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Assessment of larval striped bass, Morone saxatilis (Walbaum), stocks in Maryland and Virginia waters. Part II. Assessment of spawning activity in major Virginia rivers. Segment 2. Distribution and abundance of striped bass eggs and larvae in the James and Chickahominy Rivers, Virginia, during spring 1981 : draft final report

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FINAL REPORT

by

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Distribution and Abundance of Striped Bass Eggs and Larvae in the James and Chickahominy Rivers, Virginia, During Spring 1981

INTRODUCTION

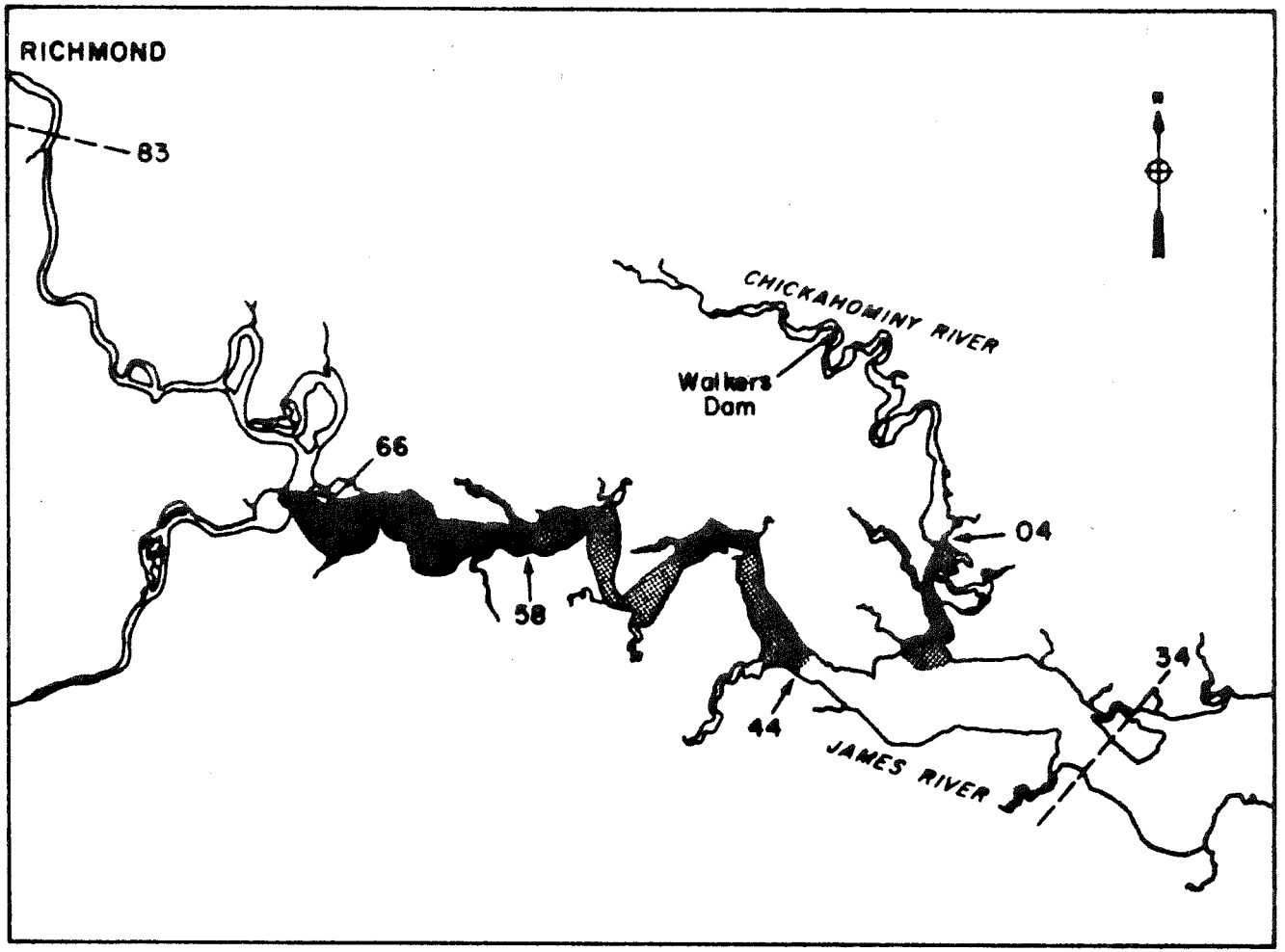
The James River is one of the most historically significant tributaries of the United States, serving as it did at the beginning of the seventeenth century as both site and sustenance of the English colony at Jamestown. Writings of these early colonists' provide a vivid presentation of both the abundance of James River fish at that time, and the colonists general ineptitude at catching them. The first known observation on anadromous movements of striped bass was that of Alexander Whitaker in 1613: "The sea-fish come into our rivers in March and continue the end of September. Great schools of herring come in first; shads of a great bigness and the rockfish follow them." (Wharton, 1957).

A slow adaptation to already successful Indian fishing methodology eventually developed into a long-standing and productive fishery for striped bass in the James River. This continued until the closure of fishing in 1975, necessitated by the introduction of Kepone into the river system below Hopewell. This pervasive and persistent insecticide, readily incorporated in the tissues of river fishes, has since prevented the marketing of James River

striped bass, frequently found with concentrations of Kepone above the maximum permissable level.

Documentation of the use of the James River as a spawning site for striped bass was provided by Tresselt (1952) in a limited survey of Virginia rivers during spring months of 1950. His single survey of the Chickahominy River from May 5-8, 1950, yielded only 3 eggs from 30 collections. In the James River proper, eggs were more frequent at stations extending from Jamestown Island to the Turkey Island Cutoff (Fig. 1), but were not found in abundance (57 eggs in 38 collections, May 9-10). Considering that Tresselt had earlier collected many thousands of eggs on April 30 in the Mattaponi River (York River system), it is likely that the later sampling of the James and Chickahominy rivers had missed peak spawning. Although subsequent trawling and seining surveys by the Virginia Institute of Marine Science have repeatedly demonstrated, through catches of juveniles and young-of-the-year striped bass, that spawning occurs each year in the James River, there has been no direct confirmation of Tresselt's (1952) observations on striped bass spawning. No direct observations on striped bass larvae in the James or Chickahominy rivers are available.

The present study was designed to document the distribution of striped bass eggs and larvae in the



1. James and Chickahominy rivers, showing geographical limits of surveying for striped bass eggs and larvae, 1981. River-miles at key points given in nautical miles from river mouth.

Chickahominy and James rivers during spring 1981, in continuance of similar surveys in the York River system in 1980 and in response to objectives of the Emergency Striped Bass Study (Chafee Amendment to the Anadromous Fish Act).

METHODS AND MATERIALS

Field Methods

The rivers under investigation were divided into 3-mile strata, from which stations were randomly selected prior to each sampling trip. Weekly surveys of the Chickahominy were begun on April 21, following an abbreviated preliminary sampling run on April 8, and on the James River on the 22nd of April. These were continued for nine weeks, until June 19, 1981. Six 3-mile segments of the Chickahominy River extended from its mouth to Walker Dam; these strata were sampled on eight surveys (not sampled during week of May 25, 1981). Sampled segments of the James River extended from river-mile 34 (34 miles above river mouth and off Jamestown Island) to river-mile 83, just below Richmond. Except for the lowermost two segments (river miles 33-38), which were vacated after the initital sampling date because of high salinities (see below), each of the segments was sampled from six to nine times during the nine weeks of observations (Tables 1 and 2; Fig. 1).

Regular collections at each station consisted of 2 to 16 minute stepped oblique (usually 2 min per 2-meter interval) tows of a 60-cm bongo sampler, equipped with 333 µm mesh nets. Both nets were metered with G-0 flowmeters for volumetric estimates (Tables 3 and 4) and catches were combined on board before preservation with 5-8%

buffered formalin. All collections were made in daylight hours.

Ancillary data at each station included surface and bottom measurements of temperature, salinity and dissolved oxygen. Maximum depth of visibility was determined by Secchi disc.

Laboratory Processing of Collections

Whole collections were sorted for Morone spp. eggs and larvae. Larvae of other species were identified (at least to family) and enumerated, after separation into vials by sorters. Morone saxatilis eggs were easily identified, using descriptions by Mansueti (1958) and Pearson (1938). We elected a conservative count in collections with damaged eggs, talleying only intact eggs and separated embryoes.

As reported in our first year's study of York River Morone (Grant and Olney, 1981), striped bass and white perch (Morone americana) larvae are easily separated only as yolk-sac larvae (Drewry and Mihursky, 1980) and after differential development of anal-fin spines. Larvae at intermediate sizes (8-13 mm) must be cleared and stained for positive identification (Fritzsche and Johnson, 1979, 1980). We have continued our search for osteological characters serving to separate larvae of these two closely-related species. In practice, we have cleared and stained all

collected larvae above yolk-sac size, and devoid of yolk material, so as to be positive of identifications. Specimens that are still questionable after this treatment are listed as Morone sp, rather than attempting to classify them any further.

RESULTS

Preliminary surveys, prior to funding authorization, were undertaken to assure that all sampling gear was in working order. An initial survey in the Pamunkey River, site of 1980 sampling, revealed no evidence of striped bass spawning on 26 March 1981. Temperatures were low (8-10°C) and salt water extended as far upriver as mile 45, an abnormal condition resulting from a persistent drought (1980-1981). A second abbreviated survey was conducted on 8 April in the Chickahominy River (4 stations). Temperatures were within the limits of expected striped bass spawning (16.0-17.8°C) and two of the four stations were above the limit of salt water at river mile 12, but no eggs or larvae were found.

Regular weekly surveys were begun on 21 April in the Chickahominy River and on the following day in the James River. Nine surveys of the James and eight of the Chickahominy were completed on 19 June 1981, resulting in a total of 172 collections. Exact locations of stations within river-mile strata, measurements of physical characterisitcs of sampled water and volumes of water sampled for each collection are provided in Tables 1 and 2.

Physical Characteristics of the Rivers

Temperature

Sampled temperatures ranged from 15.6 to 31.2°C in the James River and from 16.0 to 29.2°C in the Chickahominy. As evidenced from the 16°C temperatures observed in our preliminary 8 April survey of the Chickahominy, rapid warming did not occur until after the start of our regular sampling. Upper portions of the James River reached 20°C by the first week in May; all reaches of both rivers were above 25°C by the first week in June. Virginia river and Chesapeake Bay temperatures were exceptionally high in June and July, 1981.

Salinity

Saline water (using 0.5 °/oo as the upper limit for designation as fresh water) penetrated upriver to river-miles 42-44 in April and 41-50 in May in the James River, a reflection of the continuance of the 1980-1981 drought. Stream gauge readings in the James River at Cartersville (Virginia Climate Advisory) showed daily flows in the winter of 1981 as the lowest on record and 30% below readings for March 1931, the year of the worst drought on record. Some freshening of the James occurred in June when all of the sampled river above mile 39 or 40 was fresh, but this occurred well after the end of spawning (see below). A

similar pattern was evident in the Chickahominy River where fresh water extended to the river mouth only in June.

Dissolved Oxygen

Largely because of sampling only during daylight hours, dissolved oxygen levels were usually at or near saturation, varying mostly with temperature. Questionably high measurements were taken on the last sampling date in the James River; these are considered unreliable.

Water Transparency

Water in the Chickahominy River (Table 2) was relatively clear, with Secchi disc depths less than 0.5 m occurring only at its confluence with the James River. Secchi readings below 0.5 m were frequent in the James River below mile 69.

Egg Distribution and Abundance

One of the two deficiencies in sampling noted after 1980 York River sampling (Grant and Olney, 1981) was overcome in our 1981 sampling: the lowermost segments of the James River sampled were below the limits of striped bass spawning. However, as in 1980, regular sampling could not be started until after the onset of spawning; eggs were present on the first regular surveys (21-22 April 1981).

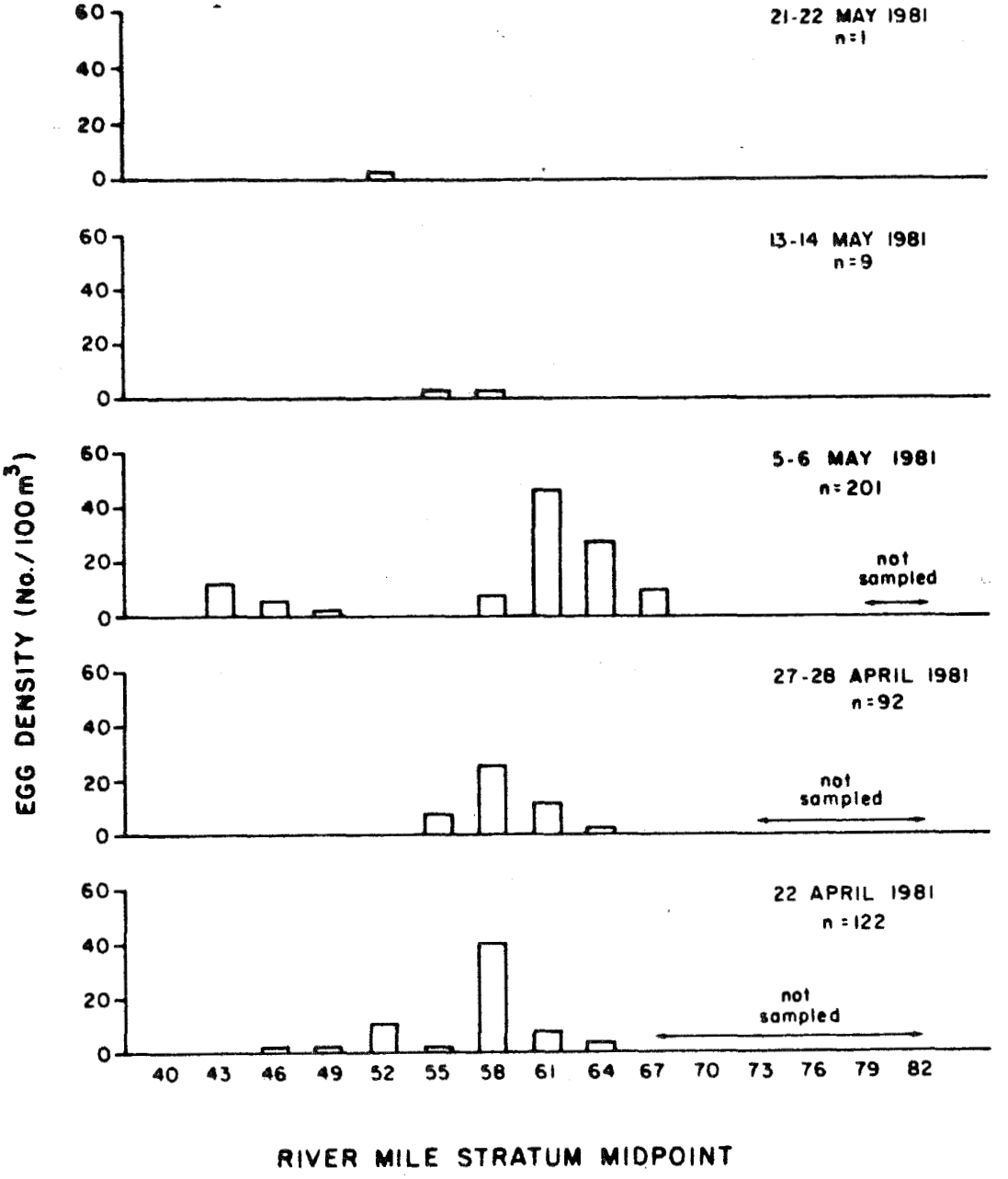
James River

Striped bass eggs occurred between river-miles 44 (Upper Chippokes Creek) and 66 (below Turkey Island Cutoff) (Figs. 1 and 2; Table 3) in the James River; over 80% of all eggs collected were found within the upper 9 miles of this section between river-miles 58 (Herring Creek) and 66 (blackened area of Fig. 1). Maximum observed densities of eggs (per 100 m^3) were 46 at river-mile 62 on May 5, 40 at mile 58 on April 22 and 28 at mile 65 on May 5. These maximum densities occurred in fresh waters and in temperatures from 16.8 to 20.2°C.

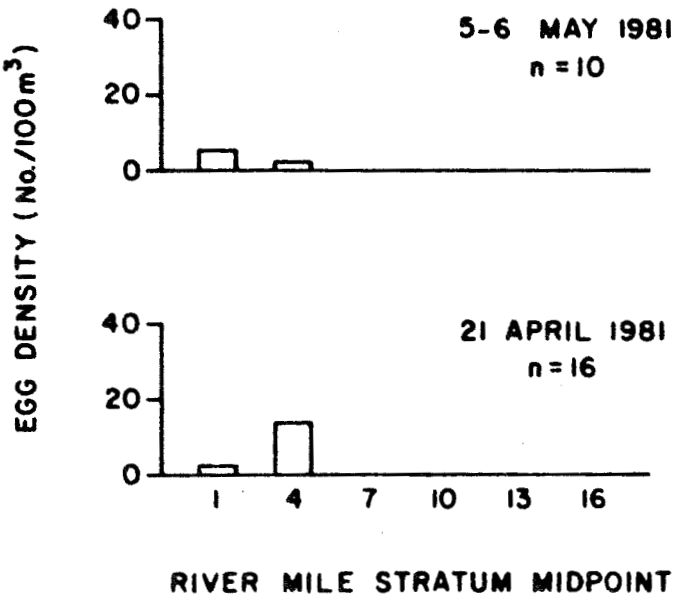
On the first two surveys in April, peak densities occurred at river-mile 58. On the next survey in the first week of May, the distribution was disjunct, with a minor peak at river-mile 44 and a major one at river-mile 62. The second survey in May produced only 12 eggs, six each at river-miles 55 and 59; a single egg was found at river-mile 51 in the third week of May. No eggs were found during the last four surveys. Thus, the spawning season appeared to be of brief duration in the James River, with spawning essentially ended after the first week of May.

Chickahominy River

Sampling for striped bass eggs in this major tributary to the James River was largely unsuccessful. Eggs were found (Table 4 and Fig. 3) in low numbers only at lowermost stations on April 21 and May 6. These dates coincided with



2. Distribution and abundance of striped bass eggs, James River, spring 1981.



3. Distribution and abundance of striped bass eggs, Chickahominy River, spring 1981.

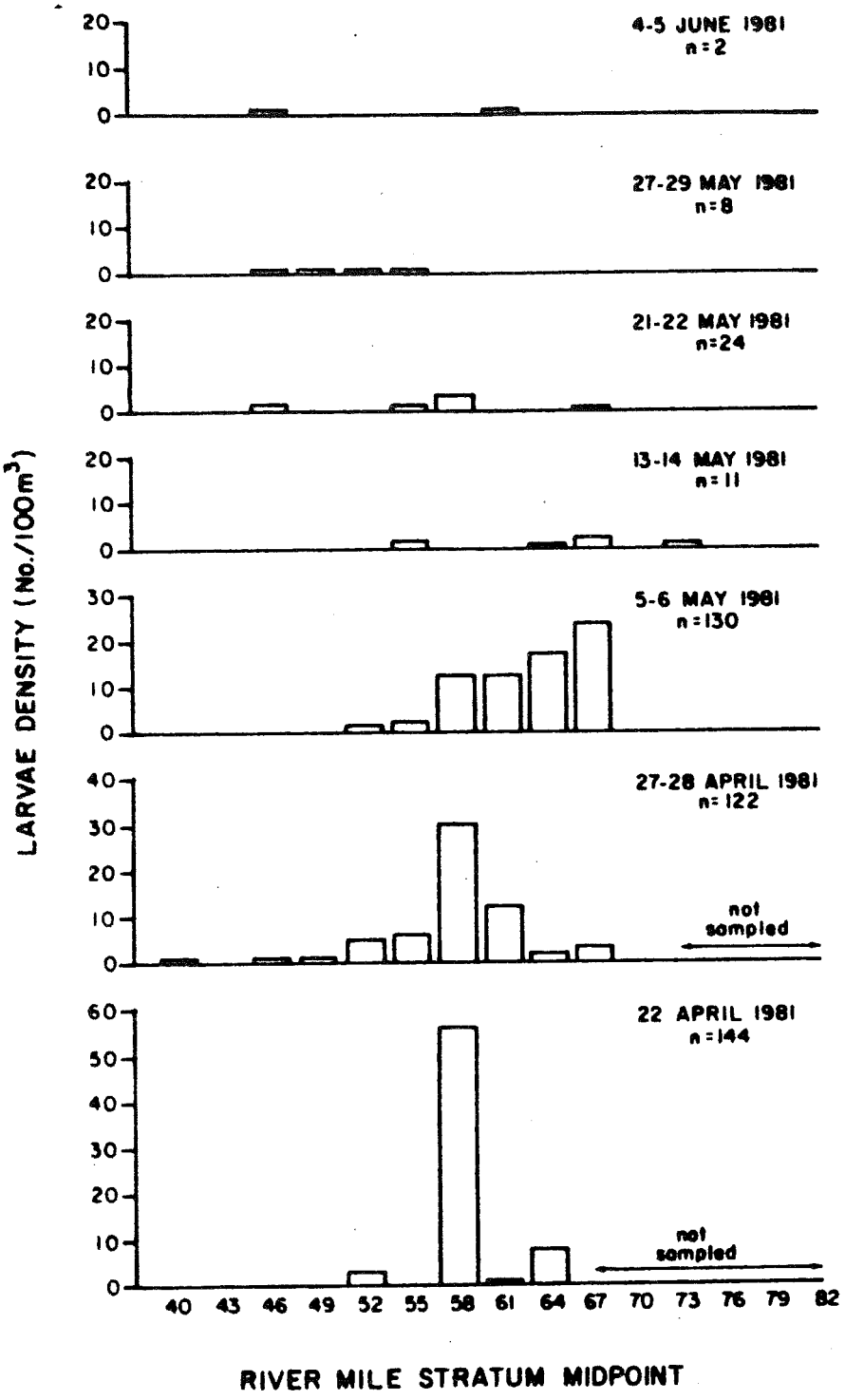
the furthest downstream occurrences of striped bass eggs in the James River proper and it is likely that the James River was the source of these eggs. The maximum observed density was only 13 per 100 m^3 at river-mile 6 (off Yarmouth Creek) on April 21.

Distribution and Abundance of Larvae

Larvae of striped bass, in addition to eggs, were present in our first survey of the James River on 22 April 1981. All of these, however, were yolk-sac larvae; no larger larvae were found. It is not likely that spawning had commenced much earlier than mid-April. Distribution and density of larvae in the James River are shown in Fig. 4 (see Table 3 for total numbers caught).

James River

Larvae collected on the initial survey of 22 April were distributed from river-mile 52 to the upper limit of sampling at river-mile 63. Subsequent surveys were extended further upriver. The peak density on 22 April was 55.5/100 m^3 at river-mile 58; this density was also the seasonal high for all collections. In the following week, a few larvae were distributed downriver to mile 40; the upriver limit was found at mile 66. Peak abundance on the second survey (April 27-28) remained at mile 58. In the first week of May, larvae were most abundant at their



4. Distribution and abundance of striped bass larvae, James River, spring 1981.

upriver limit at mile 66, with densities tailing off to mile 53. Densities decreased rapidly through May until May 27-29 when only a few larvae were found between river-miles 47 and 54. The last larvae were captured in the first week in June; none were found during the last two surveys.

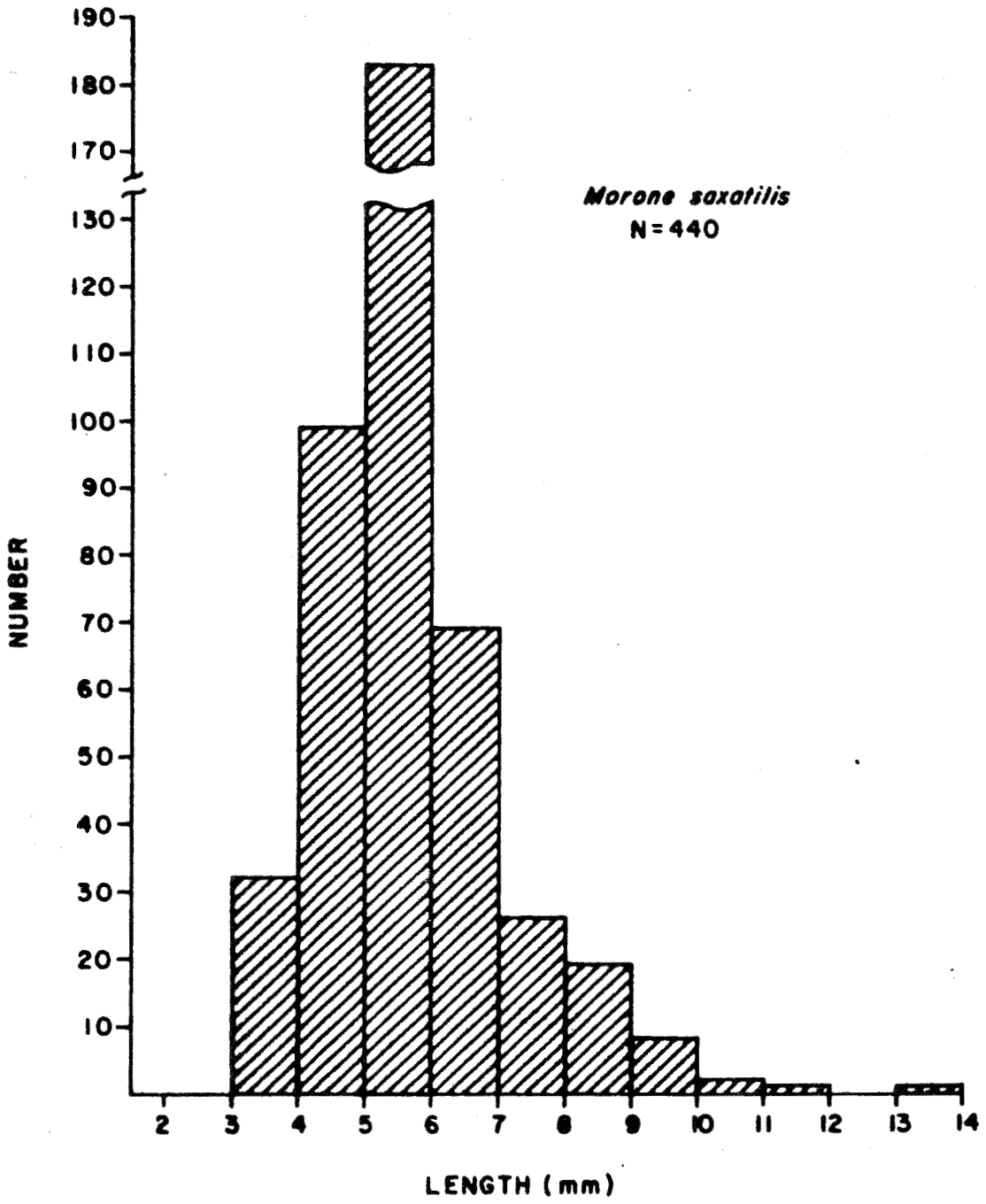
Chickahominy River

No striped bass larvae were collected in this tributary throughout the sampling period, further evidence that the river was not a site of spawning in 1981.

Size Distribution of Larvae

The length frequency of striped bass larvae within each week's survey (Table 5) shows a very gradual increase in average size. The model length during the first three weeks was 5.0-5.9 mm, the most common length of yolk-sac larvae. A few larvae 4.0-4.9 mm were hatched as late as May 21-22. Maximum size of larvae increased from 7.0-7.9 mm April 22 to 13.0-13.9 mm on June 4-5, the last survey in which striped bass larvae were found.

As shown in Fig. 5, overall size distribution of larvae in our collections from the James River was sharply peaked at 5-6 mm (yolk-sacs), with very few post-yolk-sac larvae represented. Only a dozen larvae larger than 9 mm were collected.



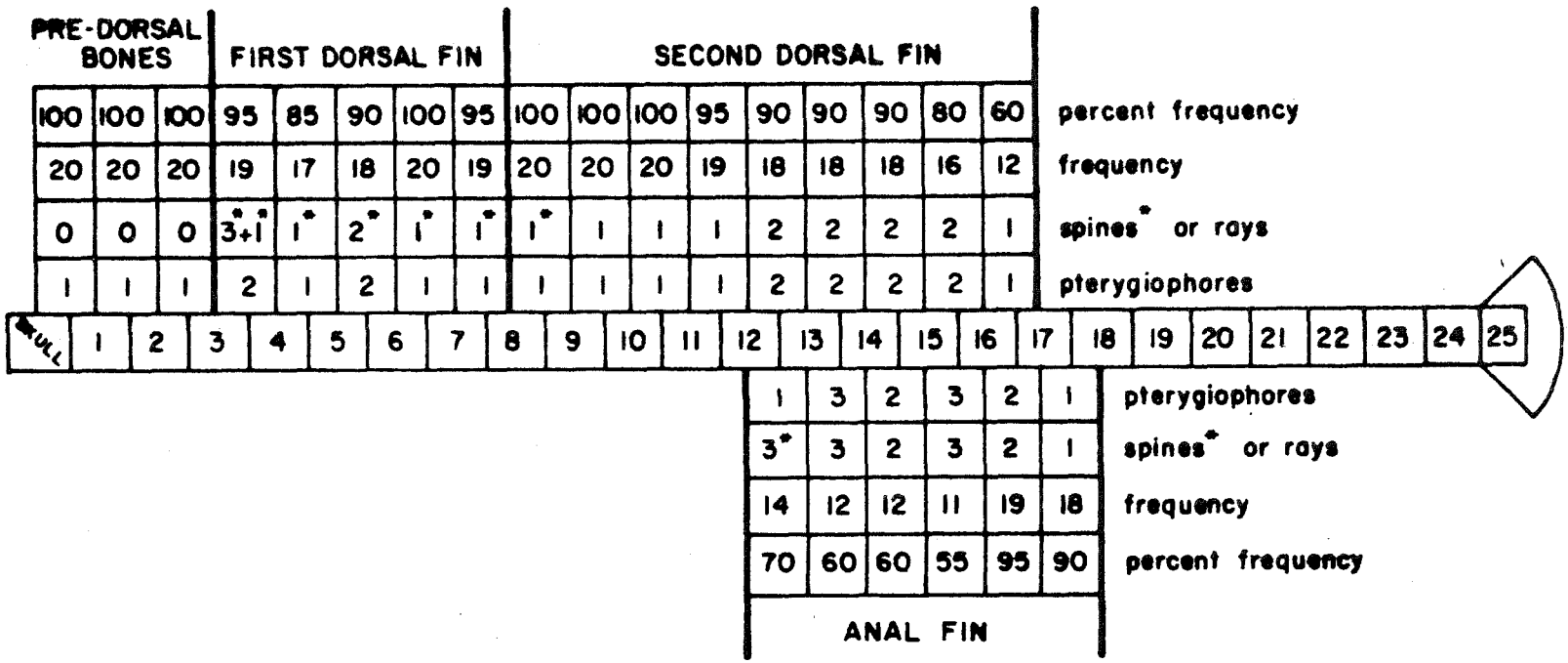
5. Length frequency of striped bass larvae collected from the James River, spring 1981.

Further Developments in the Use of Osteological Characters in Identification

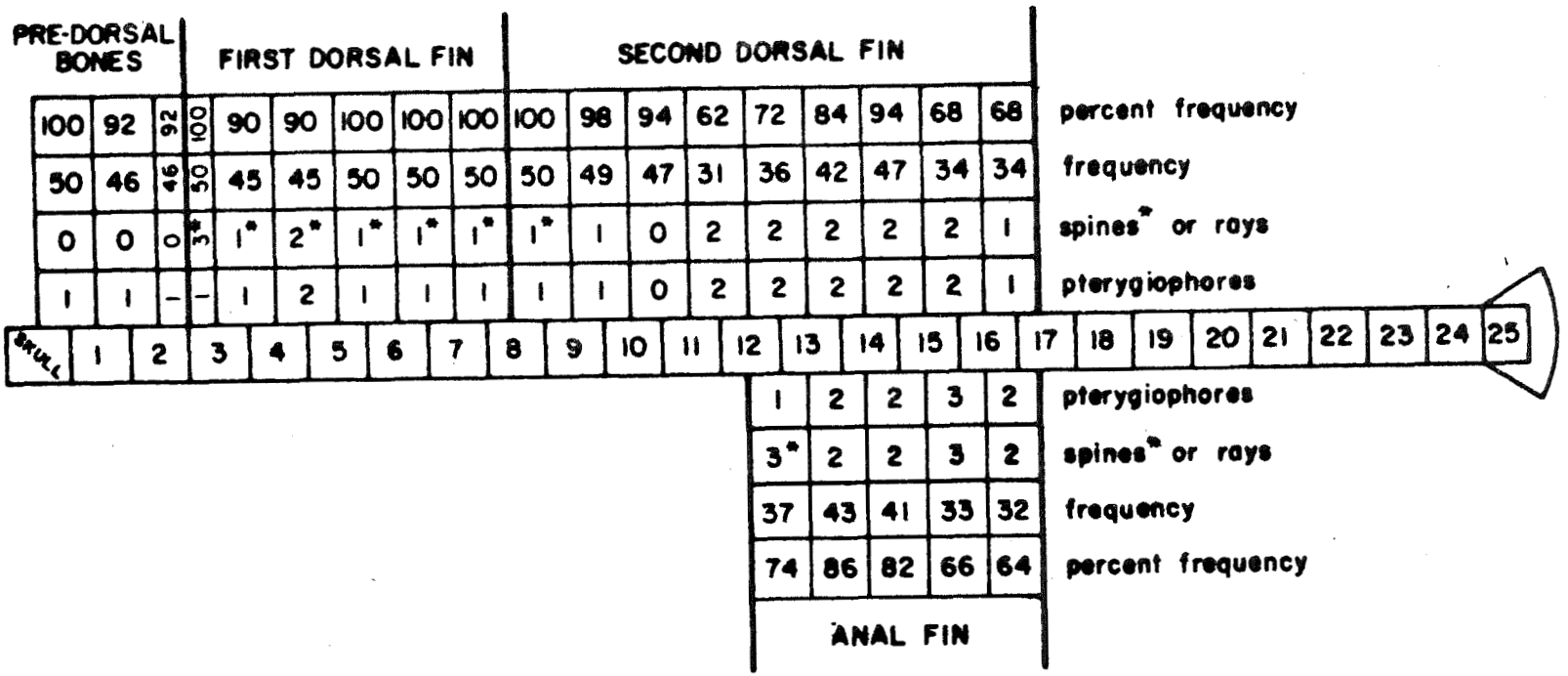
Although 1981 yielded few M. saxatilis larvae suitable for examination of osteological development, we have continued our search for internal characters useful in the separation of Morone spp. larvae through further examination of 1980 material. Our initial treatment of these specimens (Grant and Olney, 1981) confirmed (using wild material) the observations of Fritzsche and Johnson (1980) which were based primarily on cultured larvae. Fritzsche and Johnson (1980) relied primarily on the morphology and placement of rostral and predorsal cartilages and anterior anal and dorsal pterygiophores. With the exception of rostral cartilage, these features are characteristic of postflexion larvae in our material. As a result, we have had difficulty identifying flexion larvae lacking oil remnants between 7.0-9.0 mm NL/SL. Since pterygiophores of the soft dorsal and anal fins are first to develop, however, we have concentrated on characters associated with these fin supports in an effort to identify Morone larvae in earlier stages of development. Following the methods of Matsui (1967), Potthoff (1974) and Houde and Potthoff (1976), we have examined the pattern and number of pterygiophores associated with interneural and interhaemal spaces in fully developed larvae of both species. The diagrammatical technique (which we call a Potthoff diagram) allows a

quantification of inter-/intraspecific variability of key osteological characters. The results indicate several additional specific characters repeating in high percent frequencies which delimit larval Morone (in Virginia waters) at early developmental stages.

The most common arrangement of pterygiophores in relation to vertebrae in both Morone species is depicted in Figures 6 and 7. Analysis of variability in M. saxatilis (Fig. 6) is based on examination of 20 specimens ranging in size from 11.3-17.1 mm SL and 50 specimens (10.4-20.0 mm SL) in M. americana (Fig. 7). Blocks stacked perpendicular to the vertebral column represent interhemal or interneural spaces with the appropriate number of pterygiophores and spines/rays associated with these supporting bones indicated. Frequency and percent frequency indicate repeatibility in our sample. We considered percent frequencies greater than 85% to represent reliable traits. As reported by Fritzsche and Johnson (1980), the placement of the posterior predorsal cartilage and the first pterygiophore of the dorsal fin relative to the neural spine of the third vertebra reliably separates all Morone larvae in our sample. In addition, differential placement of pterygiophores and associated spines/rays in the interneural spaces of vertebrae 3-4, 4-5, 5-6 and 10-11 represent reliable traits.



6. The most common arrangement of pterygiophores, spines and rays in relation to vertebrae for 20 Morone saxatilis larvae.

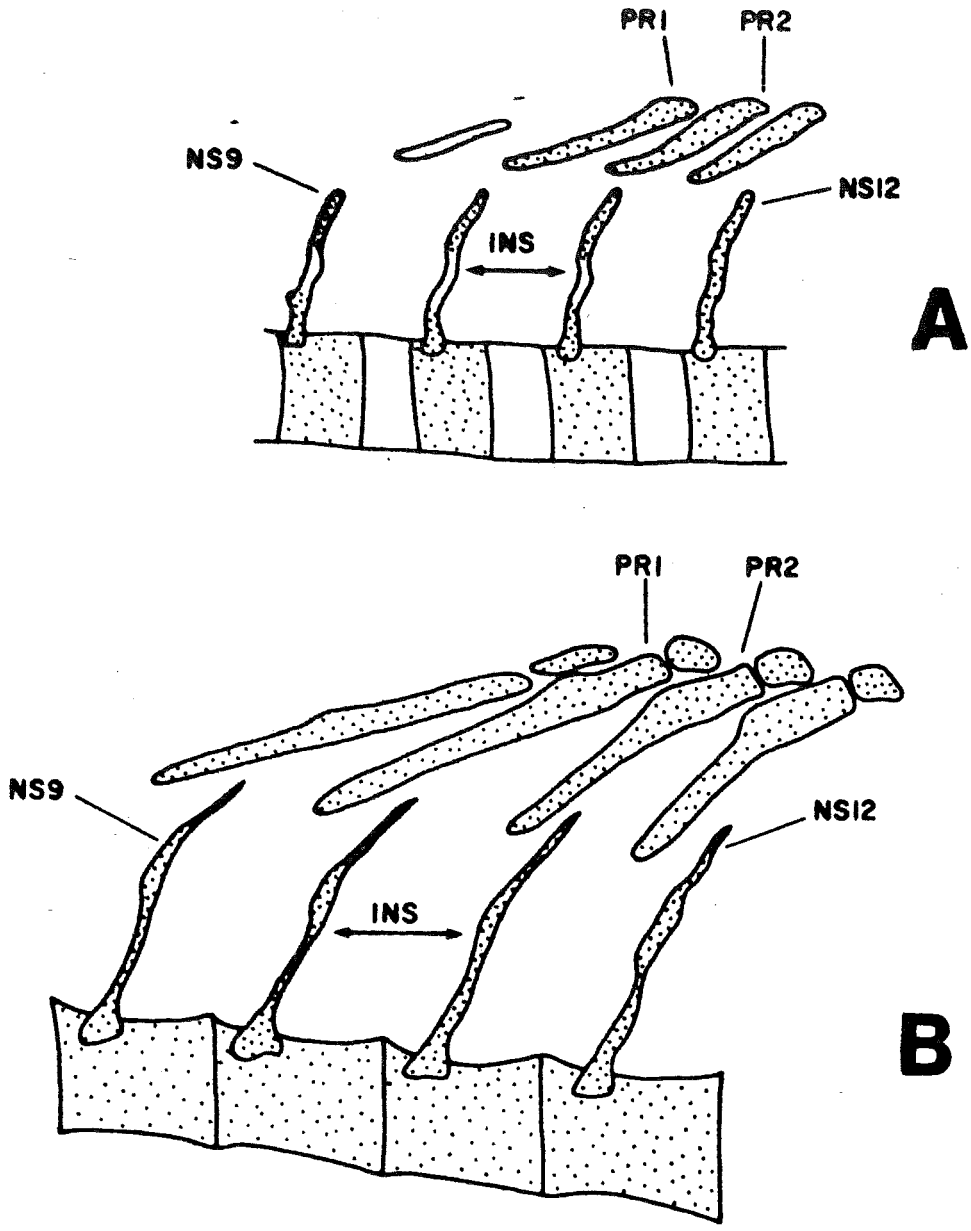


7. The most common arrangement of pterygiophores, spines and rays in relation to vertebrae for 50 Morone americana larvae.

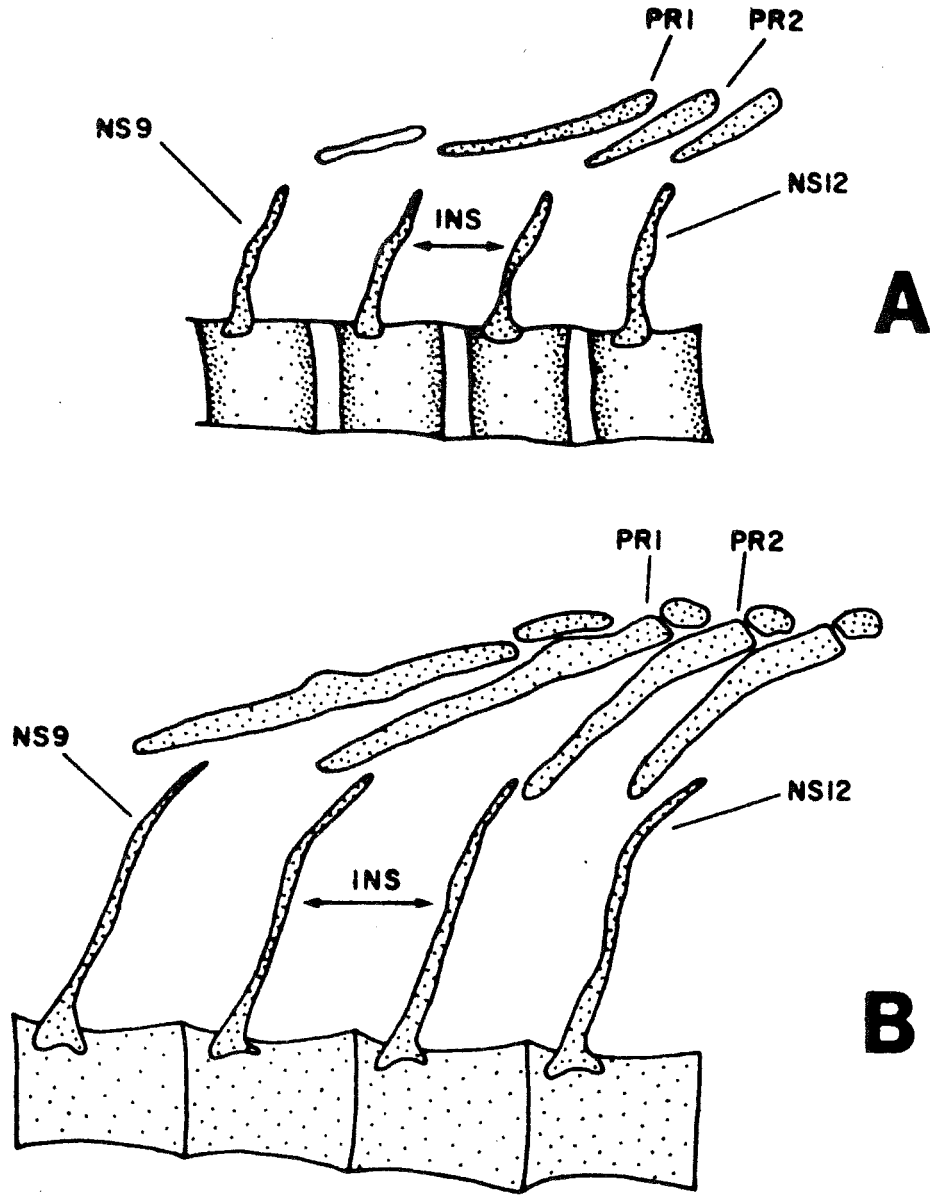
The absence of a single pterygiophore within the interneural space of vertebrae 10 and 11 in white perch and its presence in striped bass is considered a diagnostic character useful at small sizes. The arrangement of these bones is depicted in Figures 8 and 9. Although incompletely developed, M. saxatilis flexion larvae 8.5/9.0 mm SL/NL (Fig. 7) and smaller are recognizable since the ventral tip of the proximal radial (PR2) supporting the second soft ray lies anterior to the vertical plane extended from the tip of the eleventh neural spine (NS11). In addition, the distance between the ventral tips of PR1 and PR2 is greater than the distance between the tips of NS10 and NS11 in M. americana and less than that distance in M. saxatilis.

Analysis of the most common arrangement of pterygiophores and spines/rays of the anal fin relative to vertebrae (Figs. 6 and 7) revealed few reliable traits useful in small larvae. However, our data indicate that the anal fin formula 3/1+1+1/1+1 commonly found in flexion M. saxatilis was absent in 98% of M. americana larvae examined. This character, used in conjunction with others previously discussed, allows reliable species separation in our material.

In addition to interspecific variability of these key characters, we have examined the extent of morphological variation between populations of M. saxatilis larvae in the



8. The arrangement of neural spines and dorsal pterygiophores in Morone saxatilis. A. 8.5 mm SL. B. 11.1 mm SL. Abbreviations used are: INS - interneural space; NS9 - ninth neural spine; NS12 - twelfth neural spine; PR1 - proximal radial supporting the first soft ray of the second dorsal fin; PR12 - proximal radial supporting the second soft ray of the second dorsal fin. Stippling indicates positive Alcian blue stain reaction.



9. The arrangement of neural spines and dorsal pterygiophores of Morone americana. A. 8.5 mm SL. B. 11.2 mm SL. Abbreviations used listed in Figure 8. Stippling indicates positive Alcian blue stain reaction.

York and Potomac rivers. Preliminary data indicate that differential placement and numbers of fin supports in interneural spaces of vertebrae 4-6 reliably separate larvae of these two populations at high percent frequencies (85-90%). As more material becomes available, we will pursue this line of research by attempting to isolate sources of error in our analysis. The successful completion of this work may rely on future availability of funds. The possiblilty, however, that this may represent larval evidence of genetic differences at population levels, genetic homogeneity by river system and population tags for fisheries application is intriguing.

DISCUSSION

Egg Distribution and Abundance

Tresselt (1952) sampled the James and Chickahominy rivers for striped bass eggs from May 4 through May 10, 1950. This brief survey, successful only in collection of 57 eggs from the James and 3 eggs from the Chickahominy, provides the only records for comparison with the present survey. Tresselt found eggs distributed in the James River from Jamestown Island to Turkey Island Cutoff (approximately our mile 66), i.e. a distribution of eggs similar to our findings. Temperatures at positive sites of collection ranged from 19.0 to 21.1°C, which is somewhat above the temperature range of maximum spawning. This fact, together with the much better success in collecting eggs from the Pamunkey and Mattaponi rivers earlier in spring, 1950, suggests that peak spawning was missed by Tresselt in his James River survey. Comparison of density estimates from his survey of 1950 with ours in 1981 is, therefore, not reasonable.

Tresselt's (1952) records of a few eggs in the Chickahominy River do not confirm the use of that tributary as a spawning site. Although one or two eggs were found further upstream than ours, eggs were coincidentally occurring in the James River at the Chickahominy's mouth. Our conjecture that the source of Chickahominy striped bass

eggs was the James River channel could be applied to his data, as well.

Maximum densities of eggs observed in the James River of 46/100 m^3 were less than half the maximum recorded the previous year (1980) in the York River system (Grant and Olney, 1981).

Distribution and Abundance of Larvae

Larvae of striped bass were absent from our collections in the Chickahominy River, strengthening evidence from egg distribution analysis that suggests non-utilization of that tributary as a spawning site by striped bass. In the James River, larvae were predominantly yolk-sac larvae and found in maximum densities similar to those of eggs. This suggests that survival through hatching was good. However, a general lack of larger, developing larvae in collections (only twelve larvae 9 mm and larger were found) is suggestive of high mortality following yolk absorption. Following termination of spawning near early May, density of larvae decreased rapidly until the last occurrence in the first week of June.

Although maximum density of yolk-sac larvae found in the James River was approximately three times that from the York River in 1980 (55 vs. 18/100 m^3), the number of larger larvae was proportionally much smaller and they occurred for

a shorter period of time. Whether this stems from a higher mortality in the James in 1981 or from differences in growth rate or behavior between populations is unknown.

Identification of Larvae

In our previous report (Grant and Olney, 1981), we reported on our field confirmation of Fritzsche and Johnson's (1980) study of osteological development in Morone larvae and its utility in separation of striped bass larvae. We have continued our use of the clearing and staining method for identification of post-yolk-sac Morone larvae and a search for additional characters useful in positive identification. We now feel confident in identification of all larvae having developed sufficiently to possess a partially complete and stainable set of cartilaginous bones (as well as yolk-sac larvae which have been fairly easily separable). The gap in the size distribution for which distinguishing characters are known (for separation of M. saxatilis and M. americana larvae) has been narrowed considerably with the discovery of certain characters not fully treated by Fritzsche and Johnson (1980). Of particular utilization in this separation of species is the absence of one pterygiophore within the interneural space of vertebrae 10 and 11 in white perch and its presence in striped bass. Coupled with differences in anal fin formulae and configuration and placement of dorsal pterygiophores and

rays, larvae down to a size approaching those with yolk material remaining (striped bass) are now confidently identified.

An unexpected development in this study that will have far-reaching implications if confirmed with further work was the discovery of osteological differences between striped bass larvae from the Potomac and York rivers. This promising avenue of investigation needs further support.

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Table 1. Physical data and water volumes filtered (m^3) from striped bass egg and larval survey of the James River, Spring 1981. Mean temperature (^oC), salinities ($^o/oo$), and dissolved oxygen concentrations (mg/l) are presented. Secchi disc depth in meters.

River Mile Stratum		Date 4/22	4/27	5/5-6	5/13-14	5/21-22	5/27,29	6/4-5	6/10,12	6/18-19
33-35	River Mile	34	--	--	--	--	--	--	--	--
	Temp	16.0								
	Sal	2.78								
	DO_2	9.1								
	Secchi	--								
	Volume (m^3)	250.95								
36-38	River Mile	38	--	--	--	--	--	--	--	--
	Temp	16.1								
	Sal	0.93								
	DO_2	9.4								
	Secchi	0.4								
	Volume (m^3)	62.96								
39-41	River Mile	39	40	40	39	41	--	39	40	40
	Temp	16.0	17.5	17.8	19.5	18.5		25.2	26.8	28.5
	Sal	1.22	0.85	2.23	2.62	0.47		0.42	0.08	0.14
	DO_2	9.1	8.6	7.9	7.8	6.6		6.6	6.2	6.1
	Secchi	0.2	0.3	0.5	0.5	0.4		0.3	0.5	0.3
	Volume (m^3)	196.44	116.91	177.51	216.43	128.25		167.31	179.07	166.43
42-44	River Mile	42	44	44	44	43	--	43	43	43
	Temp	16.6	18.0	18.0	19.6	18.5		25.4	26.5	28.8
	Sal	0.47	0.38	0.95	0.46	0.29		0.09	0.06	0.06
	DO_2	9.0	9.5	7.5	7.0	6.1		5.0	6.0	5.5
	Secchi	0.4	0.4	0.4	0.4	0.4		0.4	0.4	0.4
	Volume (m^3)	178.38	151.31	227.96	178.71	228.06		229.15	224.26	290.82
45-47	River Mile	46	47	46	45	45	47	47	46	45
	Temp	16.7	17.8	17.8	19.3	19.5	21.9	25.4	26.0	28.3
	Sal	0.24	0.16	0.63	0.36	0.27	0.11	0.11	0.06	0.06
	DO_2	9.4	7.8	7.2	7.0	5.9	6.5	4.8	5.4	4.8
	Secchi	0.5	0.6	0.4	0.4	0.4	0.4	0.5	0.6	0.5
	Volume (m^3)	182.46	234.41	231.42	157.75	135.76	595.25	236.01	156.47	289.61
48-50	River Mile	49	48	50	48	50	48	50	48	48
	Temp	15.6	17.6	18.5	19.7	19.0	22.0	25.8	27.0	28.2
	Sal	0.11	0.16	0.23	0.19	0.11	0.10	0.15	0.26	0.05
	DO_2	9.1	7.7	6.7	6.5	5.3	6.0	4.8	5.8	4.4
	Secchi	0.6	0.5	0.4	0.4	0.45	0.4	--	0.6	--
	Volume (m_3)	157.19	224.73	183.48	159.84	187.08	483.52	217.38	170.88	154.78

Table 1. (Continued)

River Mile Stratum		Date 4/22	4/27	5/5-6	5/13-14	5/21-22	5/27,29	6/4-5	6/10,12	6/18-19
51-53	River Mile	52	52	53	51	51	51	53	52	51
	Temp	16.9	17.9	18.3	19.5	19.1	22.0	25.8	27.0	28.5
	Sal	0.22	0.11	0.12	0.11	0.10	0.10	0.09	0.05	0.05
	DO_2	9.6	7.8	5.8	6.4	5.4	6.2	5.9	5.5	3.7**
	Secchi	0.5	--	0.5	0.45	0.4	0.5	0.5	0.75	0.7
	Volume (m^3)	103.91	175.61	290.85	122.89	250.58	538.31	197.92	168.85	185.82
54-56	River Mile	56	55	56	55	56	54	56	54	54
	Temp	17.0	18.2	18.7	19.6	18.9	21.8	25.2	26.9	29.0
	Sal	0.20	0.10	0.11	0.25	0.11	0.08	0.12	0.15	0.07
	DO_2	10.6	11.7	6.5	6.6	7.5	6.2	6.5	6.8	4.0**
	Secchi	0.4	0.6	0.3	0.35	0.3	1.1	0.5	0.7	0.7
	Volume (m^3)	116.84	233.03	279.20	244.09	228.40	754.40	135.66	200.40	295.60
57-59	River Mile	58	58	59	59	57	59	59	59	58
	Temp	16.8	18.4	18.8	20.4	19.0	23.0	25.3	27.4	28.8
	Sal	0.10	0.08	0.09	0.12	0.09	0.08	0.08	0.04	0.05
	DO_2	10.3	11.0	6.9	8.0	7.4	7.6	7.0	8.4	5.0**
	Secchi	0.4	0.4	0.4	0.3	0.35	0.5	0.5	0.35	0.5
	Volume (m^3)	218.09	189.52	160.61	196.64	322.60	432.41	197.40	168.82	174.41
60-62	River Mile	62	60	62	61	62	62	61	60	60
	Temp	18.7	18.0	19.5	20.0	19.2	23.0	25.1	26.6	29.0
	Sal	0.10	0.08	0.16	0.11	0.08	0.08	0.22	0.06	0.19
	DO_2	13.4	9.9	8.0	7.2	9.2	7.1	7.1	8.1	10.1
	Secchi	0.3	0.4	0.4	0.4	0.3	0.5	0.5	0.5	0.5
	Volume (m^3)	137.35	245.09	177.49	116.91	489.00	419.13	197.68	249.06	209.66
63-65	River Mile	63	64	65	63	63	63	63	64	64
	Temp	17.5	18.4	19.6	20.0	19.2	23.0	24.8	26.3	29.0
	Sal	0.19	0.07	0.17	0.09	0.07	0.10	0.08	0.15	0.06
	DO_2	--	8.5	7.5	7.0	8.9	7.4	7.4	8.2	6.7
	Secchi	0.3	0.4	0.3	0.3	--	0.5	0.4	0.4	0.6
	Volume (m^3)	230.46	174.86	166.89	172.25	589.46	618.15	222.69	271.17	140.54
66-68	River Mile	--	66	66	67	67	68	66	67	66
	Temp		18.7	19.8	19.8	20.0	23.0*	25.1	26.0	29.8
	Sal		0.07	0.73	0.18	0.07	0.09*	0.04	0.05	0.05
	DO_2		9.1	7.9	6.5	7.6	--	7.1	8.6	10.9
	Secchi		0.45	--	0.4	0.4	0.6	0.6	0.5	0.7
	Volume (m^3)		114.92	203.13	183.38	489.26	307.72	387.80	201.03	169.75

Table 1. (Continued)

River Mile Stratum		4/22	4/27	5/5-6	5/13-14	5/21-22	5/27,29	6/4-5	6/10,12	6/18-19
69-71	River Mile	--	70	71	69	70	71	71	70	70
	Temp		19.2	21.0	20.2	19.2	23.8*	24.8	26.0	30.2
	Sal		0.09	0.10	0.09	0.08	0.11*	0.04	0.05	0.05
	DO_2		8.6	8.3	6.6	7.4	--	7.7	8.4	11.3
	Secchi		--	0.9	0.5	0.5	0.8	0.6	0.6	0.7
	Volume (m^3)		210.28	251.41	218.87	509.29	224.65	346.32	192.99	196.01
72-74	River Mile	--	--	73	72	74	72	72	72	72
	Temp			20.0	20.0	17.5	23.1*	24.2	24.5	31.2
	Sal			0.15	0.07	0.07	0.39*	0.07	0.05	0.06
	DO_2			8.0	6.8	9.0	--	7.6	8.8	12.8
	Secchi			0.8	0.5	--	0.8	--	0.6	--
	Volume (m^3)			210.89	188.47	397.00	259.83	339.85	195.29	219.13
75-77	River Mile	--	--	76	76	76	76	76	75	76
	Temp			19.8	19.4	17.0	22.5*	23.5	26.2	29.0
	Sal			0.11	0.08	0.06	0.11*	0.25	0.16	0.06
	DO_2			7.3	6.4	8.3	--	7.9	8.9	10.3
	Secchi			1.4	0.7	0.65	1.0	0.4	0.7	--
	Volume (m^3)			181.23	174.54	382.86	242.97	387.73	209.38	211.82
78-80	River Mile	--	--	--	79	80	80	78	78	79
	Temp				19.8	16.0	21.2*	23.5	25.4	29.2
	Sal				0.09	0.06	0.10*	0.34	0.14	0.06
	DO_2				5.9	8.8	--	8.0	8.9	12.3
	Secchi				0.7	1.2	1.1	--	0.7	1.1
	Volume (m^3)				211.99	406.70	236.75	260.08	206.47	216.18
81-83	River Mile	--	--	--	82	81	82	82	83	82
	Temp				19.6	17.8	22.8*	22.2	24.5	29.0
	Sal				0.07	0.07	0.07*	0.06	0.12	0.06
	DO_2				7.5	8.8	--	8.2	8.8	13.5
	Secchi				0.8	1.1	1.15	0.3	0.6	1.1
	Volume (m^3)				143.67	424.94	175.23	155.48	117.20	168.73

*surface temp + sal only (pump broken).

**bottom only.

Table 2. Physical data and water volumes filtered (m^3) from striped bass egg and larvae survey of the Chickahominy River, Spring 1981. Mean temperatures (^oC), salinities ($^o/oo$) and dissolved oxygen concentrations (mg/l) are presented. Secchi disc depths in meters.

River Mile Stratum		Date 4/8	4/21	4/28	5/5	5/14	5/20	6/4	6/12	6/18
0-2	River Mile	--	02	01	02	00	02	01	00	01
	Temp		16.0	18.8	17.8	19.6	24.9	25.5	26.4	28.0
	Sal		1.03	0.76	1.44	0.74	1.21	0.37	0.17	0.10
	DO_2		8.9	8.5	7.7	7.8	7.0	6.6	6.4	6.3
	Secchi		0.4	0.5	0.3	0.45	0.4	0.4	0.4	0.3
Volume (m^3)			160.26	151.25	162.61	140.25	131.78	184.53	167.47	166.77
3-5	River Mile	--	04	05	04	03	03	05	03	05
	Temp		16.1	18.5	17.9	20.0	19.0	25.6	27.0	29.0
	Sal		0.85	0.75	0.96	1.30	1.11	0.48	0.30	0.24
	DO_2		9.2	9.4	7.9	7.3	7.3	5.4	5.8	4.6
	Secchi		0.5	0.7	0.3	0.45	0.45	0.5	0.5	0.4
Volume (m^3)			97.66	123.32	114.12	191.89	120.70	116.76	178.43	168.32
6-8	River Mile	--	06	07	06	08	07	07	07	07
	Temp		16.6	19.0	18.0	19.8	18.1	25.2	27.0	28.5
	Sal		0.82	0.65	0.74	0.66	0.74	0.35	0.28	0.28
	DO_2		9.0	9.8	8.0	7.7	6.2	6.0	6.8	4.9
	Secchi		--	0.6	0.6	0.5	0.6	0.6	0.7	0.7
Volume (m^3)			96.78	189.99	129.53	167.64	111.58	159.24	208.68	162.53
9-11	River Mile	09	09	09	10	10	10	11	10	11
	Temp	16.0	16.9	18.5	18.6	20.1	18.9	25.2	27.1	29.2
	Sal	0.83	0.73	0.53	0.50	0.52	0.43	0.16	0.17	0.18
	DO_2	10.2	9.3	8.9	8.6	8.0	7.0	6.4	6.6	5.8
	Secchi	0.7	0.8	0.7	0.7	0.6	0.7	0.8	0.5	0.7
Volume (m^3)		103.35	91.13	176.67	164.14	95.59	202.92	112.90	119.45	172.21
12-14	River Mile	12	12	13	13	12	13	13	13	14
	Temp	16.0	16.9	19.5	18.4	21.0	18.5	25.0	27.4	29.0
	Sal	0.53	0.47	0.31	0.36	0.44	0.20	0.09	0.12	0.09
	DO_2	10.0	9.1	9.2	7.4	8.4	6.6	5.2	5.8	4.6
	Secchi	0.5	0.8	0.6	0.7	0.5	0.8	0.7	0.7	0.8
Volume (m^3)		58.19	84.85	152.81	143.12	102.19	131.70	47.34	89.50	140.73

Table 2. (Continued)

River Mile Stratum		Date 4/8	4/21	4/28	5/5	5/14	5/20	6/4	6/12	6/18
15-17	River Mile	15	15	17	15	17	16	15	16	15
	Temp	16.2	17.1	20.1	18.6	20.4	18.4	24.9	27.1	29.0
	Sal	0.17	0.13	0.07	0.19	0.11	0.10	0.02	0.06	0.05
	DO_2	10.9	8.8	9.0	7.7	7.5	5.3	4.0	4.3	4.2
	Secchi	--	1.0	--	0.9	0.5	0.7	0.8	0.7	0.7
	Volume (m^3)	57.48	72.09	112.77	69.93	183.64	126.70	91.93	116.64	129.55
18-dam	River Mile	dam	dam	--	--	--	--	--	--	--
	Temp	17.4	17.0							
	Sal	0.05	0.05							
	DO_2	10.7	6.7							
	Secchi	0.7	1.0							
	Volume (m^3)	59.38	72.43							

not sampled).

River Mile Stratum		Date 4/22	4/27-28	5/5-6	5/13-14	5/21-22	5/27,29	6/4-5	6/10-12	6/18-19
33-35	River Mile	34	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Eggs	0	--	--	--	--	--	--	--	--
	Larvae	0	--	--	--	--	--	--	--	--
36-38	River Mile	38	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Eggs	0	--	--	--	--	--	--	--	--
	Larvae	0	--	--	--	--	--	--	--	--
39-41	River Mile	39	40	40	39	41	n.s.	39	40	40
	Eggs	0	0	0	0	0	--	0	0	0
	Larvae	0	1	0	0	0	--	0	0	0
42-44	River Mile	42	44	44	44	43	n.s.	43	43	43
	Eggs	0	0	27	0	0	--	0	0	0
	Larvae	0	0	0	0	0	--	0	0	0
45-47	River Mile	46	47	46	45	45	47	47	46	45
	Eggs	2	0	13	0	0	0	0	0	0
	Larvae	0	1	0	0	2	1	1	0	0
48-50	River Mile	49	48	50	48	50	48	50	48	48
	Eggs	2	0	3	0	0	0	0	0	0
	Larvae	0	1	0	0	0	2	0	0	0
51-53	River Mile	52	52	53	51	51	51	53	52	51
	Eggs	12	0	0	0	1	0	0	0	0
	Larvae	3	9	4	0	0	3	0	0	0
54-56	River Mile	56	55	56	55	56	54	56	54	54
	Eggs	2	17	0	6	0	0	0	0	0
	Larvae	0	14	6	4	4	2	0	0	0
57-59	River Mile	58	58	59	59	57	59	59	59	58
	Eggs	87	47	11	6	0	0	0	0	0
	Larvae	121	58	20	0	11	0	0	0	0
60-62	River Mile	62	60	62	61	62	62	61	60	60
	Eggs	10	27	82	0	0	0	0	0	0
	Larvae	1	31	22	0	6	0	1	0	0

Table 3 (continued). Total catches of striped bass eggs and larvae, James River, spring 1981 (n.s. = stratum not sampled).

River Mile Stratum		Date 4/22	4/27-28	5/5-6	5/13-14	5/21-22	5/27,29	6/4-5	6/10-12	6/18-19
63-65	River Mile	63	64	65	63	63	63	63	64	64
	Eggs	7	1	46	0	0	0	0	0	0
	Larvae	19	3	29	1	0	0	0	0	0
66-68	River Mile	n.s.	66	66	67	67	68	66	67	66
	Eggs	--	0	19	0	0	0	0	0	0
	Larvae	--	4	49	5	1	0	0	0	0
69-71	River Mile	n.s.	70	71	69	70	71	71	70	70
	Eggs	--	0	0	0	0	0	0	0	0
	Larvae	--	0	0	0	0	0	0	0	0
72-74	River Mile	n.s.	n.s.	73	72	74	72	72	72	72
	Eggs	--	--	0	0	0	0	0	0	0
	Larvae	--	--	0	1	0	0	0	0	0
75-77	River Mile	n.s.	n.s.	76	76	76	76	76	75	76
	Eggs	--	--	0	0	0	0	0	0	0
	Larvae	--	--	0	0	0	0	0	0	0
78-80	River Mile	n.s.	n.s.	n.s.	79	80	80	78	78	79
	Eggs	--	--	--	0	0	0	0	0	0
	Larvae	--	--	--	0	0	0	0	0	0
81-83	River Mile	n.s.	n.s.	n.s.	82	81	82	82	83	82
	Eggs	--	--	--	0	0	0	0	0	0
	Larvae	--	--	--	0	0	0	0	0	0

Table 4. Total catches of striped bass eggs and larvae, Chickahominy River, spring 1981 (n.s. = not sampled).

River Mile Stratum		Date 4/8	4/21	4/28	5/6	5/14	5/20	6/4	6/12	6/18
Station	River Mile	n.s.	CCS	CCS	CCS	n.s.	CCS	CCS	n.s.	n.s.
CCS	Eggs	--	2	0	0	--	0	0	--	--
	Larvae	--	0	0	0	--	0	0	--	--
0-2	River Mile	n.s.	02	01	02	00	02	01	00	01
	Eggs	--	3	0	8	0	0	0	0	0
	Larvae	--	0	0	0	0	0	0	0	0
3-5	River Mile	n.s.	04	05	04	03	03	05	03	05
	Eggs	--	13	0	3	0	0	0	0	0
	Larvae	--	0	0	0	0	0	0	0	0
6-8	River Mile	n.s.	06	07	06	08	07	07	07	07
	Eggs	--	0	0	0	0	0	0	0	0
	Larvae	--	0	0	0	0	0	0	0	0
9-11	River Mile	09	09	09	10	10	10	11	10	11
	Eggs	0	0	0	0	0	0	0	0	0
	Larvae	0	0	0	0	0	0	0	0	0
12-14	River Mile	12	12	13	13	12	13	13	13	14
	Eggs	0	0	0	0	0	0	0	0	0
	Larvae	0	0	0	0	0	0	0	0	0
15-17	River Mile	15	15	n.s.	15	17	16	15	16	15
	Eggs	0	0	--	0	0	0	0	0	0
	Larvae	0	0	--	0	0	0	0	0	0
18-dam	River Mile	Dam	Dam	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Eggs	0	0	--	--	--	--	--	--	--
	Larvae	0	0	--	--	--	--	--	--	--

Table 5. Length frequency distribution of Morone saxatilis larvae captured in the James River, spring 1981.

Size Range (mm)	Date 4/22	4/27-28	5/5-6	5/13-14	5/21-22	5/29	6/4-5	TOTAL
3.0-3.9	28	4						32
4.0-4.9	28	50	6	2	13			99
5.0-5.9	77	39	59		8			183
6.0-6.9	4	19	42	1	2		1	69
7.0-7.9	7	6	5	3		5		26
8.0-8.9		4	9	4		2		19
9.0-9.9			7			1		8
10.0-10.9			1	1				2
11.0-11.9					1			1
12.0-12.9								0
13.0-13.9							1	1