A PRELIMINARY STUDY OF SHAD, *Alosa sapidissima* (Wilson), SPAWNING IN SOME VIRGINIA RIVERS

By

William Henry Massmann

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A PRELIMINARY STUDY OF SHAD SPAWNING IN SOME VIRGINIA RIVERS

Introduction

The shad, *Alosa sapidissima* Wilson, is one of our most important commercial fishes, yet little is known of its spawning activities. Shad spawn in the spring in tidal rivers and estuaries. Hildebrand and Schroeder (1927) state that spawning takes place soon after the fish reach fresh water. Smith (1907) maintains that shad prefer areas in rivers off the mouths of creeks, or in sounds off the mouths of rivers. Leim (1924) says that spawning in the Schubenacadie River, Nova Scotia, takes place above the tidal portion of the stream in completely fresh water. This study was undertaken to obtain more specific information on shad spawning in Virginia waters.

Sampling Methods

Shad eggs drifting free in the currents were collected in cone-shaped nets, each one meter in diameter at the mouth and three meters long. The netting was nylon marquisette having about twenty-five meshes to the inch. The nets were generally set in the current in pairs, one attached to an anchor at the bottom and one to a float at the surface (Figure 1). In this manner several pairs of nets could be set and retrieved at hourly intervals. All samples were preserved in five per cent formalin.

Eggs were collected for two successive years. During the spring of 1949 sampling was confined entirely to the tidal portion of the Pamunkey River (Figure 2). The field work was initiated on

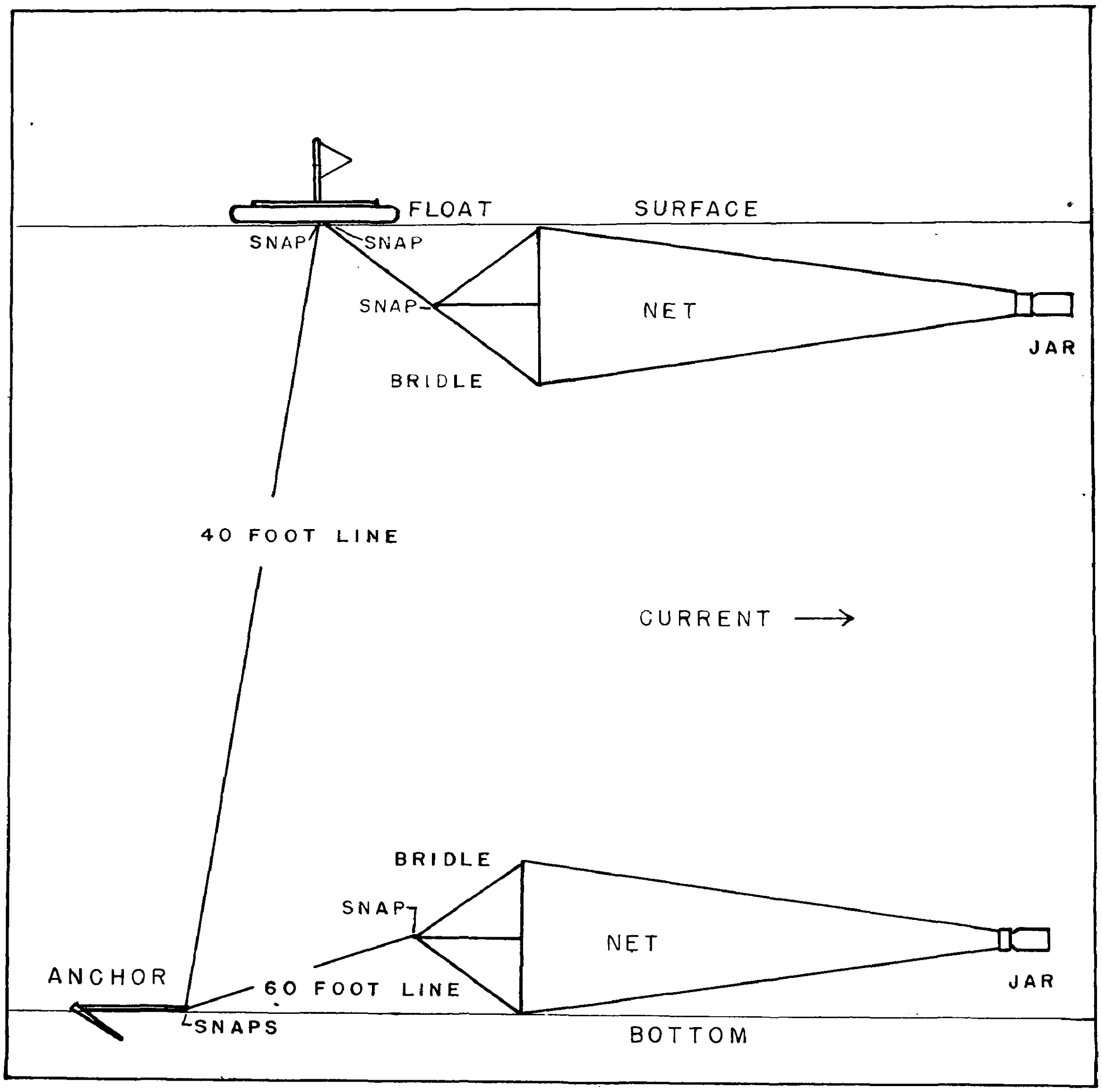

Figure 1. - Diagrammatic sketch of the manner in which plankton nets are set for the collection of shad eggs.

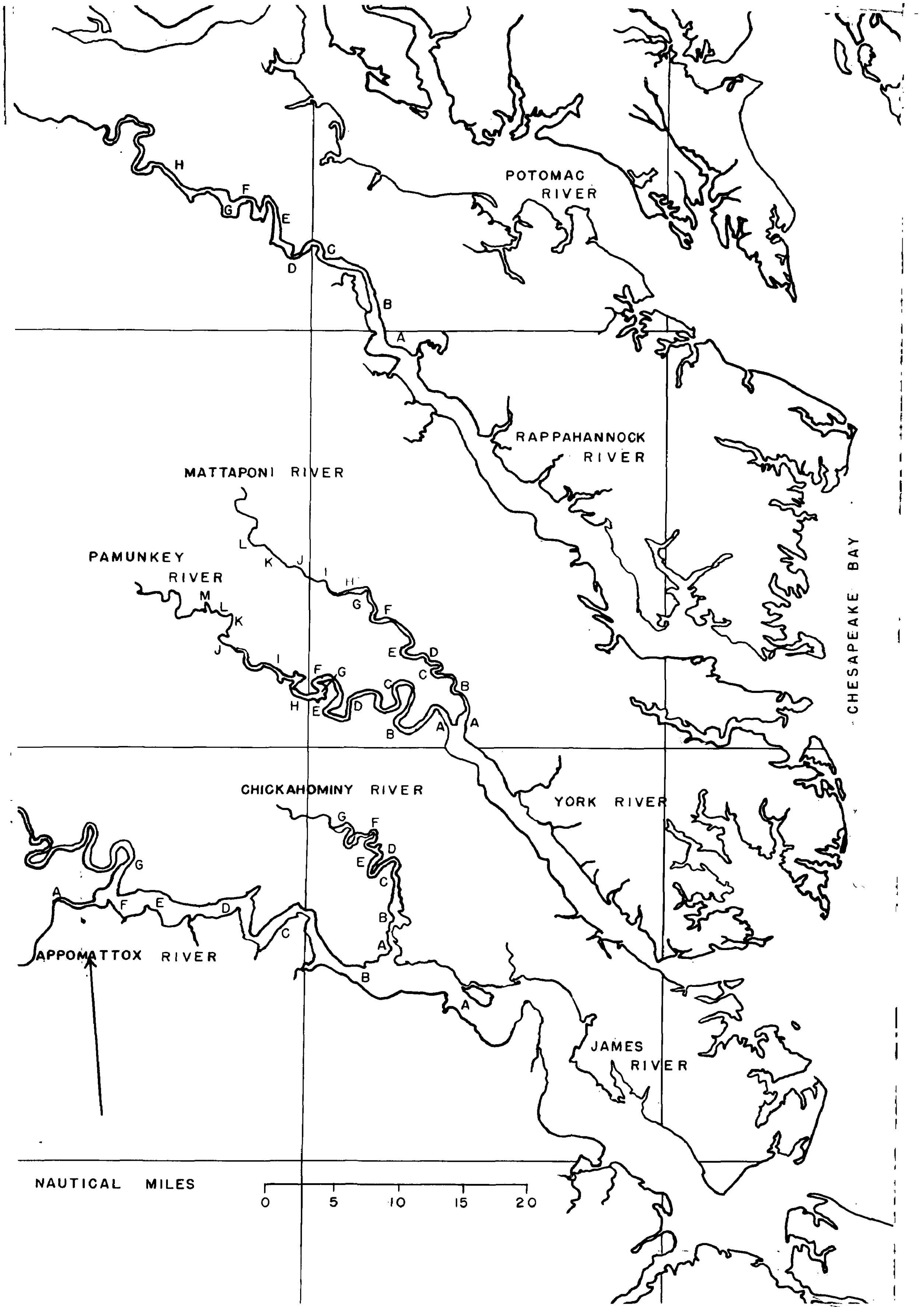

Figure 2. - Virginia rivers where shad spawning was studied. See Table 1 for the names of sampling localities indicated by letters on the map.

Table 1. - Key to the stations shown in Figure 2

Station	Rappahannock River	Mattaponi River	Pamunkey River	Chickahominy River	James River	Appomattox River
A	Mallory's Point	West Point	West Point	Barretts Point	Jamestown Is.	Point of Rocks
B	Island Point	Muddy Point	Lee Marsh	Nettles Creek	Dancing Point	
C	Layton Point	Chelsea	Devils Reach	Shipyard Ldg.	Dunmore	
D	Ketch Point	Boardley	Island Reach	Watts Point	Windmill Pt.	
E	Owl Hollow	Foxes	Cumberland Reach	Big Marsh Pt.	Jordon Pt.	
F	Wilmot	Courthouse Ldg.	Lester Manor	Lanexa	Hopewell	
G	Potobago Bay	Mattaponi	Lane Reach	Walkers Dam	Turkey Island	
H	Port Royal	Sandy Pt.	Rockahock			
I		Rickahock	Gregory's Bar			
J		Peavine Is.	Buckland Bar			
K		Line Tree Bar	Hogan Bar			
L		Pointer Landing	Spring Bar			
M			Bassetts Bar			

February 27 and collections were made at random until May 22.

In 1950, field work was started on April 1 and continued until the end of May. Samples were taken in the Pamunkey, Mattaponi, Chickahominy, James, Appomattox, and Rappahannock Rivers (Figure 2). Each river was sampled at intervals of from three to five miles [1], stations in the longer rivers were occupied at the greater intervals. Sampling stations extended from brackish water to near the head of tidewater in the Pamunkey, Mattaponi, and Chickahominy Rivers. On the other rivers it was necessary to discontinue sampling before reaching the head of tidewater in order to obtain coverage of more rivers during the spawning season. Stations occupied and their distances upstream from Chesapeake Bay are included in Table 2. More than 450 samples were collected from which 2,469 shad eggs were obtained. Measurements of water temperature, currents, salinity, turbidity, and oxygen supplemented most of the plankton collections.

Spawning Grounds

Spawning grounds were located primarily by observing the relative numbers of eggs collected in the nets. Shad spawning areas were also located by noting the incidence of "spawners", i.e. fish with running roe taken in commercial catches.

<u>Pamunkey River</u>.- As indicated in Table 3, shad eggs were most abundant in the area from Lester Manor to Gregory's Bar, a distance of seven miles. The few eggs collected upstream and downstream from

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[1] All mileages given are nautical miles.

Table 2. - Distances from Chesapeake Bay of stations occupied during shad investigations.

Miles from Chesapeake Bay	Pamunkey River		Mattaponi River		Chickahominy River		James River		Rappahannock River	
27-28		West Point		West Point						
29-30				Muddy Point						
31-32		Lee Marsh		Chelsea						
33-34	B		B	Boardley						
35-36								Jamestown		
37-38		Devil's Reach		Foxes						Tappahannock
39-40			F	Courthouse Ldg.			B			
41-42			SF	Mattaponi	B	Barrette Point		Dancing Point	B	Mallory's Point
43-44		Island Reach	SF			Nettles Creek				
45-46	SF	Cumberland Reach	SF	Sandy Point		Shipyard Ldg.				Island Point
47-48	SF		SF	Rickahock						
49-50	SF	Lester Manor	F	Peavine Island	SF	Watts Pt.		Dunmore		Layton Ldg.
51-52	SF		F		SF	Big Marsh Point				
53-54	SF	Rockahoch	F	Line Tree Bar	SF					Ketch Point
55-56	SF			Pointer Ldg.	SF	Lanexa	F	Windmill Point		
57-58	SF	Gregory's Bar			F		F			Owl Hollow
59-60					F	Walker's Dam	F			
61-62		Buckland Bar					EF	Jordon Point	F	Wilmot
63-64							F		EF	Portobago Bay
65-66		Spring Bar					F	Hopewell	F	
67-68		Bassett Bar					EF	Turkey Island	F	Port Royal

B. Approximate boundary between fresh and brackish water.
S. Area of shad spawning as interpreted in this paper.
F. Region of extensive flats.
E. Location where some spawning occurred.

Table 3. - Egg collections from the Pamunkey River in 1949 and 1950.

Station	No. One-Hour Samples /*	Total Eggs	Eggs Per Hour
West Point	4	0	0.00
Lee Marsh	12	0	0.00
Devil's Reach	28	2	0.07
Island Reach	52	5	0.10
Cumberland Reach	24	6	0.25
Lester Manor	52	123	2.37
Lane Reach	34	15	0.44
Lily Point Marsh	27	1	0.04
Rockahock Reach	75	1,515	20.20
Gregory's Bar	12	488	40.67
Buckland Bar	8	7	0.88
Hogan Bar	4	0	0.00
Oak Spring Bar	8	11	1.38
Bassett Bar	6	0	0.00
TOTAL	346	2,173	6.30

/* These are one-hour samples with nets of one-meter diameter anchored in the current, some being set at the bottom and some at the surface. Samples of greater or less duration, using other gear, or made by towing one-meter nets are not included.

these points indicate that spawnings of considerably less intensity may take place for at least seven miles in both directions of the major region. Eggs were found neither in the vicinity of brackish water nor from waters near the head of the tide.

Mattaponi River.- The Mattaponi River was sampled during the period of April 25 to 30, 1950. This was thought to be the height of the spawning season. Examination of more than one hundred samples indicated that eggs were most abundant at Mattaponi and Sandy Point (Table 4). No shad eggs were collected below Mattaponi; a few were taken upriver as far as Line Tree Bar, 10 miles above Sandy Point.

Chickahominy River.- The two shad eggs collected from the Chickahominy River were taken near Watts Point during the period May 5 to 8, 1950. Low current velocities prevented sampling farther upstream. Spawning shad, many of which are utilized by a hatchery in the Lanexa area, are found in commercial catches from Big Marsh Point upriver at least as far as Lanexa, suggesting that the major spawning effort takes place in this region.

A dam at Walkers, five miles above Lanexa, was completed during 1942. Although it was feared by many that the dam would interfere seriously with, if not eliminate, the Chickahominy shad run, this has not occurred. It appears that the major spawning area is well below the dam.

James River.- Two eggs were collected from the James River a few miles below Hopewell and one egg near Turkey Island Cutoff, a few miles above that city indicating that the Hopewell area is in the region of shad spawning. Sampling took place from May 9 to 10, 1950. Interviews

Table 4. - Egg collections from the Mattaponi River in 1950

Station	No. One-Hour Samples/*	Total Eggs	Eggs Per Hour
West Point	4	0	0.00
Muddy Point	8	0	0.00
Chelsea	5	0	0.00
Boardley	5	0	0.00
Clifton Landing	5	0	0.00
Foxes	11	0	0.00
Courthouse Landing	10	0	0.00
Mattaponi	16	204	12.76
Sandy Point	16	54	3.38
Rickahock	5	24	4.80
Peavine Island	4	0	0.00
Line Tree Bar	5	7	1.40
Pointer Landing	4	0	0.00
TOTAL	98	289	3.40

/* These are one-hour samples with nets of one-meter diameter anchored in the current, some being set at the bottom and some at the surface. Samples of greater or less duration, using other gear, or made by towing one-meter nets are not included.

with local fishermen failed to reveal information regarding the catch of spawners.

Appomattox River.- A few samples were taken in the Appomattox River on May 10 at Point of Rocks, five miles above Hopewell. These samples contained two shad eggs which probably drifted from the old Walthal Channel, a branch of the Appomattox in which shad are sometimes caught. The greater portion of the Appomattox between Hopewell and Petersburg, particularly in the vicinity of Petersburg, is heavily polluted with industrial and domestic wastes, and therefore this river is probably of little importance as a shad spawning region.

Rappahannock River.- Rappahannock River collections of 1950 contained no shad eggs. This river was visited rather late in the spring, from May 17 to 21, although well within the time and temperature range at which eggs were collected in the Pamunkey the preceding season. Large masses of filamentous algae clogged the nets and undoubtedly reduced their efficiency. A few clupeid larvae, some of which appear to be shad, were obtained in the Portobago Bay samples. Fishermen reported that spawning shad are often taken in that section of the river.[/2]

Spawning in Relation to Physical and Chemical Factors

Observations were made on certain physical and chemical factors that may influence shad spawning.

[/2] A survey conducted on the Rappahannock River in 1951 indicated that Portobago Bay was probably the most important shad spawning area in that river.

Water temperature.- Bigelow and Welsh (1924) assert that the temperature must be 10° to 13°C. before shad will enter a stream for spawning. It has been reported (Anon. 1946) that a temperature of 12°C. is necessary before spawning occurs.

In the Pamunkey River during 1949, the range of temperature through the sampling period was 6.4°C. to 21.9°C. (Table 5). A few eggs were collected at a water temperature of 9.2°C. but eggs were not taken in abundance until the temperature had reached 14.0°C. On the average, in those collections which contained eggs, less than one egg per hour was taken at water temperatures of 11.9°C. or below, about seven eggs per hour at temperatures from 12°C. to 17.9°C. and over 16 eggs per hour at temperatures of 18°C. and above. Temperature, therefore, appears to have a definite influence on the spawning activities of shad.

Temperature may govern the number of eggs present in the water at any one time not only by influencing the time of spawning but also by altering the rate of development. Ryder (1885) observed that hatching took place in 17 days at a temperature of 12.2°C., while at 23.3°C. only three days were required. Thus individual eggs would be present more than five times as long at the lower temperatures.

Turbidity.- Most Virginia tidewater rivers, especially in spring, are characterized by turbidities that are much greater than those in the waters of Chesapeake Bay. Generally, the higher turbidities were encountered in the regions of mixing of fresh river water with the saline water from the Bay (Figure 3). These areas are indicated in Table 1. Therefore, shad migrating to their spawning grounds must

Table 5. - Average surface water temperatures observed on successive sampling trips to the Pamunkey River in 1949

Sampling Dates	Average Water Temperature in Degrees Centigrade
February 26-27-28	9.3
March 4-5	6.4
March 12-13	7.4
March 20	7.0
March 26-27	15.1
March 31-April 1	15.9
April 8-9	13.5
April 16-17	14.5
May 1-2	18.0
May 10	21.9
May 21-22	21.6

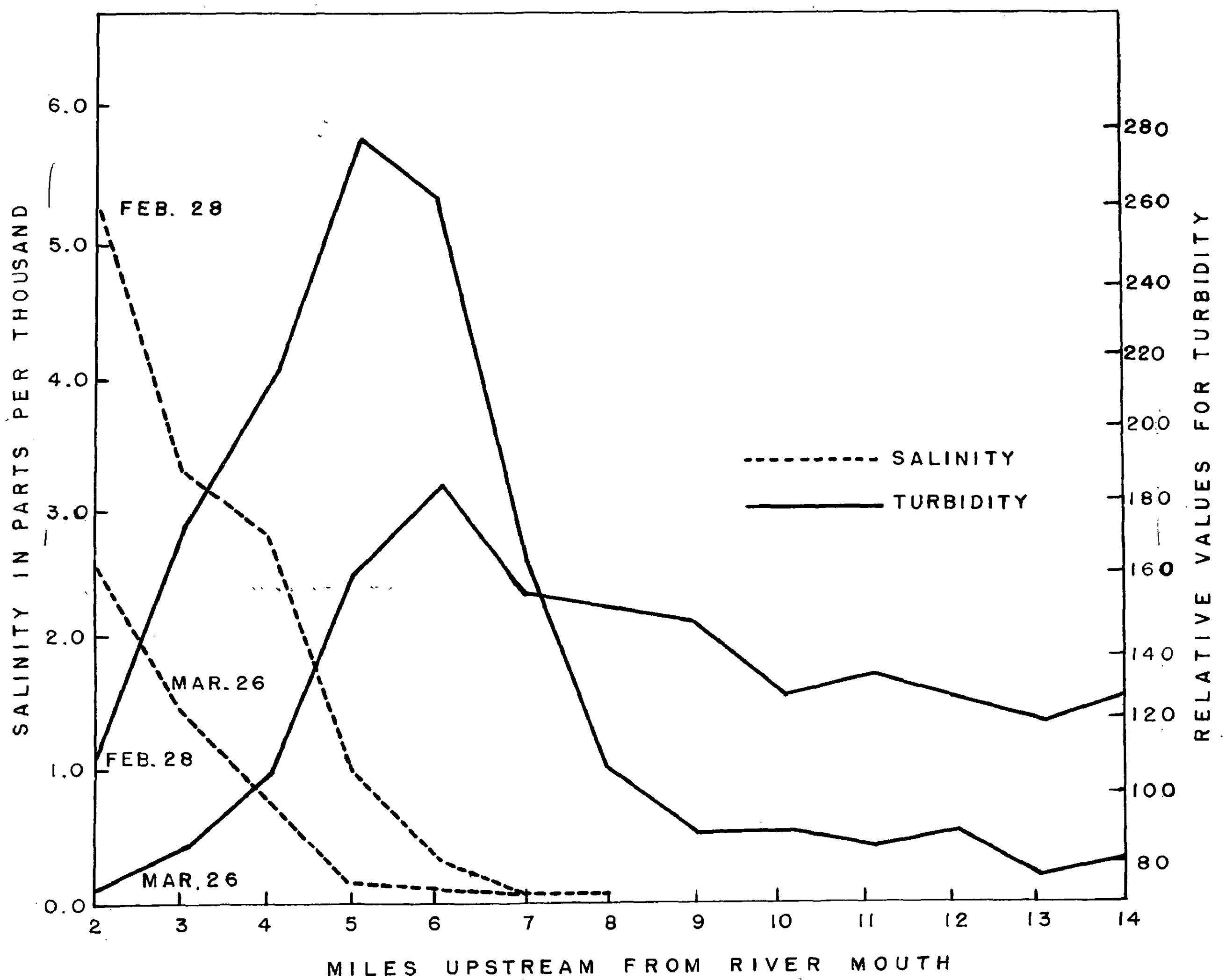

Figure 3. - Salinity and turbidity relationships on two cruises up the Pamunkey River in 1949. The samples were taken at approximately high tide. Turbidity values are in scale readings of a Klett-Summerson photoelectric colorimeter with a 40 millimeter cell and a K.S. 40 filter.

pass through these maximum turbidities. Although the Mattaponi and Chickahominy Rivers are clearer than the Pamunkey, James or Rappahannock there is no substantial evidence to indicate that the shad prefer the clearer waters.

Currents.- All shad spawning observed took place within the limits of tidal influence. Current velocities on the spawning areas varied from zero at slack water to slightly more than three feet per second. The tidal current transports drifting shad eggs upstream and downstream, the net effect being a slight downstream displacement related to river runoff.

Shad eggs are slightly heavier than water and are supported by the currents in two ways. Since water velocities near the surface are greater than those close to the bottom, the resultant force is directed upward. This force, except under conditions of very low velocity of flow, is sufficient to overcome the slight negative buoyancy of the eggs. In addition, numerous and variable eddies are present which tend to buoy up the eggs. It appears that currents may, by keeping the eggs in motion, prevent them from being covered by the silt and organic detritis prevalent in the rivers.

The number of eggs collected in each spawning area appeared to be directly related to the current. All collections, irrespective of the time and place of sampling, were grouped into three categories based upon surface current rates. On the average the following relationship was established: at currents of less than one foot per second, less than one egg per net hour; one to two feet per second, about ten eggs per net hour; two to three feet per second, over twenty eggs per net hour.

Bottom topography.- Based on its bottom topography, each river may be divided roughly into three rather homogenous sections. The lower part consists mostly of deep channels with few shoals and relatively steep banks. Further upriver, channels are present but much of the area consists of shallow flats, often only a few feet below the surface. Beyond this section the river is, for the most part, deeper with rather precipitous banks. The locations of these various sections are indicated in Table 1. Spawning shad apparently prefer river sections dominated by extensive flats.

Bigelow and Welsh (1924) stated that shad spawning occurs over the shallow flats, while Smith (1907) concluded that although most spawning activity takes place over the flats, it may occur anywhere in the rivers. In this study egg collections over the shallower flats yielded few eggs. Since currents at such points were often insufficient to extend the nets, towing was tried, but still no eggs were obtained. It seems probable that in still waters the eggs sink to the bottom and are therefore available to nets for only a short period. However, at depths of from 5 to 20 feet five times as many eggs were collected per hour as were taken in deeper waters.

Shad frequently spawn in channel areas near the flats as is evidenced by the collection of newly spawned eggs from such locations. It is not known whether the greater spawning effort takes place in the deeper water near the shallows or on the shallows themselves. Apparently two different habitats for developing eggs may be present, in one of which the eggs rest on the bottom in relatively still water, while in the other eggs are carried along in deeper water by tidal currents of varying duration and velocity.

The relationship between shad spawning and shallow areas may reveal that flats are more important as nursery areas for the young fish than as locations necessary for the act of spawning.

Although bottom samples contained about five times as many eggs per hour of sampling as did those taken from the surface, spawning probably occurs more generally near the surface, for a greater percentage of early stage eggs was taken in the surface samples (Table 6).

Salinity.- Salinity samples revealed that spawning invariably took place in fresh water[3]. The distances above brackish water of the major spawning areas varied from river to river (Table 1). The boundary of fresh and brackish water varies in a single river as pointed out by Galtsoff, Chipman, Engle, and Calderwood (1947). Although shad appear to spawn only in fresh water there is no evidence that the spawning arees are located at a fixed distance above brackish water.

Oxygen.- Young shad appear to be highly sensitive to oxygen deficiencies. Ellis, Westfall, Meyer, and Platner (1947) have shown that oxygen values of 5 p.p.m. may cause distress and some mortality

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[3] However, Leim (1924) showed experimentally that shad eggs hatched and larvae developed better in brackish water.

Table 6. - Percentages of some of the developmental stages of shad eggs found in surface and bottom samples from the Pamunkey River in 1949

Stage of Development	Percentage of Eggs in Surface Samples	Percentage of Eggs in Bottom Samples
One cell	40.15	29.70
Two cells to many cells	46.21	43.88
Blastula and Gastrula	8.34	18.81
Primitive streak to hatching	5.31	7.62

in shad while at values of 4 p.p.m. a high mortality may occur. During the period of sampling, bottom oxygen values were above 5 p.p.m. in all areas except in one part of the James River. Here the concentration of dissolved oxygen was 4.5 p.p.m. at four stations in a 20 mile stretch just below Hopewell.

Abundance and mortality.- It was difficult to evaluate such factors as currents, temperature and net clogging as influencing the abundance of shad eggs. Estimates of absolute abundance were not attempted for in no collections were eggs present in large numbers. An average of only 4.9 eggs per net-hour was collected in the Pamunkey and Mattaponi, the most productive rivers studied. However, much of the sampling was designed to delimit the spawning area and therefore many collections contained no eggs. The largest single-hour sample contained 155 eggs. By contrast more than one-half the samples secured by Leim (1924) on the Schubenacadie River contained over one hundred eggs, in many over one thousand were found, and the largest haul contained six thousand. These collections were made at night, and embraced the entire period of darkness. Furthermore, they were taken above tidal waters, with nets of unspecified size and mesh.

Almost two-thirds of the shad eggs collected in Virginia rivers were dead[4]. It would be hazardous to draw conclusions regarding absolute mortality from simple comparisons between live and

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[4] An egg was considered dead if the yolk had coagulated or had adhered to the vitelline membrane instead of drifting free within.

dead eggs. Sixty-six per cent of eggs taken in the Pamunkey River were dead as compared with 80 per cent from the Mattaponi. Live and dead eggs were almost equally distributed in surface and bottom samples.

Time of day.- Previous investigators have not been successful in collecting shad eggs during daylight hours. During the present study, eggs were collected with equal facility both day and night. For example: at Rockahock on the Pamunkey River on April 17, 1949, samples were taken between 7:00 p.m. and 12:00 midnight on an ebb tide using four one-meter nets. About fifty eggs per hour were collected. The following day approximately fifty eggs per net-hour were taken on the succeeding ebb tide from 8:00 a.m. to 1:00 p.m.

The approximate age of shad eggs may be estimated from their known rate of development at various water temperatures. A series of hatchery shad eggs preserved at known time intervals after spawning was obtained from James Sykes of the U. S. Fish and Wildlife Service. These eggs had been reared in water of 16° to 17°C., which is close to the average water temperature at the time that the present collections were made. The stages of development attained at various time intervals are summarized in Table 7.

Single samples or series of samples collected from the rivers did not contain sufficient numbers of live eggs to be of much value in age studies. Therefore, all the live eggs collected during the more intensive study of the Pamunkey in 1949 were grouped together and arranged into three series according to time of day, as follows:

Table 7. - The approximate stage of development of shad eggs obtained at various time intervals from a hatchery sample maintained at temperatures of 16° to 17°C.

Stage of Development	Designation	Age in Hours
One cell	I	2
Many cells	II	4
Blastula	III	6
Gastrula	IV	13
Primitive streak	V	20-1/2
Early embryo	VI	25-1/2
Embryo with tail attached to yolk	VII	38
Embryo with tail free from yolk	VIII	42
Hatching		96

6:00 a.m. to 12:00 noon, 12:00 noon to 6:00 p.m., and 6:00 p.m. to 12:00 midnight (little sampling had been done between midnight and dawn). Figure 4 shows that only a small percentage of the live eggs collected in the morning were in the one-celled stage or less than three or four hours old. In the afternoon 38 per cent of the eggs, and in the evening 35 per cent were in this stage of development. The proportions of eggs having from two to many cells (from four to six hours old) appeared to follow the same general pattern. This seems to indicate that spawning, in the Pamunkey River at least, although somewhat more intense in the period noon to midnight, takes place during all hours of the day and night.

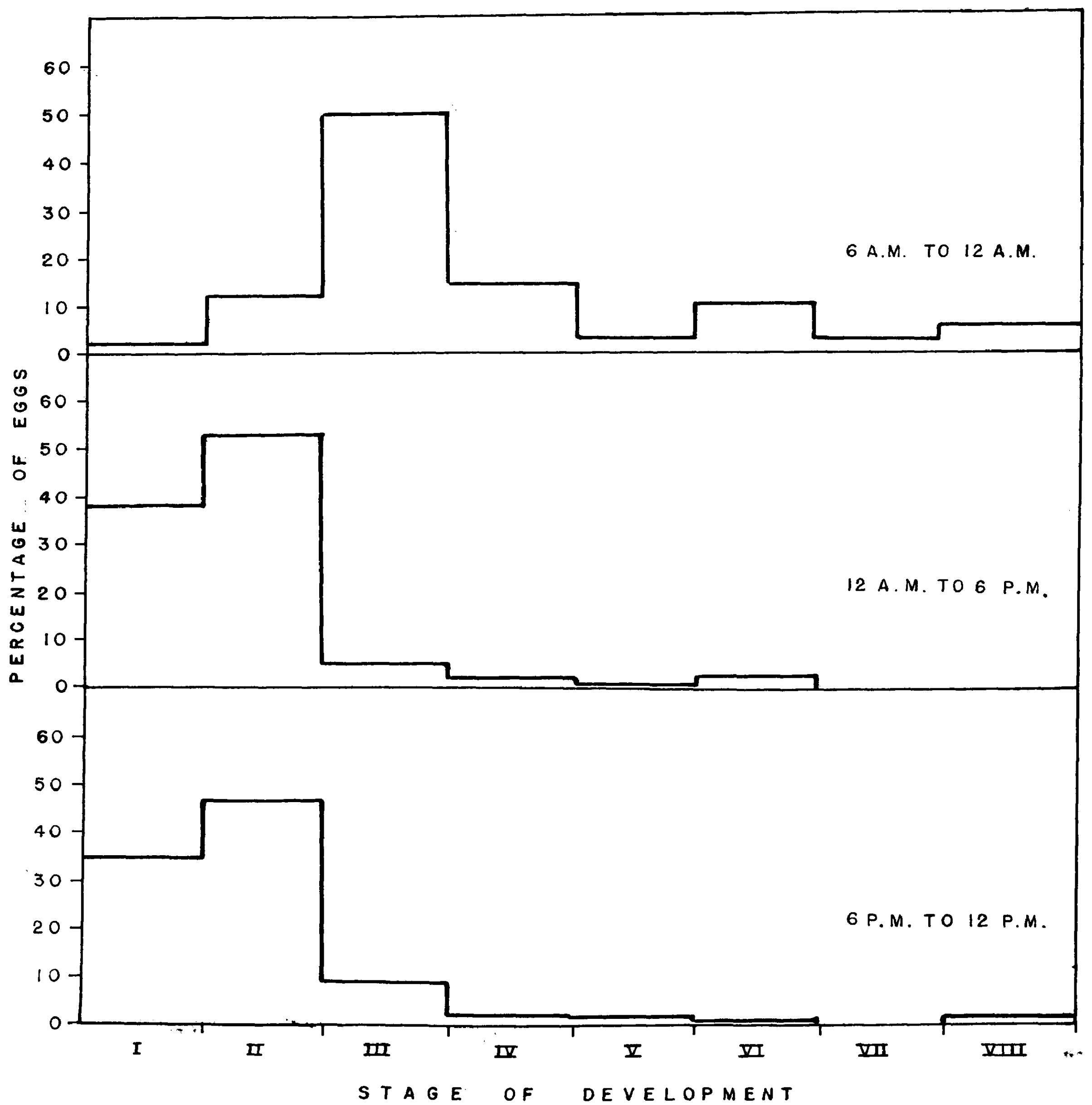

Figure 4. - The percentages of shad eggs of various stages of development in the catch during different periods of the day. Roman numerals refer to developmental stages listed in Table 6.

Summary

In 1949 and 1950 shad spawning was studied in six tidewater rivers. The major spawning areas were located in three of these, while on the others, areas where some spawning took place were located.

The spawning areas in each river were located in fresh water subject to tidal influence. A few shad eggs were collected at water temperature of 9.2°C. but more were taken after the temperature was 14.0°C. Eggs were still being taken at a temperature of 21.9°C. when sampling was discontinued. There appeared to be little evidence that turbidity was a factor in determining the spawning areas. Tidal current velocities of from zero to over three feet per second were observed on the spawning grounds. Bottom topography appeared to be an important factor in the location of spawning areas; those sections of rivers dominated by widespread flats were most extensively utilized.

Fewer than five shad eggs per net hour were collected from the most productive rivers; almost two-thirds of these were dead. On the Pamunkey River spawning took place during all hours of the day but was more intense in the period from noon to midnight.

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