15 to 22°C) during the spawning period. Water temperatures upstream from Station 4, where it was assumed that spawning occurred, ranged from 65 to 70°F (18 to 21°C) during the peak spawning period. The peak spawning period was correlated with a rise in water temperatures from 59 to 65°F (15 to 18°C). The spawning peak was also correlated with a rise in mean daily flow measured at Station 2.

Measurements of dissolved oxygen, free carbon dioxide, and total alkalinity were made periodically at three of the sampling stations. No correlation was apparent between changes in these measurements and spawning period.

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INTRODUCTION

History of the Problem

The striped bass or "rock", Roccus saxatilis (Walbaum), is an important anadromous fish to the commercial and sporting interests of both the Atlantic and Pacific Coasts of North America. This fish is widely distributed along the Atlantic Coast from the St. Lawrence River in Canada to the St. Johns River in northeastern Florida, and in the Gulf of Mexico from West Florida to tributaries of Lake Pontchartrain, Louisiana. The range on the Pacific Coast, where it was introduced in the last quarter of the 19th century, now extends from Grays Harbor, Washington, to Los Angeles County, California (Bigelow and Schroeder, 1953).

Following an upstream migration in the spring, the striped bass spawns in fresh or virtually fresh water. The time of spawning varies with latitude, local temperature conditions, and physiological factors. Spawning normally occurs in North Carolina from mid-April until late May or early June. The Roanoke River, a tributary of Albemarle Sound, is the principal striped bass spawning area in North Carolina.

Water temperature is one of the principal factors controlling the time of spawning (Rathjen and Miller, 1957). The minimal temperature at which spawning occurs

in most areas is about 58°F. Peak spawning usually occurs at temperatures between 60 and 67°F (Raney, 1952). Water temperatures at the end of the spawning season are from 70 to 72°F (McCoy, 1959).

During the spawning act, a single large female is surrounded by a few to several dozen males. The so-called "rock fights", which are really spawning behavior, then occur. These antics consist of vigorous movements and splashings which are accompanied by casting of the eggs. Spawning by females stimulates the males to fertilize the eggs, and at times the water may become clouded with sperm. The eggs are spherical, transparent, non-adhesive, and relatively large. They are planktonic and buoyant and are thus carried downstream by the current. The unfertilized egg averages 1.3 mm. in diameter, while the fertilized, water hardened egg measures 3.4 mm. (Mansueti, 1958). The egg is characterized by a single large oil globule, a lightly granulated yolk mass, a very wide perivitelline space, and a clear chorion or eggshell.

Hatching time of striped bass eggs varies with the water temperature. Forty-eight hours was required at an average water temperature of 64°F (Pearson, 1938). At 71-72°F hatching occurs in about 30 hours, while at 58-60°F hatching normally takes place in about 70 to 74 hours (Merriman, 1941).

Many phases of the biology of the striped bass population of the east coast have been investigated, but many problems remain partially or totally unsolved. One such problem is the subject of the present study which is concerned with spawning grounds of the striped bass in the Tar River, North Carolina.

The Roanoke River is the only known area in North Carolina where many striped bass are found in the spawning run (Chapoton and Sykes, 1961). This river has long been known as an outstanding spawning area for striped bass. It has been stated that there are a number of coastal streams such as the Tar River and the Cape Fear River which superficially have the same characteristics as the Roanoke and it would be possible for the fish to spawn in these rivers (Dickson, 1958). Striped bass are known to occur in these rivers, but it has not been ascertained whether or not the fish spawn there. Raney (1952) suggested that yearly investigations of egg production in all major eastern rivers be established.

The section of the Tar River between Rocky Mount and Old Sparta is a known spawning area for shad, Alosa sapidissima (Wilson), and other migratory fish. It has been found that in general the spawning areas of the shad and striped bass are the same, with the area used by the bass possibly extending a little further downstream (Morgan and Gerlach, 1950). Striped bass spawning has

been assumed to occur in the same general area as shad spawning in the Tar River, but little is known of the location, the extent, or the success of this spawning (Smith and Bayless, 1964). It was recommended by Smith and Bayless (1964) that a study be conducted on striped bass spawning in the Tar River.

Objectives of the Investigation

The purpose of this investigation was to conduct a study of striped bass spawning in the Tar River. This study had the following objectives:

(1) To determine if significant spawning occurred by sampling for striped bass eggs.

(2) To determine the period of spawning.

(3) To determine the location of the spawning grounds.

(4) To determine the conditions under which spawning occurred.

The study was limited to an area of the Tar River approximately 52 miles in extent because of the time involved in taking samples, limited manpower, and other commitments. The study was exploratory in nature and was designed to lead to more detailed future studies. Data for this study was collected during the period from March 29 until May 24, 1965.

Study Area

The Tar River Basin, draining an area of approximately

3,080 square miles, lies wholly within the State of North Carolina. It is bounded on the north by the Roanoke River Basin, on the east by the Pamlico River Basin, and on the south by the Neuse River Basin.

The Tar River rises in the Piedmont Plateau near the village of Mill Creek in Person County, and follows a southeasterly course through the Piedmont and Coastal Plain regions until it empties into the Pamlico River at Washington, approximately 195 miles from the headwaters. The river falls vertically 27 feet at what is known locally as "the Falls", after passing through a dam at Rocky Mount. This is the natural fall line between the Piedmont and Coastal Plain regions, and at this point the land changes from the rolling slopes of the headwaters to a flatter terrain, and the river falls only 58 feet to its mouth at Washington.

In the Upper Coastal Plain, the Tar River and its major tributaries are turbid during much of the year, and the stream discharges are subject to rapid rise and fall. The sampling area was established within this portion of the river since it was thought that striped bass spawning occurred in this general area (Smith and Bayless, 1964).

Flow data was available from the U. S. Geological Survey during the study. This data was taken at a U. S.

Geological Survey Gaging Station located at the bridge on U. S. Highway 64 in Tarboro at River Mile 46.2. The mean daily discharge for the month of April 1965 was 1,814 cubic feet per second and the mean daily discharge in May 1965 was 1,012 cubic feet per second. The mean daily discharge for the water year, October 1964 to September 1965, was 2,689 cubic feet per second as compared to an average daily discharge of 2,262 cubic feet per second for a period of 31 years at this station.

REVIEW OF LITERATURE

Previously Located Spawning Areas

In the past, striped bass probably spawned in most of the rivers from the St. Lawrence to the Savannah as well as in some of the tributaries of the Gulf of Mexico (Raney, 1952). Merriman (1941) stated that as cities were built and dams and pollution spoiled one area after another, the number of rivers that were suitable for spawning decreased. At the present time there is every indication that by far the greater part of the production of striped bass along the Atlantic Coast takes place from New Jersey to North Carolina.

It has long been known that striped bass spawn in the Roanoke River at Weldon, North Carolina. It is probable that spawning takes place over a good stretch of the river from Weldon down (Merriman, 1941). This spawning site is a rock-strewn area characterized by rapids and strong currents. Pearson (1938) collected eggs during May and June 1932 in the Susquehanna River, Maryland in a swift section of the stream similar to the spawning site at Weldon.

Merriman (1941) found that striped bass formerly spawned in Connecticut, but plankton and bottom hauls have failed to reveal any evidence that spawning occurs there now. Merriman also cited two probable spawning

areas in other northern waters based on collection of juvenile striped bass. These areas included the Hudson River as far up as Albany, New York; and the Parker River near Newburyport, Massachusetts.

In 1950, Tresselt (1952) made a study of the spawning grounds of the striped bass in some Virginia rivers tributary to Chesapeake Bay, namely the James, Chickahominy, Pamunkey, Mattaponi, and Rappahannock. He collected eggs in plankton nets during April and May and concluded that most of the spawning occurs within the first 25 miles of fresh water in this region.

Vladykov and Wallace (1952), on the basis of collections of ripe females, stated that striped bass spawning grounds in Chesapeake Bay are located in the upper tidal reaches of rivers where the water is almost fresh, where the current is $2\frac{1}{2}$ to 3 miles per hour, and where the bottom is usually mud or sand. Mansueti (1963) concluded that no one area in Chesapeake Bay produces the bulk of eggs, although the Potomac River and the upper Bay with all its tributaries may contribute a large part together. He also stated that the spawning areas in the Chesapeake Bay vary from year to year depending on the amount of rainfall, salinity, and other natural factors. He outlined eleven different spawning areas in Maryland waters.

Rathjen and Miller (1957) made a study of striped

bass spawning grounds in the Hudson River. They collected eggs in plankton nets and concluded that the spawning grounds included the area of the river from Bear Mountain to a point near Kingston. They found the principal spawning area to be centered in the vicinity of the U. S. Military Academy at West Point in essentially fresh water. A large percentage of the total spawning occurred within a relatively short segment of the river characterized by a strong current, deep water, and rocky banks.

Studying the occurrence of ripe fish in the commercial fishery and the distribution of young in the summer, Wallace and Neville (1942) concluded that the principal spawning and nursery areas of striped bass on the Atlantic Coast are found in the Hudson River, Delaware Bay, Pamlico Sound, Chesapeake Bay, and their tributaries.

Hatton (1942) was the first to establish definite information as to location of striped bass spawning areas in California. He collected eggs at night in set plankton nets in several localities in the lower Sacramento-San Joaquin Delta during the middle of May, 1940. Woodhull (1947) observed striped bass spawning in the San Joaquin River, about 60 miles above the Golden Gate, where the river is tidal, swift, and fresh. Calhoun and Woodhull (1948), on the basis of egg and larval collections, concluded that all of the major spawning grounds in California are in the Central Valley. Calhoun, Woodhull, and Johnson

(1950) reported that during May and early June 1948, striped bass eggs were present in considerable numbers throughout the lower Sacramento system, except in the American River.

Erkkila et al. (1950) conducted studies on spawning areas of striped bass in the Sacramento-San Joaquin Delta in 1948 and 1949. On the basis of egg collections they concluded that the initial spawning was heaviest in the southern and central portions of the Delta, with a gradual shift to the western or lower San Joaquin River portion. Albrecht (1964) also took developing striped bass eggs from the Sacramento and San Joaquin Rivers in plankton nets.

In Oregon, Morgan and Gerlach (1950) observed spawning in the tidal area of the upper Coos River, in the lower parts of the South Fork of Coos River, and in the Millicoma River.

Period of Spawning

Striped bass spawn in fresh or virtually fresh water from April to July (Raney, 1952). The spawning season varies with latitude, water temperature, and physiological factors. In the Roanoke River, North Carolina, spawning occurs from late April to May, with a few stragglers as late as June (Merriman, 1941). Spawning normally occurs in North Carolina from mid-April to late May or early June (Trent, 1962).

In the tributaries of Chesapeake Bay, the spawning period extends from May to July (Vladykov and Wallace, 1952). Tresselt (1952) found evidence of spawning in several Virginia rivers in April and May. In the Hudson River, Rathjen and Miller (1957) found evidence of spawning from mid-May through mid-June. Recent studies have indicated that most spawning in the Potomac River in 1959 was completed by May 15.

In California, the following authors provide evidence that spawning occurs from April through June: Woodhull (1947), Calhoun, Woodhull, and Johnson (1950), and Erkkila et al. (1950). According to Morgan and Gerlach (1950), spawning in the Coos River, Oregon takes place in May and June.

Water Temperature at Spawning

Worth (1884) took ripe striped bass from the Roanoke River at Weldon, North Carolina in April and May 1884 at water temperatures that increased from 58 to 71°F. Pearson (1938) took ripe fish at Weldon in May 1931 as the water temperature increased from 61 to 71°F. He also collected freshly deposited eggs in the lower Susquehanna River, Maryland in May and June 1931, when the water temperature increased from 60 to 70°F.

Woodhull (1947) noted that the water temperature was 67°F when he observed striped bass spawning in the San Joaquin River, California on May 6, 1946. Hatton (1942)

collected eggs in May 1940 in the lower Sacramento-San Joaquin Delta where water temperatures ranged from 66 to 68°F. According to Calhoun, Woodhull, and Johnson (1950), spawning does not begin in the lower Sacramento River system until the water temperatures reach about 60°F. They observed that spawning ceased during storms when the water temperatures declined and resumed when the weather became fair and temperatures rose. Erkkila et al. (1950) pointed out that water temperatures appeared to have exerted a very important influence in determining the time of spawning and the rate of development of larval and post-larval striped bass in the Sacramento-San Joaquin Delta. They found that spawning activity as reflected by egg collections occurred in temperatures of 58°F and higher, with a peak between 60 and 67°F. Raney (1952) concluded that peak spawning usually occurs at water temperatures between 60 and 67°F.

Rathjen and Miller (1957) collected striped bass eggs in the Hudson River in water temperatures which varied from 59 to 68°F. In Virginia rivers, Tresselt (1952) found eggs where the water temperatures ranged from 54 to 70°F.

Mansueti (1963) stated that striped bass are known to spawn when water temperatures are between 50 and 75°F, but most eggs are produced at about 65°F. In North Carolina waters spawning activity usually occurs after the water

temperature reaches 60°F (Dickson, 1958). McCoy (1959) stated that spawning in the Roanoke River does not begin until water temperatures reach approximately 58 to 60°F. He also stated that the majority of spawning occurs at water temperatures of 64 to 68°F, with water temperatures at the end of the spawning season from 70 to 72°F.

Salinity on Spawning Grounds

Actual observation of spawning (Woodhull,1947; Morgan and Gerlach, 1950), and the collection of recently spawned developing striped bass eggs (Pearson, 1938; Woodhull, 1947; Calhoun, Woodhull, and Johnson, 1950; Tresselt, 1952; and Rathjen and Miller, 1957) have shown that striped bass spawn in fresh water in a moderate to swift current. Raney (1952) stated that striped bass spawn in fresh or virtually fresh river water.

Spawning has never been observed in brackish or salt water (Albrecht, 1964). Tresselt (1952) collected some eggs in slightly brackish water in Virginia rivers but it seemed probable that these eggs had been carried downstream by the current. Albrecht (1964) stated that newly hatched bass have been captured in California in brackish waters, but they could easily have drifted into these areas from fresh water.

Location of Eggs After Spawning

Pearson (1938) was one of the first investigators to use a plankton net for the collection of striped bass

eggs. He collected eggs in the Lower Susquehanna River, Maryland in 1932. Merriman (1941) included some plankton samples in his work, but he did not collect any striped bass eggs.

Hatton (1942) collected eggs at night in set plankton nets, usually within four or five feet of the bottom, in several localities in the lower Sacramento-San Joaquin Delta. Woodhull (1947) picked up freshly spawned eggs in the San Joaquin River, California with a number six plankton net on May 6, 1946. The next day he found eggs at depths of 15 to 35 feet, but generally they were taken within five feet of the river bottom.

In the Sacramento River, California; Calhoun, Woodhull, and Johnson (1950) collected eggs in 1948. They used cone-shaped nets, with a mouth diameter of 19 inches, made of silk bolting cloth having 30 meshes per inch. Quart jars tied at the small end of the nets served as collecting bottles. Their standard procedure in taking a sample was to lower a net into a river from a bridge, in the middle of the channel, keeping it submerged just beneath the surface for 15 minutes.

Erkkila et al. (1950) sampled for striped bass eggs and larvae in 1948 in the Sacramento-San Joaquin Delta by taking standard surface plankton hauls of five and ten minutes duration. In 1949, they conducted sampling for eggs which generally consisted of three five-minute

plankton hauls at each station. Albrecht (1964) collected developing striped bass eggs from the Sacramento and San Joaquin Rivers in large-mesh plankton nets (23 meshes per inch) set in the current from an anchored skiff. These nets were 20 inches in diameter with a cone approximately four feet long. A quart jar was attached at the apex of each net to serve as a collecting bottle.

In Virginia rivers, Tresselt (1952) used nets made of nylon marquisette having about 25 meshes per inch. He used four nets with a diameter of one meter at the mouth, one with a diameter of $\frac{1}{2}$ meter, and one sled type net in the shape of a semicircle which had a radius of $\frac{1}{4}$ meter. The nets were set in the current and samples were taken at both the surface and bottom. Originally bottom sampling was stressed, but more eggs were found in the surface samples. The nets were set for approximately one hour. Morgan and Gerlach (1950) used plankton hauls in their studies on the Coos River, Oregon in 1949 and 1950. They made plankton hauls once a week at the forks of Coos River and occassionally below Allegany in order to obtain striped bass eggs and larvae.

Rathjen and Miller (1957) employed plankton collecting gear in their studies on the Hudson River, New York in 1955. Most widely utilized were half-meter plankton nets made of nylon netting. Two nets were towed simultaneously for 20 minute periods, one at the surface and the other

12 to 18 feet below the surface. Where tidal action was sufficient, some nets were set in the current. They found a subsurface net to be more efficient than a surface net, but in general, the subsurface samples were not much greater than the surface samples.

Mansueti (1963) stated that surveys have shown that striped bass spawn in eleven different areas in Maryland based on the capture of floating eggs. These eggs were collected in a fine meshed, cone-shaped net either towed by a boat or anchored in the current.

McCoy (1959) used two sizes of plankton nets in his studies on quantitative sampling for striped bass eggs in the Roanoke River, North Carolina. He used small nets with an average net-opening diameter of 10.1 inches and large nets with an average diameter of 38.9 inches. He made comparisons of samples taken in the small and large nets and found no difference between the two in the number of eggs collected after adjustments for net size were made. He also compared striped bass egg samples as to days, time of day, and positions of nets. In general, he found no significant difference between days, between time of day, or between horizontal and vertical positions of the net samples.

In the San Joaquin River in 1962, Albrecht (1964) made observations on the vertical distribution of eggs by fishing three plankton nets simultaneously at different

depths and comparing catches. Net sets ranged from 10 to 20 minutes in duration. He found that at surface velocities of 0.6 to 0.9 of a foot per second, eggs were generally collected in larger numbers near the bottom, while at higher velocities distribution was more variable. He also suggested that large egg collections may indicate recent spawning at or near the surface, and that these eggs may not have had time to disperse.

MATERIALS AND METHODS

Stations

Seven stations were selected at the outset of the problem. These stations, which covered approximately 52 miles of the main course of the river, were selected on the basis of ease of accessibility to the river. The locations of the stations are illustrated in Figure 1.

Station 1 was located at the Wildlife Fishing access area at Bells Bridge near Tarboro at River Mile 57.0. Station 2 was located at the Tarboro City boat landing near U. S. Highway 64 Bridge at River Mile 46.2. Station 3 was located at the Wildlife Fishing access area near U. S. Highway 42 Bridge at Old Sparta at River Mile 38.5. Station 4 was located at the Wildlife Fishing access area near the bridge on County Road 1400 at River Mile 30.0. Station 5 was located at the Wildlife Fishing access area at Greenville at River Mile 22.0. Station 6 was located at the end of County Road 1533 near Port Terminal at River Mile 15.5. Station 7 was located at the access area near the bridge on County Road 1565 north of Grimesland at River Mile 5.5.

Stations 1, 3, 5, and 7 were established for sampling purposes at the beginning of the sampling period, March 29. These four stations were selected in order to cover the entire sampling area. After the first striped bass eggs were collected at Station 5 on April 14, Stations

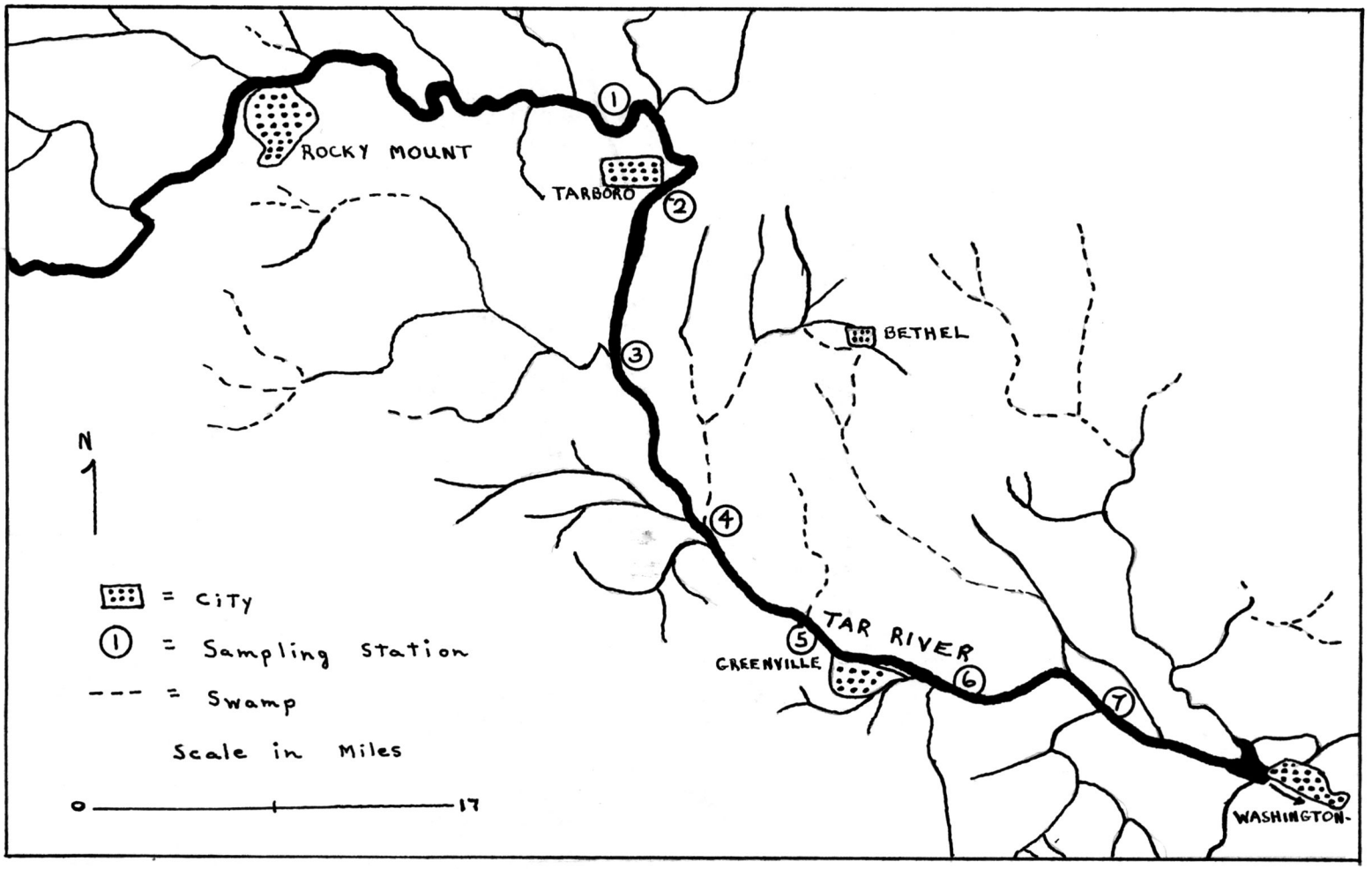

Figure 1. Map of the sampling area and station locations in the Tar River, North Carolina

2, 4, and 6 were added in order to cover the area more thoroughly.

On April 21, Station 7 was abandoned since tidal effects encountered at this point made sampling impractical. At times the river current was imperceptible at this station due to wind tides.

Collecting Samples

Sampling was conducted at each station using a cone-shaped net made of nylon marquisette, a fine material having approximately 30 meshes per inch. The net used had a diameter of 15 inches at the mouth. The cone of the net was 36 inches in length with a pint plastic bottle tied at the apex to serve as a collecting bottle.

Previous work in the Roanoke River, North Carolina indicated that there was no significant difference in samples from nets set at different vertical and horizontal positions (McCoy, 1959); hence, the net was set just beneath the water surface near midstream at each station as a matter of convenience. The set was made either from a bridge or an anchored boat. From March 29 to May 4, the net was set for 30 minutes for each sample. From May 4 until the termination of the sampling period, May 24, net sets were made for 15 minutes for each sample. The sampling time was shortened, since it became impractical to sort the large numbers of eggs collected in the 30-minute samples.

During the period from March 29 until April 13, sampling was conducted at Stations 1, 3, 5, and 7. Two stations were sampled on alternate days; Stations 1 and 3 being sampled one day, and Stations 5 and 7 being sampled the following day. After April 14, the sampling schedule was revised to include Stations 2, 4, and 6. Stations 1, 2, and 3 were then sampled one day and Stations 4, 5, and 6 were sampled the following day, whenever possible. Station 7 was sampled whenever time permitted until it was abandoned on April 21.

Water and air temperatures were determined with a Taylor pocket thermometer while each sample was being collected. Weekly analyses of chemical features of the water were made at Stations 1, 3, and 5. A field kit prepared by the North Carolina Wildlife Resources Commission was utilized in these determinations. Dissolved oxygen concentrations were determined at streamside using the azide modification of the Winkler method. This method employed the use of alkaline-iodide-azide in place of alkaline-iodide.

Free carbon dioxide was determined as total acidity by titration of a water sample with N/44 sodium hydroxide to the phenolpthalein end-point. Total alkalinity was determined by a mixed titration with 0.02N/H_2SO_4 using bromocresol green-methyl red indicator. This indicator was used in preference to methyl orange because of the

difficulty encountered in determining the methyl orange end-point in highly stained waters.

Sorting Samples and Preserving Eggs

Samples taken at each station were placed in quart plastic bottles and sorted as soon as possible, usually within two or three hours. Striped bass eggs in the samples were separated from the detritus and other debris by pouring a shallow layer of the sample into a flat disc-shaped pie tin 12 inches in diameter. A bright lamp placed just above the tin made the striped bass eggs, which protruded above the water surface, readily visible. The eggs were removed from the tin with a seven millimeter bore pipette. They were counted and placed in small vials containing 7% formalin solution. Eggs from each sample were placed in separate vials which were labeled as to time, date, and location of the sample. The vials were then stored.

Staging Eggs

In June and July 1965, the striped bass eggs which were collected during the sampling period were examined individually using a dissecting microscope. Whenever possible, eggs were classified as to approximate stage of development by comparing them with figures and descriptions of eggs given by Mansueti (1958); and by use of a set of color slides of developing striped bass eggs prepared by the North Carolina Wildlife Resources Commission.

RESULTS

Sampling and Egg Collections

The sampling records for Stations 1-6 (see Figure 1) are summarized individually (Tables 1-6). The extreme right column indicates the number of eggs collected per minute of sampling. This provides a rough index to the relative abundance of striped bass eggs at different times during the sampling period, that extended from March 29 to May 24, 1965. The total number of eggs collected at each station is indicated at the bottom of each table.

Since Station 2 was the only station for which flow data was available, estimates of the number of eggs which passed this station at different times during the sampling period are presented in Table 7. The estimated flow of eggs past Station 2 is indicated in the two extreme right columns of the table. This was determined by converting the rates of egg capture outlined in column 5 to estimates of numbers of eggs passing the station during a one minute and a one hour period. The rate factor was based on the proportion of the total flow actually sampled.

Period of Spawning

The period of spawning is indicated in the tables which summarize the records of sampling and striped bass egg collections (Tables 1-6). This period was considered

TABLE 1. Record of sampling and striped bass egg collections from Station 1 in 1965

Date	Time Sampling Started	Sampling Duration Min.	Surface Water Temp °F	Striped Bass Eggs Number	Striped Bass Eggs Number per Minute
3/29	3:00 PM	30	55	0	0
3/31	2:35 PM	30	57	0	0
4/2	9:30 AM	30	53	0	0
4/4	10:15 AM	30	53	0	0
4/6	1:45 PM	30	57	0	0
4/8	11:50 AM	30	60	0	0
4/11	7:15 PM	30	62	0	0
4/13	2:20 PM	30	65	0	0
4/15	12:50 PM	30	61	1	0.033
4/18	11:55 PM	30	65	17	0.567
4/20	1:45 PM	30	62	1	0.033
4/22	10:55 AM	30	62	0	0
4/24	1:15 PM	30	64	5	0.167
4/26	2:25 PM	30	63	0	0
4/28	2:45 PM	30	60	10	0.333
4/29	3:40 PM	30	60	29	0.967
5/1	1:45 PM	30	59	8	0.267
5/3	2:20 PM	30	65	2230	74.333
5/5	2:30 PM	15	70	274	18.267
5/7	7:30 AM	15	66	43	2.867
5/8	11:45 PM	15	70	15	1.000
5/11	8:25 AM	15	70	64	4.267
5/13	10:00 AM	15	71	1	0.067
5/15	6:30 AM	15	68	2	0.133
5/17	3:30 PM	15	71	0	0
5/19	1:20 PM	15	73	0	0
5/21	1:00 PM	15	74	0	0
Total				2700	

TABLE 2. Record of sampling and striped bass egg collections from Station 2 in 1965

Date	Time Sampling Started	Sampling Duration Min.	Surface Water Temp °F	Striped Bass Eggs Number	Striped Bass Eggs Number per Minute
4/15	1:50 PM	30	61	1	0.033
4/20	2:45 PM	30	62	4	0.133
4/22	12:15 PM	30	63	0	0
4/24	2:15 PM	30	64	53	1.767
4/26	3:15 PM	30	63	2	0.067
4/28	3:45 PM	30	60	52	1.733
4/29	2:35 PM	30	60	67	2.233
5/1	9:35 AM	30	59	12	0.400
5/3	3:15 PM	30	65	232	7.733
5/5	3:00 PM	15	70	128	8.533
5/7	8:10 AM	15	66	28	1.867
5/9	12:30 AM	15	70	50	3.333
5/11	9:00 AM	15	70	5	0.333
5/13	10:30 AM	15	71	4	0.267
5/15	7:30 AM	15	68	5	0.333
5/17	3:00 PM	15	71	0	0
5/19	2:00 PM	15	73	0	0
5/21	1:30 PM	15	74	0	0
Total				643	

TABLE 3. Record of sampling and striped bass egg collections from Station 3 in 1965

Date	Time Sampling Started	Sampling Duration Min.	Surface Water Temp °F	Striped Bass Eggs Number	Striped Bass Eggs Number per Minute
3/29	4:30 PM	30	56	0	0
3/31	3:55 PM	30	57	0	0
4/2	10:50 AM	30	54	0	0
4/4	12 Noon	30	54	0	0
4/6	3:10 PM	30	57	0	0
4/7	4:15 PM	30	60	0	0
4/8	1:30 PM	30	61	0	0
4/9	4:10 PM	30	64	0	0
4/11	6:00 PM	30	62	0	0
4/12	4:20 PM	30	65	0	0
4/13	3:30 PM	30	66	0	0
4/15	3:00 PM	30	61	3	0.100
4/19	1:00 AM	30	65	0	0
4/20	4:15 PM	30	62	2	0.067
4/22	2:10 PM	30	64	0	0
4/24	3:30 PM	30	64	5	0.167
4/26	4:30 PM	30	63	2	0.067
4/28	4:40 PM	30	60	20	0.667
4/29	1:20 PM	30	59	14	0.467
5/1	3:10 PM	30	59	1	0.033
5/3	4:20 PM	30	65	200	6.667
5/5	3:45 PM	15	70	241	16.067
5/7	8:45 AM	15	67	21	1.400
5/9	1:20 AM	15	70	31	2.067
5/11	9:35 AM	15	70	12	0.800
5/13	11:15 AM	15	70	1	0.067
5/15	8:00 AM	15	69	0	0
5/17	2:25 PM	15	71	0	0
5/19	2:40 PM	15	75	0	0
5/21	2:10 PM	15	76	0	0
Total				553	

TABLE 4. Record of sampling and striped bass egg collections from Station 4 in 1965

Date	Time Sampling Started	Sampling Duration Min.	Surface Water Temp °F	Striped Bass Eggs Number	Striped Bass Eggs Number per Minute
4/14	5:00 PM	30	65	0	0
4/22	4:10 PM	30	64	0	0
4/25	1:25 PM	30	61	48	1.600
4/26	5:30 PM	30	63	0	0
4/29	12 Noon	30	59	4	0.133
4/30	4:20 PM	30	60	142	4.733
5/2	1:30 PM	30	61	21	0.700
5/4	2:45 PM	30	67	620	20.667
5/6	11:05 AM	15	68	67	4.467
5/7	2:05 PM	15	70	80	5.333
5/10	2:30 PM	15	72	15	1.000
5/12	2:05 PM	15	72	10	0.667
5/14	7:30 AM	15	69	2	0.133
5/16	3:45 PM	15	72	0	0
5/18	11:50 AM	15	72	3	0.200
5/19	4:00 PM	15	75	0	0
Total				1012	

TABLE 5. Record of sampling and striped bass egg collections from Station 5 in 1965

Date	Time Sampling Started	Sampling Duration Min.	Surface Water Temp °F	Striped Bass Eggs Number	Striped Bass Eggs Number per Minute
3/30	2:10 PM	30	56	0	0
4/1	11:50 AM	30	55	0	0
4/3	7:45 AM	30	53	0	0
4/5	5:45 PM	30	56	0	0
4/7	2:00 PM	30	59	0	0
4/9	2:00 PM	30	63	0	0
4/11	9:35 AM	30	62	0	0
4/12	2:20 PM	30	64	0	0
4/14	7:30 AM	30	62	4	0.133
4/16	7:00 AM	30	61	7	0.233
4/18	11:45 AM	30	64	2	0.067
4/19	12:20 PM	30	66	0	0
4/21	2:00 PM	30	63	0	0
4/23	1:55 PM	30	65	2	0.067
4/25	2:50 PM	30	62	6	0.200
4/27	3:55 PM	30	63	0	0
4/29	10:35 AM	30	59	23	0.767
4/30	3:05 PM	30	60	1	0.033
5/2	12:25 PM	30	61	3	0.100
5/4	1:35 PM	30	66	334	11.133
5/6	10:20 AM	15	68	121	8.067
5/7	3:05 PM	15	70	97	6.467
5/10	3:15 PM	15	72	54	3.600
5/12	3:00 PM	15	72	10	0.667
5/14	8:30 AM	15	69	30	2.000
5/16	4:40 PM	15	72	1	0.067
5/18	12:45 PM	15	72	0	0
5/20	11:00 AM	15	74	0	0
5/24	1:45 PM	15	78	0	0
Total				695	

TABLE 6. Record of sampling and striped bass egg collections from Station 6 in 1965

Date	Time Sampling Started	Sampling Duration Min.	Surface Water Temp °F	Striped Bass Eggs Number	Striped Bass Eggs Number per Minute
4/14	3:00 PM	30	64	2	0.067
4/16	2:50 PM	30	63	0	0
4/19	2:05 PM	30	66	1	0.033
4/21	3:45 PM	30	63	1	0.033
4/23	3:15 PM	30	66	0	0
4/25	4:35 PM	30	62	3	0.100
4/27	12:55 PM	30	62	0	0
4/29	9:00 AM	30	59	9	0.300
4/30	1:55 PM	30	60	11	0.367
5/2	10:55 AM	30	60	10	0.333
5/4	3:35 PM	30	67	114	3.800
5/6	2:00 PM	15	70	73	4.867
5/7	4:25 PM	15	70	4	0.267
5/10	4:45 PM	15	72	15	1.000
5/12	4:00 PM	15	72	0	0
5/14	2:30 PM	15	72	0	0
5/16	6:05 PM	15	72	2	0.133
5/18	1:45 PM	15	72	0	0
5/20	12:40 PM	15	75	0	0
5/24	2:30 PM	15	78	0	0
Total				245	

TABLE 7. Estimated flow of striped bass eggs down the Tar River past Station 2 in 1965

Date	River Dsch. cfs	River XS Area Sq Ft	Vel mph	Eggs/Min Sampling	Estimated Flow of Eggs	
					Per Min	Per Hour
4/15	1460	835	1.2	0.067	22	1320
4/20	1200	715	1.1	0.133	77	4620
4/24	1330	775	1.2	1.767	1113	66780
4/26	1200	720	1.1	0.067	39	2340
4/28	1760	975	1.2	1.733	1375	82500
4/29	2200	1195	1.3	2.233	2171	130260
5/1	4080	1910	1.5	0.400	621	37260
5/3	2160	1180	1.2	7.733	7416	444960
5/5	1490	835	1.2	8.533	5794	347640
5/7	1100	665	1.1	1.867	1010	60600
5/9	898	580	1.1	3.333	1573	94380
5/11	902	580	1.1	0.333	157	9420
5/13	906	585	1.1	0.267	127	7620
5/15	770	510	1.0	0.333	138	8280

to be correlated with striped bass egg collections. Therefore, the period of spawning as indicated in the tables extended from April 14 to May 18. The approximate peak spawning period, as reflected by numbers of eggs collected, occurred from May 3 to May 11.

Location of Spawning Grounds

Estimates of the distribution of spawning based on aging the eggs taken at different stations and determining the approximate rate at which they were transported downstream are indicated in Figure 2. These estimates were based on an average incubation period for striped bass eggs of 48 hours, as described by Mansueti (1958). The transport rate of the eggs was considered to be the same as the current velocity, which averaged approximately one mile per hour during the sampling period.

Conditions at Spawning

Temperature

Surface water temperatures, which were taken while each sample was being collected, are indicated in the fourth column of Tables 1-6. The temperature range during the spawning period varied from 59 to 72°F (15 to 22°C).

Flow Data

The mean daily river discharge and the average current velocity at different times at Station 2 are indicated in Table 7. This was the only station for which flow data was available. The mean daily river discharge ranged

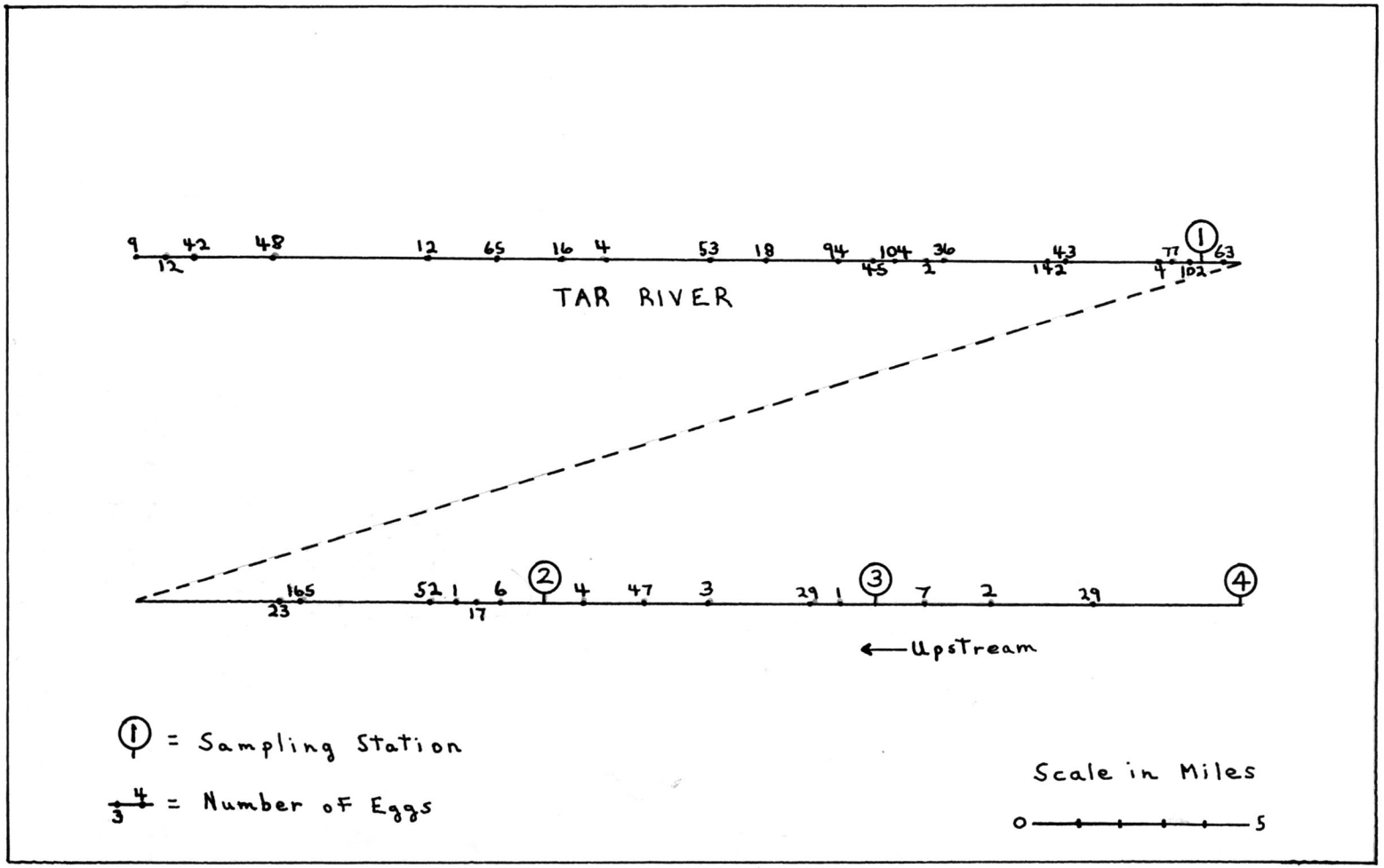

Figure 2. Estimated distribution of spawning in the Tar River in 1965, based on back staging eggs in relation to age and transport rate

from 770 to 4,080 cubic feet per second and the current velocities varied from 1.0 to 1.5 miles per hour at this station during the spawning period.

Chemical Analyses of Water

The results of the weekly water analyses taken at Stations 1, 3, and 5 are indicated in Tables 8, 9, and 10. Measurements of dissolved oxygen, free carbon dioxide, and total alkalinity are shown. The dissolved oxygen concentrations ranged from 6.2 to 10.6 ppm, free carbon dioxide measurements from 4 to 16 ppm, and total alkalinity measurements from 23 to 30 ppm at these stations.

TABLE 8. Record of weekly water chemical analyses at Station 1 in 1965

Date	Time	Dissolved Oxygen ppm	Carbon Dioxide ppm	Total Alkalinity ppm
3/29	3:30 PM	9.2	10	24
4/4	10:45 AM	10.0	6	23
4/13	2:50 PM	9.6	6	27
4/20	2:15 PM	9.0	6	29
4/28	3:15 PM	9.0	10	24
5/5	2:45 PM	7.2	10	29
5/17	3:45 PM	9.6	13	30

TABLE 9. Record of weekly water chemical analyses at Station 3 in 1965

Date	Time	Dissolved Oxygen ppm	Carbon Dioxide ppm	Total Alkalinity ppm
3/29	5:00 PM	10.6	9	26
4/4	12:30 PM	10.0	7	24
4/13	3:30 PM	9.2	8	27
4/20	4:45 PM	9.0	8	30
4/28	5:10 PM	9.4	10	28
5/5	4:00 PM	7.6	9	27
5/17	2:45 PM	9.2	14	29

TABLE 10. Record of weekly water chemical analyses at Station 5 in 1965

Date	Time	Dissolved Oxygen ppm	Carbon Dioxide ppm	Total Alkalinity ppm
3/30	2:40 PM	10.0	7	27
4/5	6:15 PM	10.0	6	25
4/14	8:00 AM	8.2	4	26
4/21	2:30 PM	8.4	6	28
4/29	11:05 AM	7.6	11	24
5/6	10:20 AM	7.0	10	26
5/16	4:55 PM	6.2	16	28

DISCUSSION

Sampling and Egg Collections

Sampling began on March 29, 1965 since observations and available literature had indicated that striped bass eggs might be expected in the river at any time after that date. The first striped bass eggs were collected at Station 5 (see Figure 1) on April 14. Eggs were collected periodically at Stations 1-6 after April 14 until the last eggs were recovered at Station 4 on May 18.

The numbers of eggs collected in the samples compared favorably with numbers of eggs collected by several investigators in other locations. Rathjen and Miller (1957) collected a total of only 71 striped bass eggs in the Hudson River, New York in 1955. They collected 0.44 eggs per hour in a surface net, 1.42 eggs per hour in a subsurface net, and 0.61 eggs per hour in a bottom trawl. Erkkila et al. (1950) collected significant numbers of striped bass eggs in the Sacramento-San Joaquin Delta, California in 1948 and 1949. They delineated the spawning areas of the striped bass in the Delta based on the assumption that the number of eggs recovered was an index of spawning intensity.

The largest number of eggs per minute taken in a single 15 minute surface sample by Calhoun, Woodhull, and Johnson (1950) was 13.06. They considered this sample,

in which nearly 200 eggs were collected, something of a record. On several occasions, which can be seen in the extreme right columns of Tables 1-6, samples containing more than 13 eggs per minute were collected in the present study.

Quantitative estimates of the flow of striped bass eggs past Station 2 are shown in Table 7. This was the only station for which flow data and cross sectional area measurements were available. Since previous work in the Roanoke River, North Carolina had indicated that there was no significant difference in samples from nets set at different vertical and horizontal positions (McCoy, 1959); the matter of differential distribution of eggs was not considered when the estimates were made. The estimates were determined by expanding the mean number of eggs collected each minute by the ratio of the river area to net area. The net area was determined as being 1.23 square feet, and the cross sectional area of the river was determined at different times from information supplied by the U. S. Geological Survey.

The estimates of numbers of eggs per minute flowing past Station 2 were expanded to numbers per hour by multiplying the value per minute by 60. As can be seen in Table 7, estimates of up to approximately 445,000 eggs per hour are indicated. It was assumed in deriving these estimates that water was strained by the nets as rapidly

as it was passing down the river, and that all the eggs survived the netting and were found. Both of these asumptions are a probable source of error. However, since the estimates would only have increased because of the error involved, they were considered to be minimal. The estimates are of interest since there is little doubt that at least this many eggs flowed past Station 2.

Assuming that the number of eggs recovered in the samples (see Tables 1-6) and that the estimated flow of eggs past Station 2 (see Table 7) is an index of spawning intensity, it is evident that significant striped bass spawning occurred in the Tar River in 1965. Therefore, it is possible that the spawning population in the Tar River contributes significant numbers to the commercially important striped bass population of the east coast.

Period of Spawning

The period of spawning, which was considered to be correlated with striped bass egg collections, is indicated in Tables 1-6. The first striped bass eggs were collected at Station 5 on April 14. Eggs were collected periodically at Stations 1-6 until the last eggs were taken at Station 4 on May 18. Therefore, the period of spawning in 1965 was considered to extend from April 14 to May 18. This spawning period is in general agreement with observations and available literature on spawning in North Carolina waters. Merriman (1941) stated that

in the Roanoke River (North Carolina) spawning occurs from late April to May, with a few stragglers as late as June. Trent (1962) stated that spawning in North Carolina normally occurs from mid-April to late May or early June. It should be pointed out, however, that the striped bass spawning season varies with latitude, water temperature, and other natural factors.

The approximate spawning peak, as reflected by large egg collections, occurred from May 3 to May 11. This peak period was correlated with factors such as water temperature and flow which will be discussed in a later section.

Location of Spawning Grounds

One of the original objectives of this investigation was to determine the location of the spawning grounds, or at least to determine the spatial limits of spawning in the Tar River. This was to be done by aging the eggs and determining the rate at which they were transported downstream. By back staging the eggs in relation to the rate of transport, it would be possible to determine the locations where the eggs were spawned. However, this method proved generally impractical since a uniform method for determining the transport rate of the eggs was not available. Also the aging of eggs in this study was based on an average incubation period of 48 hours as described by Mansueti (1958). It has been found that the incubation

period of striped bass eggs varies with water temperatures. For example, at 72°F the incubation period is 30 hours and at 59°F the incubation period is 72 hours.

Even with the fore-mentioned shortcomings, some suggestions as to spatial limits of spawning and magnitude of river area involved are indicated in Figure 2. This figure shows estimates of the distribution of spawning based on aging eggs in relation to a 48-hour incubation period and an approximate transport rate of one mile per hour. According to these estimates, all the spawning occurred upstream from Station 4 over an approximate 50-mile segment of river. Approximately 75% of the spawning occurred over a 20-mile span of river centered near Station 1.

It should be noted that an unusually large number of eggs was collected at Station 1 on May 3 (see Table 1). As pointed out by Albrecht (1964), large egg collections may indicate recent spawning at or near the water surface and these eggs may not have had time to disperse. It should also be noted that an apparent "rock fight" (vigorous spawning activity at the water surface) was observed just below the bridge from which the sample was being taken on May 3. This was the only spawning activity which was actually observed during the entire study.

According to the estimates indicated in Figure 2, the information concerning the unusually large egg collection, and the observed spawning activity; it may well be that

the majority of spawning in 1965 was centered in the general area of Station 1. This type of information could be important in determining the possible future location of a striped bass hatchery on the Tar River. Also, the location and importance of the spawning grounds should be carefully considered before the construction of dams and other water retarding structures is initiated.

Conditions at Spawning

Temperature

The surface water temperatures during the spawning period varied from 59 to 72°F (15 to 22°C) as indicated in the fourth column of Tables 1-6. This range is in general agreement with temperature ranges found by several investigators, as mentioned in the Review of Literature. Dickson (1958) stated that in North Carolina waters, spawning usually occurs after the water temperature reaches 60°F. McCoy (1959) stated that spawning in the Roanoke River, North Carolina does not begin until temperatures reach approximately 58 to 60°F. The majority of spawning occurs at temperatures of 64 to 68°F, with temperatures at the end of the spawning season from 70 to 72°F.

It should be noted that the beginning of the spawning peak on May 3 was coincident with a sharp rise in water temperatures from 59 to 65°F (15 to 18°C) as indicated in Tables 1-6. Overall water temperatures during this peak period varied from 65 to 72°F (18 to 22°C). The

temperatures upstream from Station 4, where it was assumed that spawning occurred, ranged from 65 to 70°F (18 to 21°C) during the peak. Temperatures at the end of the spawning period were approximately 72°F (22°C) at each station.

Flow Data

Flow data was available only for Station 2 during this study. The mean daily river discharge at different times at this station are indicated in the second column of Table 7. Discharges during the spawning interval ranged from 770 to 4,080 cubic feet per second. The beginning of the peak spawning period was closely correlated with a sharp rise in the mean daily flow which occurred on May 1. This was also correlated with the rise in water temperature.

Chemical Analyses of Water

The results of the weekly water analyses taken at Stations 1, 3, and 5 are indicated in Tables 8, 9, and 10. Measurements of dissolved oxygen, free carbon dioxide, and total alkalinity are shown. No correlation was apparent between changes in these measurements and the spawning period.

Dissolved Oxygen

The dissolved oxygen concentrations throughout the sampling period varied from 6.2 to 10.6 ppm. Previous studies in North Carolina have indicated that at least

4.0 ppm is necessary to permit the proper breeding and self-maintenance of the more desirable forms of fish. The range encountered was well above 4.0 ppm during the sampling period, thus the dissolved oxygen concentration was not considered to be a major factor in egg production.

Free Carbon Dioxide

Free carbon dioxide measurements made throughout the sampling period varied from 4 to 16 ppm. This range was well below the harmful limit which is generally in excess of 20 ppm.

Total Alkalinity

Total alkalinity measurements ranged from 23 to 30 ppm during the sampling period. Since total alkalinity values up to 200 ppm have little effect on fishes, this was not considered to be a major factor in egg production.

SUMMARY

This study had the following objectives:

1. To determine if striped bass spawning occurred in the Tar River in 1965 by sampling for eggs.
2. To determine the period of spawning.
3. To determine the location of the spawning grounds.
4. To determine the conditions at spawning.

The sampling period extended from March 29 to May 24, 1965. Samples were collected at seven permanently located stations which covered approximately 52 miles of the main course of the river. Four stations were established for sampling purposes on March 29. After the first striped bass eggs were collected on April 14, the other three stations were added to cover the sampling area more thoroughly. Station 7 (near the bridge on County Road 1565 at River Mile 5.5) was abandoned on April 21.

Sampling was conducted at each station using a 15 inch plankton net having 30 meshes per inch. The cone of the net was 36 inches in length with a pint collecting bottle tied at the apex. The net was set just beneath the water surface near midstream at each station. The set was made from a bridge or an anchored boat. From March 29 to May 4, the net was set for 30 minutes for each sample. From May 4 to May 24, 15 minute sets were made.

Surface water temperatures were recorded while each sample was being collected. Chemical analyses of water were determined periodically at three stations during the sampling period. Measurements of dissolved oxygen, free carbon dioxide, and total alkalinity were made.

Striped bass eggs taken in samples were sorted, counted, and stored in separate vials. In June and July 1965, eggs were classified as to approximate age by comparing them with figures and descriptions of eggs of known age.

Sampling and Egg Collections

Sampling began on March 29, and the first striped bass eggs were collected at Station 5 (near Greenville at River Mile 22.0) on April 14. Eggs were collected periodically at six of the sampling stations until the last eggs were taken at Station 4 (near the bridge on County Road 1400 at River Mile 30.0) on May 18.

Quantitative estimates of the flow of striped bass eggs past Station 2 (near U. S. Highway 64 Bridge at River Mile 46.2) were made. These estimates were determined by expanding the mean number of eggs collected each minute by the ratio of the river area to net area. Estimates of numbers of eggs per minute were expanded to numbers per hour yielding values of up to approximately 445,000 eggs per hour.

Assuming that the number of eggs recovered in the

samples and that the estimated flow of eggs past Station 2 was an index of spawning intensity, it was evident that significant striped bass spawning had occurred in the Tar River in April and May 1965.

Period of Spawning

The period of spawning was considered to be correlated with egg collections. Therefore, the spawning period extended from April 14 to May 18. The approximate peak spawning period, as reflected by large egg collections, occurred from May 3 to May 11.

Location of Spawning Grounds

Estimates of the spatial limits of spawning and the magnitude of river area involved were made. This was done by aging the eggs in relation to a 48-hour incubation period and determining the approximate rate at which they were transported downstream. By back staging the eggs in relation to age and transport rate, it was possible to determine the general areas where the eggs were spawned. According to the estimates, spawning occurred upstream from Station 4 (near the bridge on County Road 1400 at River Mile 30.0) over a 50 mile stretch of river. Approximately 75% of the spawning occurred over a 20 mile span of river centered near Station 1 (near Bells Bridge at River Mile 57.0). Apparent striped bass spawning activity was observed near this station on May 3. Based on estimates of the distribution of spawning and observed

spawning activity, it is probable that most striped bass spawning in 1965 was centered in the general area of Station 1.

Conditions at Spawning

Temperature

The surface water temperature range during the spawning period was from 59 to 72°F (15 to 22°C). The beginning of the peak spawning period was coincident with a rise in water temperature from 59 to 65°F (15 to 18°C). Temperatures upstream from Station 4 (where it was assumed that spawning occurred) ranged from 65 to 70°F (18 to 21°C) during the spawning peak. Water temperatures at the end of the spawning period were approximately 72°F (22°C) at each station.

Flow Data

Mean daily river discharges ranged from 770 to 4,080 cubic feet per second at Station 2 during the spawning period. The initial peak spawning was correlated with a sharp rise in mean daily flow.

Chemical Analyses of Water

Periodic measurements of dissolved oxygen, free carbon dioxide, and total alkalinity were taken at three of the stations. During the sampling period, dissolved oxygen concentrations ranged from 6.2 to 10.6 ppm, free carbon dioxide from 4 to 16 ppm, and total alkalinity from 23 to 30 ppm. Since none of these factors approached

the normal harmful limits, they were not considered to be major factors involved in egg production. No correlation was apparent between changes in the measurements and the spawning period.

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