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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 3. Pt.A. Distribution and abundance of striped bass eggs and larvae in the Rappahannock River during spring, 1982 : final report

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Grant No. NA81FAD-VA5B

FINAL REPORT

By

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Gloucester Point, Virginia 23062

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INTRODUCTION

The Rappahannock River (Fig. 1) drains an area of about 2700 square miles in northeastern Virginia and is approximately 160 nautical miles in length. The river is subject to tidal influence from its mouth to Fredericksburg, Virginia, a distance of 93 nautical miles, and salt water reaches its upper limit in the vicinity of Tappahannock, Virginia between river mile 35-45. Although development and use of shoreline is extensive in the areas of Fredericksburg and Tappahannock, the upper, freshwater portions of the river are undeveloped and are generally considered pristine relative to similar segments of other major Virginia tributaries. Virginia's largest population of nesting bald eagles, for example, resides in this habitat (Dr. Mitchill Byrd, personal communication).

Documentation of the use of the Rappahannock River as a spawning site for striped bass, *Morone saxatilis*, was provided by Tresselt (1952) in a limited survey (four sampling dates in May 1950) which yielded a total of five (5) eggs. Although subsequent trawling and seining surveys of juveniles and young-of-the-year conducted by the Virginia Institute of Marine Science (VIMS) and commercial catch statistics of spawning females (VIMS, unpublished data) have repeatedly demonstrated

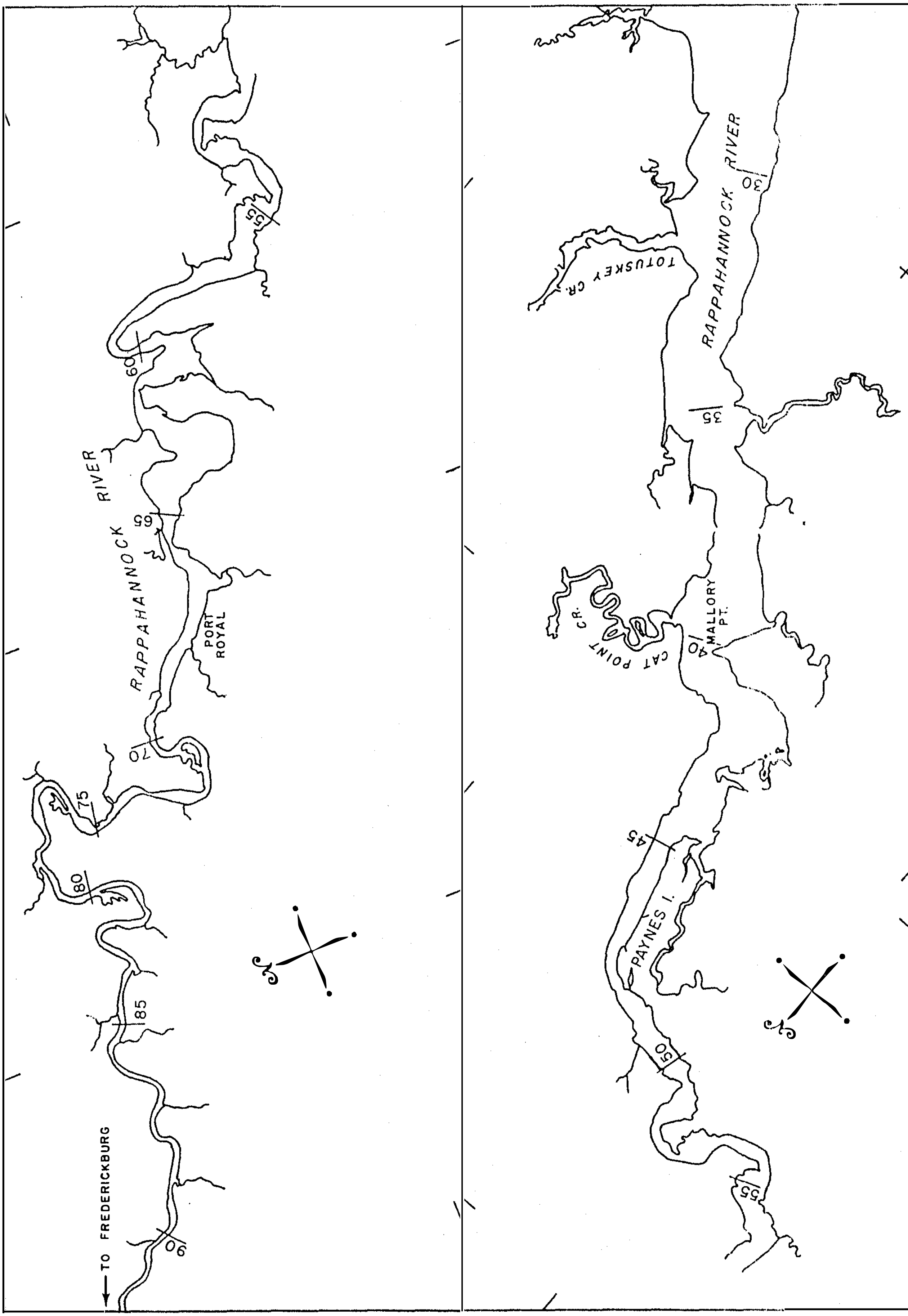

Fig. 1. Rappahannock River study area.

annual spawning activity, there have been no additional direct observations of eggs or larvae in the Rappahannock River.

In response to the objectives of the Emergency Striped Bass Study (Chafee Amendment to the Anadromous Fish Act), the present investigation was designed to describe the abundance and distribution of eggs and larvae during the spring spawning season, 1982. Similar surveys of the York and James Rivers were conducted during spring 1980 and 1981 respectively, and are the subjects of previous reports (Grant and Olney 1981, 1982).

MATERIALS AND METHODS

A 42 mile portion of the Rappahannock River was divided into 3-mile strata from which stations were randomly selected prior to each cruise. Twice-weekly surveys were conducted following initial, exploratory cruises on 5 and 8 April 1982 and a partial survey (13 April 1982) which was discontinued due to vessel failure. Intensive twice-weekly sampling in the ten 3-mile segments between river miles 39-68 was conducted during the 11-week period between 16 April and 23 June 1982 (Tables 1, 2 and 3).

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-O flowmeters for volumetric estimates (Table 1-3) and catches were combined on board before preservation with 5-8% buffered formalin. All collections were made in daylight hours.

Table 1. Physical data and water volumes filtered (m^3) from striped bass egg and larvae survey of the Rappahannock River, April 1982. Mean temperatures (^oC), salinities ($^o/oo$) and dissolved oxygen concentrations (mg/1) are presented. Secchi disc depths in meters.

River Mile Stratum		(April 1982) 4/5	4/8	4/13	Date 4/16	4/21	4/23	4/30
39-41	River Mile	n.s.	n.s	n.s	n.s	n.s	n.s	
	Temp							
	Sal							
	DO_2							
	Secchi							
	Volume (m^3)							
42-44	River Mile	n.s	n.s	n.s	n.s	44	42	44
	Temp					16.1	15.5	16.5*
	Sal					1.33	1.21	0.24*
	DO_2					9.4	9.9	-
	Secchi					0.25	0.2	0.15
	Volume (m^3)					106.9	60.0	96.8
45-47	River Mile	n.s	n.s	n.s	45	46	46	46
	Temp				12.9	15.8	15.2	15.3
	Sal				0.60	0.59	0.26	
	DO_2				10.5	9.7	10.2	9.7
	Secchi				0.2	0.2	0.15	0.2
	Volume (m^3)				85.5	120.8	111.0	110.9
48-50	River Mile	n.s	49	n.s.	49	50	49	50
	Temp		9.5		12.5	15.7	15.2	16.1
	Sal		0.06		0.17	0.10	0.09	0.06
	DO_2		11.2		10.5	9.7	10.0	9.5
	Secchi		0.1		0.2	0.2	0.2	0.25
	Volume (m^3)		90.4		100.0	129.0	79.0	83.2
51-53	River Mile	n.s.	52	n.s.	52	53	52	52
	Temp		9.9		13.3	16.0	15.2	16.2
	Sal		0.05		0.06	0.06	0.06	0.07
	DO_2		10.7		10.7	10.1	10.2	9.4
	Secchi		0.15		0.25	0.2	0.2	0.3
	Volume (m^3)		111.9		165.8	145.9	165.0	170.0
54-56	River Mile	n.s.	55	n.s.	55	56	55	56
	Temp		9.1		13.5	16.4	15.6	16.2
	Sal		0.05		0.06	0.06	0.06	0.12
	DO_2		10.5		10.6	9.6	10.3	9.8
	Secchi		0.2		0.25	0.25	0.25	0.3
	Volume (m^3)		101.6		153.2	74.6	171.3	66.1

Table 1 (Cont'd)

River Mile Stratum		4/5	4/8	4/13	4/16	4/21	4/23	4/30
		Date						
57-59	River Mile	58	58	n.s	57	57	58	58
	Temp	13.2	9.4		14.2	16.6	15.2	16.8
	Sal	0.05	0.05		0.06	0.05	0.06	0.08
	DO_2		9.8		10.8	9.9	10.3	9.6
	Secchi	0.2	0.2		0.25	0.3	0.25	0.35
	Volume (m^3)	91.3			110.1	59.2	109.0	107.9
60-62	River Mile	62	61	60	60	61	61	61
	Temp	13.0	8.0	11.1	14.1	16.6	14.0	16.7
	Sal	0.05	0.05	0.05	0.05	0.06	0.06	0.18
	DO_2		11.0	10.9	10.6	10.2	9.8	9.3
	Secchi	0.2	0.2	0.25	0.2	0.3	0.25	0.35
	Vol	73.5	127.0		140.6	119.3	84.1	94.3
63-65	River Mile	63	63	64	64	64	65	64
	Temp	13.1	8.3	11.6	14.7	16.1	14.2	16.9
	Sal	0.05	0.06	0.05	0.05	0.06	0.06	0.05
	DO_2		10.1	10.8	10.6	9.8	10.0	9.0
	Secchi	0.2	0.25	0.25	0.25	0.3	0.3	0.4
	Vol	108.3	123.9	98.4	74.2	84.2	89.0	67.2
66-68	River Mile	66	68	67	66	67	68	68
	Temp	12.7	10.1	12.1	14.7	15.0	14.2	16.9
	Sal	0.05	0.05	0.05	0.05	0.06	0.06	0.05
	DO_2		10.4	10.6	10.8	9.5	9.7	8.7
	Secchi	0.1	0.3	0.2	0.3	0.35	0.3	0.8
	Vol		96.7	118.4	165.1	105.5	94.1	70.7
69-71	River Mile	69	70	n.s.	n.s.	n.s.	n.s.	n.s.
	Temp	12.5	10.9					
	Sal	0.05	0.06					
	DO_2		9.6					
	Secchi	0.3	0.3					
	Vol	76.4	93.4					
72-74	River Mile	73	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Temp	12.6						
	Sal	0.05						
	DO_2							
	Secchi	0.5						
	Vol	92.1						
75-77	River Mile	75	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Temp	12.9						
	Sal	0.05						
	DO_2							
	Secchi	0.5						
	Vol							

Table 1 (Cont'd)

River Mile Stratum		Date 4/5	4/8	4/13	4/16	4/21	4/23	4/30
78-80	River Mile	78	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Temp	12.9						
	Sal	0.05						
	DO_2							
	Secchi							
	Vol.							

* Surface only

Table 2. Physical data and water volumes filtered (m^3) from striped bass egg and larvae survey of the Rappahannock River, May 1982. Mean temperatures (°C), salinities (°/oo) and dissolved oxygen concentrations (mg/l) are presented. Secchi disc depths in meters.

River Mile Stratum		(May 1982) 5/4	5/7	5/11	Date 5/14	5/18	5/21	5/25
39-41	River Mile	40	n.s.	40	39	n.s.	40	41
	Temp	18.2		19.8	21.75		24.0	22.3
	Sal	1.67		1.405	2.942		3.569	2.585
	DO_2	7.96		8.02	8.02		6.50	6.96
	Secchi	0.20		0.10	0.3		0.3	0.3
	Volume	66.3		79.9	99.0		127.5	127.2
42-44	River Mile	43	n.s.	43	44	43	44	42
	Temp	18.2		19.57	21.2	23.2	23.5	22.4
	Sal	0.38		0.762	1.237	2.150	1.419	2.292
	DO_2	8.41		8.60	7.90	7.70	7.8	6.0
	Secchi	0.10		0.10	0.25		0.3	0.3
	Volume	141.9		77.8	84.7	80.8	160.7	88.1
45-47	River Mile	47	n.s.	46	47	46	46	47
	Temp	18.1		19.9	21.17	22.8	23.9	22.4
	Sal	0.83		0.106	0.432	1.158	0.66	0.696
	DO_2	7.98		7.92	7.82	8.28	7.24	6.52
	Secchi	0.10		0.10	0.25		0.3	0.3
	Volume	139.2		91.3	115.2	112.3	46.8	78.4
48-50	River Mile	50	n.s.	50	50	49	50	48
	Temp	18.3		19.9	21.27	22.7	23.5	22.4
	Sal	0.08		0.06	0.133	0.480	0.135	0.282
	DO_2	7.86		8.0	8.08	7.88	7.82	6.80
	Secchi	0.20		0.10	0.25		0.3	0.35
	Volume	93.2		83.8	103.5	54.6	19.6	30.5
51-53	River Mile	52	n.s.	53	53	51	51	53
	Temp	18.8		19.8	21.6	22.9	23.9	22.4
	Sal	0.57		0.063	0.077	0.221	0.088	0.164
	DO_2	8.31		7.41	8.24	7.80	7.66	6.68
	Secchi	0.25		0.10	0.3		0.3	0.35
	Volume	121.7		85.1	84.2	70.1	14.9	14.1
54-56	River Mile	56	n.s.	55	55	56	55	55
	Temp	19.0		19.9	21.43	23.3	23.9	22.5
	Sal	0.65		0.054	0.062	0.066	0.063	0.143
	DO_2	7.57		7.92	8.56	8.20	7.16	6.58
	Secchi	0.10		0.20	0.3		0.35	0.3
	Volume	89.1		87.5	111.7	14.1	13.1	7.2

Table 2 (Continued)

River Mile Stratum		Date 5/4	5/7	5/11	5/14	5/18	5/21	5/25
57-59	River Mile	57	n.s.	57	57	57	59	58
	Temp	18.5		19.83	21.7	23.4	24.33	22.4
	Sal	0.058		0.053	0.055	0.055	0.048	0.066
	DO_2	7.75		8.02	8.38	8.36	7.82	6.84
	Secchi	0.25		0.15	0.35		0.4	0.35
	Volume	54.5		57.4	75.2	13.5	13.0	5.5
60-62	River Mile	62	n.s.	62	60	62	61	61
	Temp	19.5		19.47	21.73	24.0	24.23	22.3
	Sal	0.06		0.052	0.058	0.049	0.053	0.162
	DO_2	8.37		7.98	8.22	7.90	7.60	6.62
	Secchi	0.25		9.25	0.40		0.4	0.35
	Volume	71.5		51.3	67.7	12.1	9.0	8.8
63-65	River Mile	63	n.s.	64	64	65	64	64
	Temp	19.6		19.7	20.17	23.9	24.2	22.0
	Sal	0.05		0.051	0.046	0.045	0.048	0.143
	DO_2	7.61		7.90	8.66	8.34	8.0	6.48
	Secchi	0.25		0.25	0.50		0.40	0.35
	Volume	133.1		65.1	57.9	18.1	11.6	8.0
66-68	River Mile	67	66	67	66	68	68	68
	Temp	19.3	19.8	19.13	22.3	23.5	24.2	22.2
	Sal	0.08	0.089	0.056	0.046	0.046	0.046	0.053
	DO_2	7.67	6.79	7.96	9.08	7.96	7.82	6.94
	Secchi	0.15	0.30	0.20	0.50		0.50	0.4
	Volume	54.8	98.0	61.9	60.4	52.7	11.2	7.2
69-71	River Mile	n.s.	n.s.	n.s.	69	n.s.	n.s.	n.s.
	Temp				21.93			
	Sal				0.053			
	DO_2				8.42			
	Secchi				0.8			
	Volume				79.4			

Table 3. Physical data and water volumes filtered (m^3) from striped bass egg and larvae survey of the Rappahannock River, June 1982. Mean temperatures (°C), salinities (°/oo) and dissolved oxygen concentrations (mg/l) are presented. Secchi disc depths in meters.

River Mile Stratum	(June 1982)	6/1	6/4	6/8	6/11	6/14	6/17	6/23
39-41	River Mile	n.s.	n.s.	39	41	n.s.	n.s.	41
	Temp			23.9	22.9			24.5 surf.
	Sal			0.345	0.426			.187 surf.
	DO_2			8.92	6.92			
	Secchi			0.1	0.1			0.25
	Volume			35.6	21.4			150.0
42-44	River Mile	n.s.	42	44	43	n.s.	43	42
	Temp		24.3	23.5	22.93		23.5	24.5 surf.
	Sal		0.69	0.109	0.126		0.401	.110 surf.
	DO_2		7.24	8.42	7.36		7.22	
	Secchi		0.15	0.1	0.1		0.25	0.25
	Volume		54.6	65.8	28.4		58.9	487.1
45-47	River Mile	46	47	45	45	45	47	46
	Temp	25.4	24.2	22.7	22.9	21.3	23.0	24.1 surf.
	Sal	0.454	0.093	0.069	0.093	0.216	0.077	0.55 surf.
	DO_2	8.00	7.20	10.1	7.20	7.14	7.4	
	Secchi	0.2		0.1	0.2	0.2	0.3	0.35
	Volume	61.3	50.4	43.7	37.5	104.5	108.7	285.6
48-50	River Mile	49	50	48	50	50	49	50
	Temp	25.4	24.73	23.0	22.6	21.0	22.7	24.4 surf.
	Sal	0.227	0.068	0.067	0.068	0.061	0.058	0.55 surf.
	DO_2	7.68	6.98	9.78	6.30	6.82	7.7	
	Secchi	0.2	0.3	0.1	0.15	0.2	0.5	0.4
	Volume	8.9	14.6	52.4	27.3	72.2	80.3	227.4
51-53	River Mile	53	53	51	53	53	53	53
	Temp	25.67	24.8	22.3	22.03	20.7	22.23	24.6 surf.
	Sal.	0.092	0.128	0.089	0.058	0.641	0.193	0.051 surf.
	DO_2	8.28	7.28	8.54	6.38	7.00	8.24	
	Secchi	0.25	0.3	0.15	0.2	0.2	0.4	0.4
	Volume	15.7	6.2	28.6	48.8	125.5	99.4	262.6
54-56	River Mile	56	55	55	55	56	54	55
	Temp	26.0	24.8	21.9	21.9	20.2	22.1	24.8 surf.
	Sal	0.06	0.065	0.080	0.092	0.166	0.165	0.051 surf.
	DO_2	8.46	7.02	9.24	6.78	6.88	6.64	
	Secchi	0.4	0.35	0.1	0.2	0.3	0.4	0.4
	Volume	6.4	6.3	54.5	71.6	65.1	104.3	273.9

Table 3 (Continued)

River Mile Stratum	(June 1982)	Date 6/1	6/4	6/8	6/11	6/14	6/17	6/23
57-59	River Mile	59	59	59	57	58	57	57
	Temp	26.0	24.83	20.3	21.6	20.0	22.2	24.9 surf
	Sal	0.067	0.184	0.078	0.096	0.062	0.195	0.046 surf
	DO_2	8.08	6.84	8.56	6.96	6.40	6.90	
	Secchi	0.6	0.3	0.1	0.15	0.3	0.25	0.35
	Volume	6.5	6.3	37.5	40.5	105.0	72.3	185.4
60-62	River Mile	62	61	62	61	62	62	60
	Temp	25.6	24.3	19.83	21.2	20.1	22.2	25.4 surf
	Sal	0.052	0.055	0.097	0.197	0.072	0.197	0.046 surf
	DO_2	8.32	7.28	16.1	6.18	7.10	7.10	
	Secchi	0.3		0.1	0.2	0.3	0.35	0.4
	Volume	6.2	5.7	47.3	24.3	85.2	104.7	392.9
63-65	River Mile	n.s.	63	64	63	n.s.	65	64
	Temp		23.6	19.6	21.2		21.8	24.9 surf
	Sal		0.117	0.343	0.092		0.049	0.62 surf
	DO_2		7.10	9.88	6.28		7.00	
	Secchi		0.1	0.1	0.2		0.3	0.4
	Volume		12.3	0.9	46.7		69.6	127.6
66-68	River Mile	n.s.	67	66	67	n.s.	n.s.	66
	Temp		23.47	19.3	20.7			25.1 surf
	Sal		0.066	0.10	0.081			0.044 surf
	DO_2		6.44	9.18	6.04			
	Secchi		0.1	0.1	0.2			0.4
	Volume		78.2	13.6	54.8			202.0

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.

All striped bass larvae in which yolk or oil globules were not visible were cleared and stained for positive identification. We followed the methodology of Fritzsche and Johnson (1980) in osteological examination and utilized recently described pterygiophore interdigitation criteria (Olney et al., In press; Appendix I) as well as morphology of predorsal cartilages (Fritzsche and Johnson 1980) in delimiting larval *Morone* spp.

Egg production estimates were calculated following the techniques of Houde (1977) after Sette and Ahlstrom (1948) and Ahlstrom (1954, 1959). Annual egg production on the Rappahannock River was calculated using the equation (Houde 1977):

$$\text{Production} = \sum_{I=1}^{R} \frac{P_I D_I}{d_I}$$

Where,

P_I = cruise egg production estimate

D_I = the number of days represented by each cruise

d_I = 2.41 = duration of egg stage at 16°C (Setzler et al. 1980)

A total of 21 partial or complete surveys were accomplished during the period 5 April - 23 June 1982, resulting in 164 collections (April, n = 54; May, n = 61; June, n = 49). Locations of stations within river-mile strata, measurements of physical characteristics of water sampled, and volumes of water sampled for each collection are provided in Tables 1-3.

Physical Characteristics

Mean water column temperatures ranged from 8.0 - 16.9° C during April (Table 1); 18.1 - 24.3° C in May (Table 2); and 19.3 - 26.0° C in June (Table 3). Although regular sampling on the Rappahannock River was initiated several weeks prior to regular sampling on the York and James in previous years, spring warming trends had already elevated temperatures to spawning levels at the start of sampling. Temperatures remained within peak spawning activity ranges (14.4 - 21.1°C, Hardy 1978) through mid-May, a condition which coincided with observed spawning activity (Tables 4 and 5). By May 21 (Table 2) mean temperatures exceeded optimum spawning ranges (17-20° C, Setzler et al. 1980).

Saline waters (using 0.5 o/oo as the upper limit for designation of fresh water) frequently penetrated upriver to the 3-mile segment of stratum 45-47 (Tables 1-3), but river miles 39-44 consistently marked the tidal extent of the salt wedge during 1982. Stations within these strata were generally well stratified, except during periods of peak tidal current. Stations located above these strata were considered to be within tidal freshwater segments of the river and were never observed to be stratified by temperature or salinity.

Dissolved oxygen levels remained at or near saturation, varying mostly with temperature throughout the study period. Water transparency, as measured by Secchi disc depths, was generally poor, only rarely exceeding 0.35 m.

Egg Distribution, Abundance and Production

Our exploratory surveys (5 April, 8 April 1982) revealed spawning activity was initiated sometime prior to first sampling, and running ripe females were taken by commercial netters in early March (VIMS unpublished data). During the first three cruises sampling was progressively shifted to more down-river strata (Table 4), since the upper limit of egg distribution appeared in the vicinity of river-mile 69 (Fig. 2). Egg densities at positive stations ranged from 1.4 - 337.8 eggs/ $100m^3$ in April and 0.7 - 49.5 eggs/$100m^3$ in May 1982. Peak spawning activity during the sampling period was observed during the two-week interval between 13-23 April (Table 4) when peak densities ranged from 111.7 - 337.8 egg/$100m^3$. Eggs were last collected on 11 May 1982 and egg densities declined steadily after 30 April (Tables 4,5). As in surveys of spawning activity in other rivers during previous years (Grant and Olney 1981, 1982), striped bass eggs were taken within a short segment of the Rappahannock River between river miles 43-67

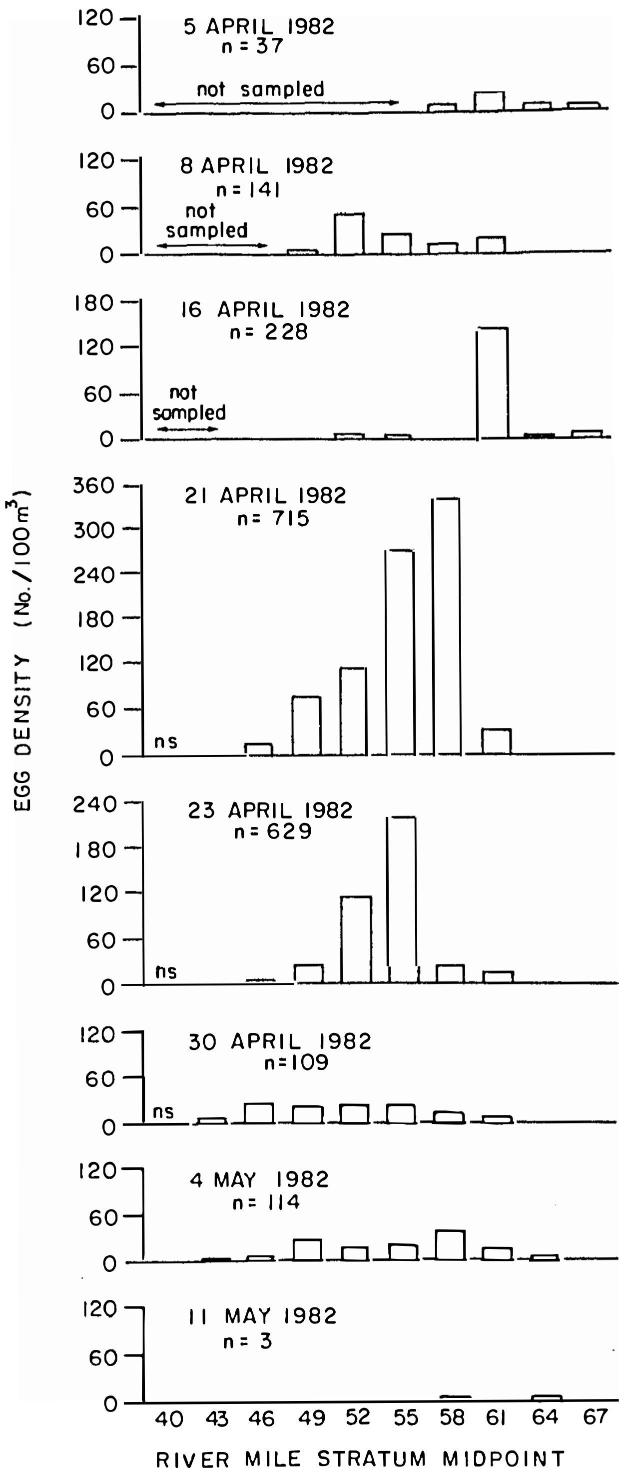

Fig. 2. Distribution and abundance of striped bass eggs, Rappahannock River, spring 1982.

Table 4. Total catches of striped bass eggs from the Rappahannock River, April 1982 (n.s. = stratum not sampled)

River Mile Stratum		Date 4/5	4/8	4/13	4/13	4/21	4/23	4/30
39-41	River mile	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Total eggs							
	Egg Density (No./100m^3)							
42-44	River mile	n.s.	n.s.	n.s.	n.s.	44	42	44
	Total eggs					0	0	5
	Egg density (No./100m^3)							5.17
45-47	River mile	n.s.	n.s.	n.s.	45	46	46	46
	Total eggs				0	18	4	23
	Egg density (No./100m^3)					14.90	3.60	20.74
48-50	River mile	n.s.	49	n.s.	49	50	49	50
	Total eggs		5		0	97	19	17
	Egg density (No./100m^3)		5.53			75.19	24.05	20.43
51-53	River mile	n.s.	52	n.s.	52	53	52	52
	Total eggs		57		10	163	190	35
	Egg density (No./100m^3)		50.94		6.03	111.72	115.15	20.59
54-56	River mile	n.s.	55	n.s.	55	56	55	56
	Total eggs		27		7	200	374	14
	Egg density (No./100m^3)		26.57		4.57	268.10	218.33	21.18
57-59	River mile	58	58	n.s.	57	57	58	58
	Total eggs	9	11		0	200	28	11
	Egg desnity (No./100m3)	9.86	12.89			337.84	25.69	10.10
60-62	River mile	62	61	60	60	61	61	61
	Total eggs	17	41	0	200	37	14	4
	Egg desnity (No./100m^3)	23.13	32.28		142.25	31.01	16.65	4.24
63-65	River mile	63	63	64	64	64	65	64
	Total eggs	8	0	0	1	0	0	0
	Egg density (No./100m3)	7.39			1.35			

Table 4. Continued

River Mile Stratum		Date						
		4/5	4/8	4/13	4/16	4/21	4/23	4/30
66-68	River mile	66	68	67	66	67	68	68
	Total eggs	3	0	0	10	0	0	0
	Egg density (No./100m^3)	4.54			6.06			
69-71	River mile	69	70	n.s.	n.s.	n.s.	n.s.	n.s.
	Total eggs	0	0					
	Egg density (No./100m^3)							
72-74	River mile	73	n.s.	n.s.				
	Total eggs	0						
	Egg density (No./100m^3)							
75-77	River mile	75	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Total eggs	0						
	Egg density (No./100m^3)							
78-80	River mile	78	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Total eggs	0						
	Egg density (No./100m^e)							

Table 5. Total catches of striped bass eggs from the Rappahannock River, May 1982. (n.s. - stratum not sampled)

River Mile Stratum		Date 5/4	5/7	5/11
39-41	River mile	40	n.s.	40
	Total eggs	0		0
	Egg density (No./100m^3)			
42-44	River mile	43	n.s.	43
	Total eggs	1		0
	Egg density (No./100m^3)	0.70		
45-47	River mile	47	n.s.	46
	Total eggs	6		0
	Egg density (No./100m^3)	4.31		
48-50	River mile	50	n.s.	49
	Total eggs	25		
	Egg density (No./100m^3)	26.82		
51-53	River mile	52	n.s.	53
	Total eggs	19		0
	Egg density (No./100m^3)	15.61		
54-56	River mile	56	n.s.	55
	Total eggs	16		0
	Egg density (No./100m^3)	17.96		
57-59	River mile	57	n.s.	57
	Total eggs	27		1
	Egg density (No./100m^3)	49.54		1.74
60-62	River mile	62	n.s.	62
	Total eggs	11		0
	Egg density (No./100m^3)	15.38		
63-65	River mile	63	n.s.	64
	Total eggs	8		2
	Egg density (No./100m^3)	6.01		3.07

Table 5. Continued

River Mile Stratum		Date 5/4	5/7	5/11
66-68	River Mile	67	66	67
	Total eggs	1	0	0
	Egg density (No./100m^3)	1.82		
69-71	River mile	n.s.	n.s.	n.s.
	Total eggs			
	Egg density (No./100m^3)			

(Fig. 3, Tables 4, 5). Although peak spawning activity (as indicated by maximum egg densities) was observed between river-miles 52-61 location of peak densities varied from cruise to cruise and densities were evenly distributed as spawning activity declined (Fig. 2).

Daily spawning estimates, cruise production estimates and associated variance data are presented in Table 6. As expected, egg production estimates peaked during cruises between 16-23 April and variance associated with these estimates was within the range of values reported by Houde (1977) for clupeid species. Annual striped bass egg production for the Rappahannock River was estimated to be 6.36×10^8 eggs, a value comparable to those reported during some years in the Roanoke River system (Hassler et al. 1981). Spawning female biomass estimates were not calculated since age - specific fecundity estimates were not available.

Larval Distribution, Abundance and Size Frequency

Yolk-sac larvae were present in low densities at a few stations during the second exploratory cruise (8 April), indicating spawning activity may have begun only a short time prior to initiation of sampling. Larval densities increased steadily, reaching peak abundances during the period 21 April - 4 May 1982 (Fig. 4, 5). Densities at positive stations ranged from 0.9 - 291.8 larvae/100m^3 (Table 7, 8, 9). Larvae were last taken on 23 June 1982 (river-mile 66) and appeared in collections only once during the three preceding cruises (Table 9). These three specimens (Table 10) were all greater than 19.5 mm SL.

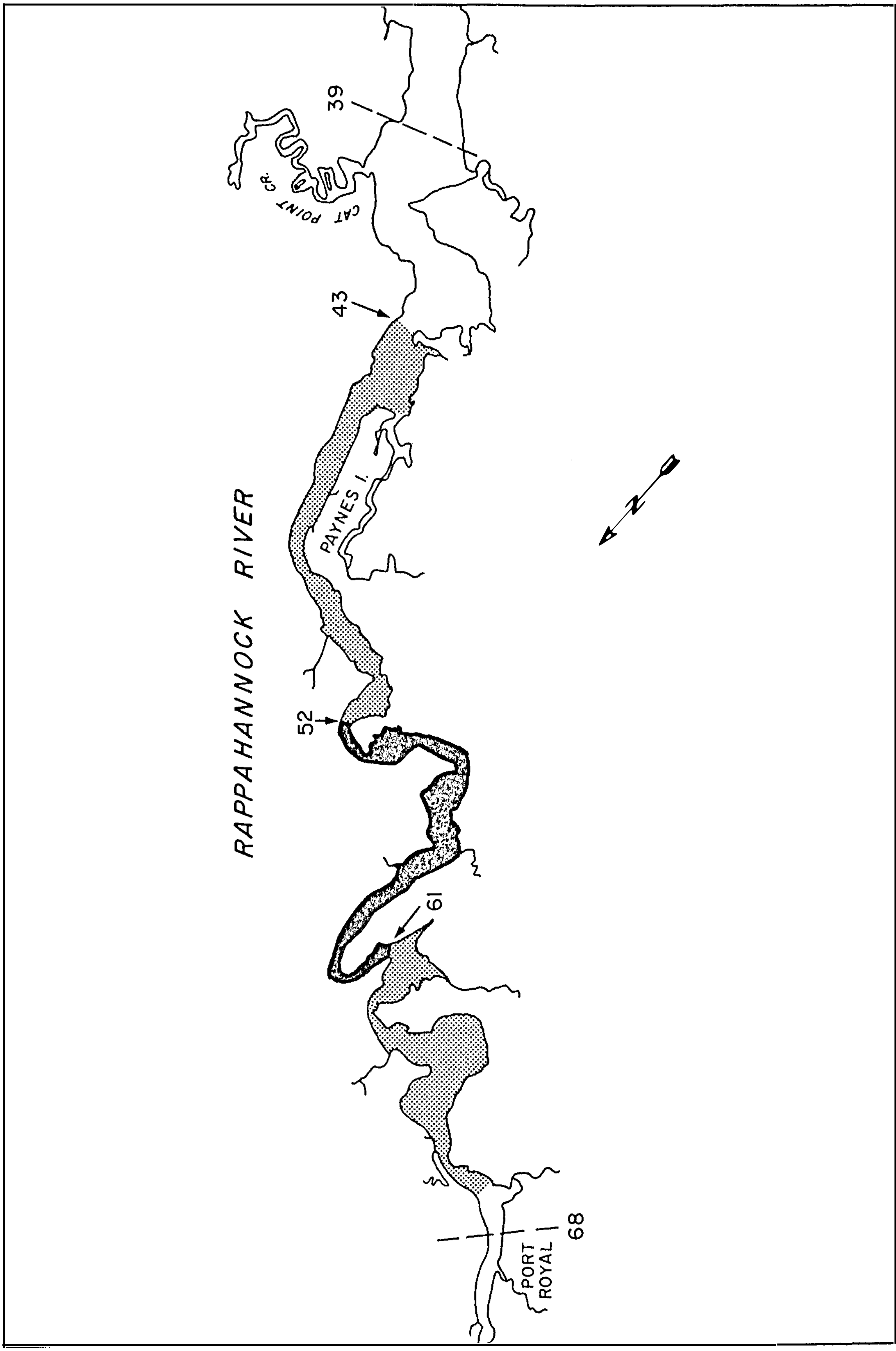

Fig. 3. Spatial extent of striped bass eggs, Rappahannock River, spring 1982. Darkest area represents greatest spawning activity.

Table 6. Egg Production Estimates on the Rappahannock River, Spring 1982.

Cruise Date	Daily Spawning Estimate (Eggs $X10^6$)	Days Represented By Cruise	Eggs Spawned During Cruise (Eggs X 10^7)	Variance Estimate (Eggs X 10^{13})
5 April	1.044	4.5	.470	5.626
8 April	2.527	6.5	1.642	4.369
16 April	6.021	7.5	4.516	10.180
21 April	19.466	4.6	8.759	8.635
23 April	16.087	5.5	8.848	10.170
30 April	1.968	6.5	1.279	4.043
4 May	2.398	6.5	1.559	3.561
11 May	.072	5	.036	1.482

Table 7. Total Catches of <u>Morone saxatilis</u> larvae from the Rappahannock River, April 1982. (n.s. = stratum not sampled)

River mile Stratum		4/5	4/8	4/13	4/16	4/21	4/23	4/30
39-41	River mile	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Total larvae							
	Larval density (no./100m^2)							
42-44	River mile	n.s.	n.s.	n.s.	n.s.	44	42	44
	Total larvae					0	0	248
	Larval density (No./100m^3)							256.2
45-47	River mile	n.s.	n.s.	n.s.	45	46	46	46
	Total larvae				1	8	48	309
	Larval density (no./100m^3)				1.2	6.6	43.2	278.6
48-50	River mile	n.s.	49	n.w.	49	50	49	50
	Total larvae		0		13	128	74	227
	Larval density (no./100m^3)				13.0	99.2	93.7	272.8
51-53	River mile	n.s.	52	n.s.	52	53	52	52
	Total larvae		3		25	121	479	262
	Larval density (No./100m^3)		2.7		15.1	82.9	290.3	154.1
54-56	River mile	n.s.	55	n.s.	55	56	55	56
	Total larvae		1		9	152	44	146
	Larval density (No./100m^3)		0.98		5.9	203.8	25.7	220.9
57-59	River mile	58	58	n.s.	57	57	58	58
	Total larvae	0	0		5	134	91	132
	Larval density (No./100m^3)				4.5	226.4	83.5	122.3
60-62	River mile	62	61	60	60	61	61	61
	Total larvae	0	0	0	5	26	0	82
	Larval density (No./100m^3)				3.6	21.8	10.7	87.0

River mile Stratum		4/5	4/8	4/13	4/16	4/21	4/23	4/30
63-65	River mile	63	63	64	64	64	65	64
	Total larvae	0	0	0	0	0	0	13
	Larval density (No./100m^3)							19.3
66-68	River mile	66	68	67	66	67	68	68
	Total larvae	0	0	0	0	0	0	0
	Larval density (No./100m^3)							
69-71	River mile	69	70	n.s.	n.s.	n.s.	n.s.	n.s.
	Total larvae	0	0					
	Larval density (No./100m^3)							
72-74	River mile	73	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Total larvae	0						
	Larval density (no./100m^3)							
75-77	River mile	75	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Total larvae							
	Larval density (No./100m^3)							
78-80	River mile	78	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Total larvae	0						
	Larval density (No./100m^3)							

*Meter reading not taken

Table 8. Total Catches of Morone saxatilis larvae from the Rappahannock River, May 1982. (n.s. = stratum not sampled)

River mile Stratum		5/4	5/7	5/11	5/14	5/18	5/21	5/25
39-41	River mile	40	n.s.	40	39	n.s.	40	41
	Total larvae	0		6	0		0	0
	Larval density (No./100m^3)			7.5				
42-44	River mile	43	n.s.	43	44	43	44	42
	Total larvae	21		16	4	0	0	0
	Larval density (No./100m^3)	14.8		20.6	4.7			
45-47	River mile	47	n.s.	46	47	46	46	47
	Total larvae	219		111	67	0	3	12
	Larval density (No./100m^3)	157.3		121.6	58.2		6.4	15.3
48-50	River mile	50	n.s.	50	50	49	50	48
	Total larvae	39		30	208	0	5	0
	Larval density (No./100m^3)	41.8		35.8	201.0		25.5	
51-53	River mile	52	n.s.	53	53	51	51	53
	Total larvae	145		81	33	4	4	0
	Larval density (No./100m^3)	119.1		95.2	39.2	5.7	26.8	
54-56	River mile	56	n.s.	55	55	56	55	55
	Total larvae	260		96	75	8	18	2
	Larval density (No./100m^3)	291.8		109.7	67.1	56.7	137.4	27.8
57-59	River mile	57	n.s.	57	57	57	59	58
	Total larvae	136		17	88	4	2	1
	Larval density (No./100m^3)	249.5		29.6	117.0	29.6	15.4	18.2
60-62	River mile	62	n.s.	62	60	62	61	61
	Total larvae	83		21	87	0	2	1
	Larval density (No./100m^3)	116.1		40.9	128.5		22.2	11.4
63-65	River mile	63	n.s.	64	64	65	64	64
	Total larvae	26		9	14	2	0	0
	Larval density (No./100m3)	19.5		13.8	24.2	11.0		

River mile Stratum		5/4	5/7	5/11	5/14	5/18	5/21	5/25
66-68	River mile	67	66	67	66	68	68	68
	Total larvae	4	2	3	18	0	1	0
	Larval density (No./100m^3)	7.3	2.0	4.8	29.8		8.9	
69-71	river mile	n.s.	n.s.	n.s.	69	n.s.	n.s.	n.s.
	Total larvae				2			
	Larval density (No./100m^3)				2.5			

Table 9. Total Catches of *Morone saxatilis,* larvae from the Rappahannock River, June 1982. (n.s. = stratum not sampled)

River mile Stratum		6/1	6/4	6/8	6/11	6/14	6/17	6/23
39-41	River mile	n.s.	n.s.	39	41	n.s.	n.s.	41
	Total larvae			0	0			0
	Larval density (No./100m^3)							
42-44	River mile	n.s.	42	44	43	n.s.	43	42
	Total larvae		1	0	0		0	0
	Larval density (No./100m^3)		1.8					
45-47	River mile	46	47	45	45	45	47	46
	Total larvae	0	1	0	1	0	0	0
	Larval density (No./100m^3)		2.0		2.7			
48-50	River mile	49	50	48	50	50	49	50
	Total larvae	0	0	0	0	0	0	0
	Larval density (No./100m^3)							
51-53	River mile	53	53	51	53	53	53	53
	Total larvae	0	0	0	0	0	0	0
	Larval density (No./100m^3)							
54-56	River mile	56	55	55	55	56	54	55
	Total larvae	0	1	0	0	0	0	0
	Larval density (No./100m^3)		15.9					
57-59	River mile	59	59	59	57	58	57	57
	Total larvae	0	0	0	0	0	0	0
	Larval density (No./100m^3)							
60-62	River mile	62	61	62	61	62	62	60
	Total larvae	0	1	0	0	0	0	0
	Larval density (No./100m^3)		17.5					

River mile Stratum		6/1	6/4	6/8	6/11	6/14	6/17	6/23
63-65	River mile	n.s.	63	64	63	n.s.	65	64
	Total larvae		0	0	0		0	0
	Larval density (No./100m3)							
66-68	River mile	n.s.	67	66	67	n.s.	n.s.	66
	Total larvae		0	0	0			
	Larval density (No./100m^3)							1.0

Table 10. Length frequency distribution of <u>Morone saxatilis</u> larvae captured in the Rappahannock River, Spring 1982.

Size Range (mm)	4/8	4/16	4/21	4/23	4/30	5/4	5/11	5/14	5/18	5/21	5/25	6/4	6/11	6/23	Total
2.0- 2.9					2	1									3
3.0- 3.9	3	2	70	86	124	24	1								310
4.0- 4.9	1	17	364	243	527	61	11	3							1227
5.0- 5.9		39	124	387	436	407	106	105							1604
6.0- 6.9			11	29	305	293	114	192	3						947
7.0- 7.9					24	135	68	134	8						370
8.0- 8.9					1	12	77	82	5	9	1				188
9.0- 9.9							12	57		7	2				78
10.0-10.9							1	22		7	2				32
11.0-11.9								1	1	3	1				6
12.0-12.9									1	5	3				9
13.0-13.9										2	3				5
14.0-14.9										1	1	1			3
15.0-15.9										1	1	1			3
16.0-16.9											2	1			3
17.0-17.9															0
18.0-18.9															0
19.0-19.9												1		1	2

Table 10. Continued.

Size Range (mm)	4/8	4/16	4/21	4/23	4/30	5/4	5/11	5/14	5/18	5/21	5/25	6/4	6/11	6/23	Total
20.0-20.9															0
21.0-21.9													1	1	2
TOTAL	4	58	569	745	1419	933	390	596	18	35	16	4	1	2	4792

Peak abundances of small larvae (yolk-sac stages) generally coincided with egg distributions in spatial extent, but by 30 April 1982 larvae were larger (Table 10), and were widely distributed throughout the sampling area (Fig. 4). No spatial trends related to size or time of capture were apparent.

Length frequency data (Table 10) indicated that fishes greater than 10.9 mm SL were only occasionally taken by the plankton gear. This probably results from lower densities of these size classes, schooling (and resulting greater contagion), increased ability to avoid the gear, assumption of a non-pelagic habit, or some combination of these factors. Fishes in size classes between 3.0 mm NL and 9.0 mm SL formed the bulk of the larval collections (Table 10, Fig. 5). By 14 May 1982, yolk sac larvae (2.0 - 4.9 mm NL) were almost completely absent from collections (Table 10, Figs. 5, 6). A decided temporal progression in median size was observed until the completion of the sampling period.

DISCUSSION

Throughout the 3-year assessment of larval striped bass stocks in Virginia Rivers (NMFS Grant No. NA80FAD-VA1B; NA81FAD-VA3B and NA81FAD-VA5B), confirmed identification of larvae has been a priority concern. We have chosen to remain conservative in our analysis and have reported progress in using larval osteology as identification criteria in previous years (Grant and Olney 1981, 1982). During the final period of "Emergency Striped Bass Study" support, we have refined our techniques and summarized our findings in a manuscript, submitted to Transactions of the American Fisheries Society and partially supported

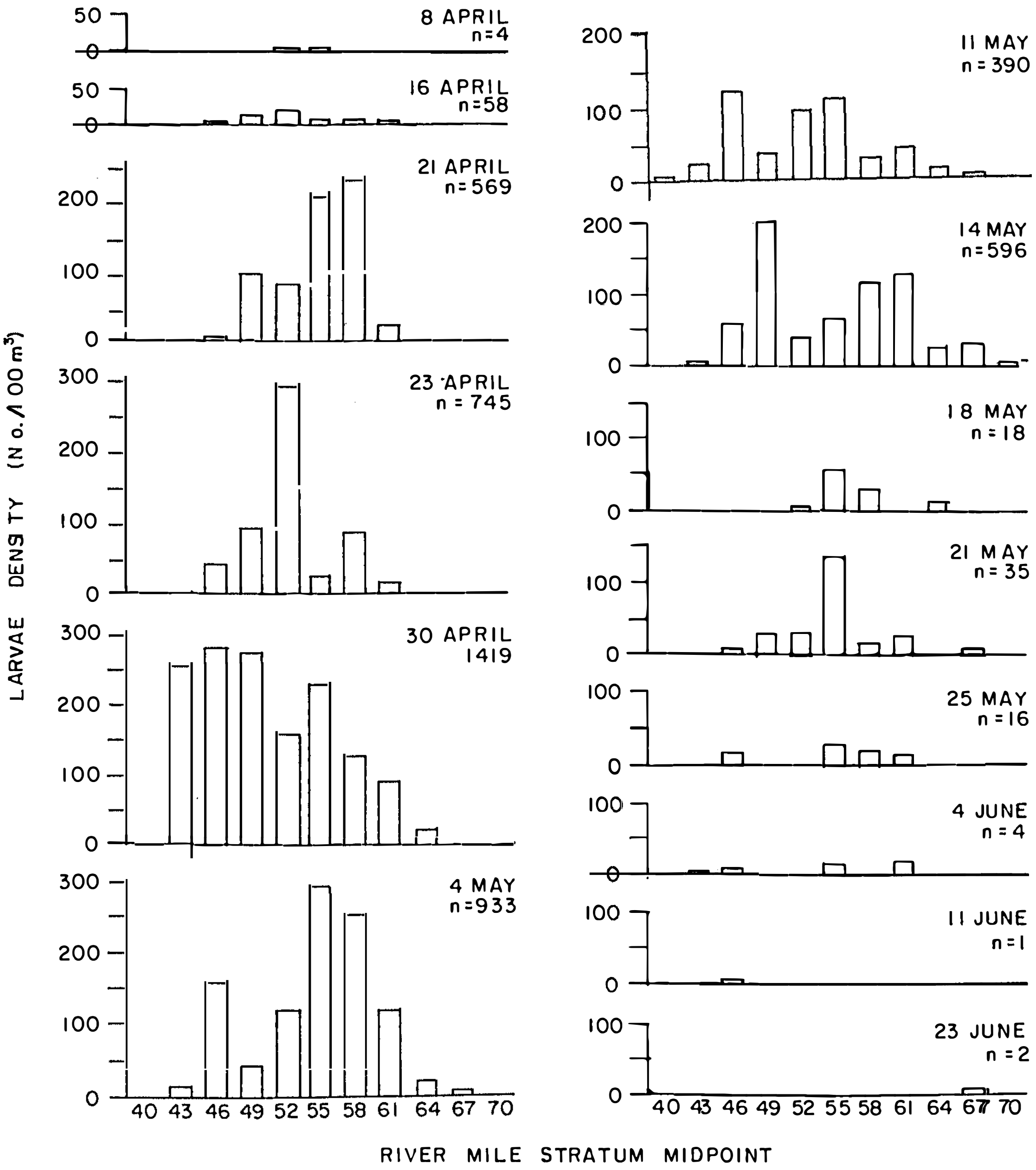

Fig. 4. Distribution and abundance of striped bass larvae, Rappahannock River, spring 1982.

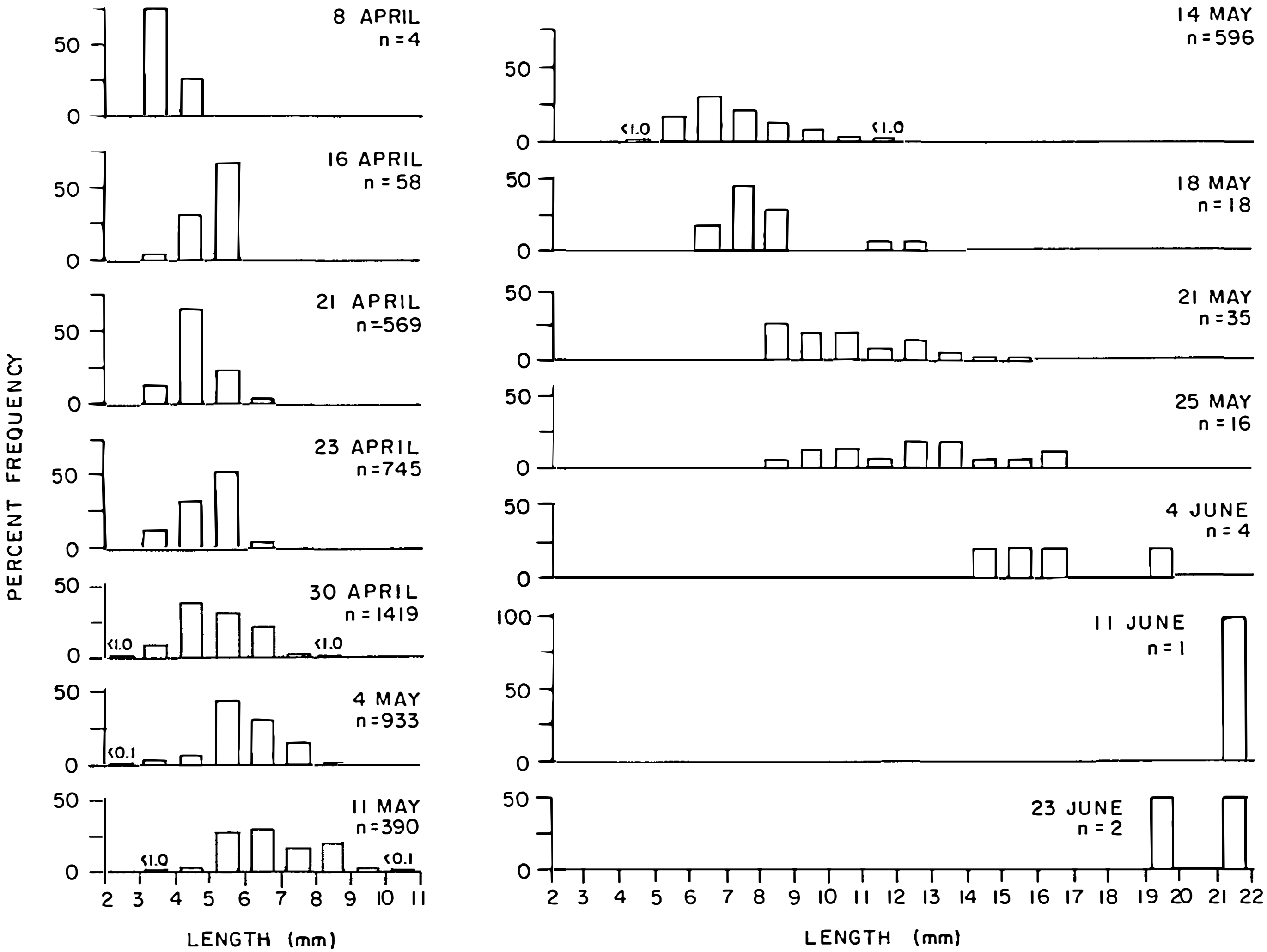

Fig. 5. Length frequency of striped bass larvae, Rappahannock River, spring 1982.

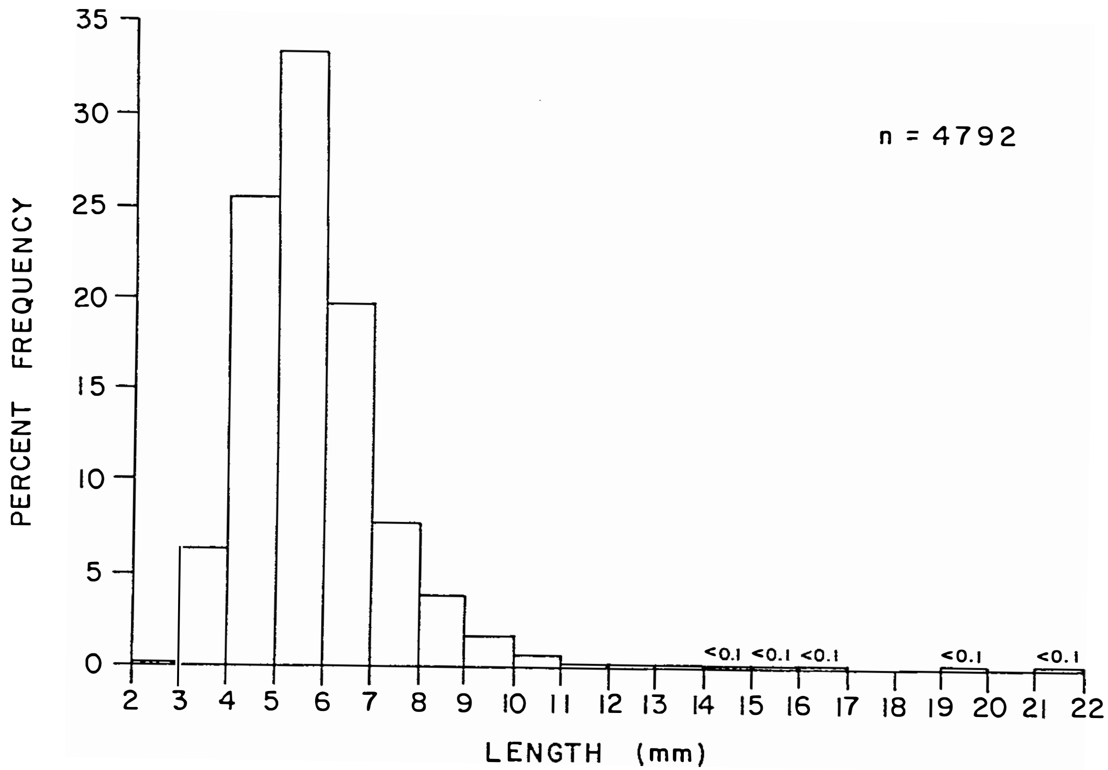

Fig. 6. Cumulative length frequency of striped bass larvae, Rappahannock River, spring 1982.

Table 11. Summary of striped bass egg and larval survey data from major Virginia tributaries, 1980-1982.

	PAMUNKEY	MATTAPONI	JAMES	RAPPAHANNOCK
First Sampling Date	16 Apr 1980	18 Apr 1980	22 Apr 1981	5 Apr 1982
Last Sampling Date	13 Jun 1980	14 Jun 1980	18 Jun 1981	23 Jun 1982
Total Survey Cruises	13	13	9	19
Total Stations	108	100	123	174
Total Eggs	500	720	428	1976
Total Larvae	162	153	431	4792

by the present contract. This manuscript is appended, and support is acknowledged.

Results of striped bass egg and larval surveys in the major tributaries of Virginia are summarized in Table 11. Comparisons of egg and larval data resulting from these three surveys of the four primary spawning areas are inappropriate since the data are disjunct and do not take into account year to year fluctuations in each spawning area or relative contribution of each river to the annual spawn. The disproportionate contribution of the Rappahannock River in this data set (Table 11) is certainly artifactual. No data exist on spawning activity or larval concentrations in the James or York River systems during 1982, a season of apparent order of magnitude differences in spawning intensity and success relative to the two preceding seasons. Further simultaneous surveys of spawning activity in the James, York and Rappahannock Rivers, based on the results of these pilot studies, are needed to answer questions of relative contribution and annual variability.

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Appendix I.

Olney, J. E., G. C. Grant, F. E. Schultz, C. L. Cooper and J. Hageman. In Press. Dorsal anal pterygiophore interdigitation patterns in four species of *Morone* (Teleostei, Percichthyidae) - an aid to larval identification. *Trans. Amer. Fish. Soc.*

Dorsal and anal pterygiophore interdigitation patterns in four species of *Morone* (Teleostei, Percichthyidae) - An aid to larval identification[1,2]

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ABSTRACT

The diagnostic potential of dorsal and anal pterygiophore interdigitation patterns was examined in larval stages of *Morone saxatilis, M. chrysops, M. americana* and *M. mississippiensis.* The number and position of pterygiophores relative to interneural spaces 1-6 and 10-13 and interhaemal spaces 12-15 as well as total number of dorsal and anal pterygiophores are characters useful in delimiting larvae of American *Morone* species. Interdigitation patterns useful in separating *M. mississippiensis* and *M. americana* larvae were not found, however these two species may not co-occur.

The genus Morone Mitchill comprises four American species (Robins et al. 1980; Setzler et al. 1980): M. americana (Gmelin), white perch; M. saxatilis (Walbaum,), striped bass; M. chrysops (Rafinesque), white bass; and M. mississippiensis Jordan and Eigenmann, yellow bass. Representatives of the genus can be found in both freshwater and marine habitats where species pairs are sympatric throughout much of the range. Morone mississippiensis and M. chrysops naturally co-occur along the Mississippi River drainage, Texas and Oklahoma with M. chrysops also inhabiting the Great Lakes (Hubbs and Lagler 1964). Morone americana and M. saxatilis inhabit the Atlantic coastline (Hildebrand and Schroeder 1928; Bigelow and Schroeder 1953; Scott and Crossman 1973; Lee et al. 1978) and M. saxatilis has been introduced along the Pacific coast (Setzler et al. 1980). Recent evidence indicates that M. americana and M. chrysops now are sympatric in the Great Lakes region (Scott and Christie 1963; Scott and Crossman 1973; Lee et al. 1978).

Difficulty in identifying larvae of the various Morone species has prompted extensive efforts to describe diagnostic external characters (Fish 1932; Yellayi and Kilambi 1969; Dorsa and Fritzche 1979; Schultz 1980; Mansueti 1958; Doroshev 1970; Hardy 1978; Drewry 1981; and others). However, genetic, environmental and preservative induced character variability may be responsible for continued identification error. Recently, Fritzsche and Johnson (1980) described osteological characters useful in the identification of two of the four American Morone species. Based primarily on cultured material, Fritzche and Johnson (1980) relied on the morphology and position of rostral and predorsal cartilages and anterior anal and dorsal fin pterygiophores to separate larval white perch and striped bass. Since the arrangement of pterygiophores, spines and rays has been shown to be useful in delimiting various teleostean fishes (Matsui 1967; Potthoff 1974, 1975, 1980; Houde and Potthoff 1976), we have examined the position of pterygiophores in relation to vertebrae in the larvae of *M. saxatilis*, *M. chrysops*, *M. americana* and *M. mississippiensis* in a search for diagnostic patterns. Our purpose was to confirm the observations of Fritzche and Johnson (1980) using wild material, quantify the natural variability in this suite of characters and expand the analysis to include all American *Morone* species.

METHODS

Specimens (N=185) utilized for this study were obtained from a variety of sources. All specimens, with the exception of two larval yellow bass (*M. mississippiensis*; 11, 18 mm SL) which were raised from eggs under laboratory conditions, were collected by plankton net. Institutional abbreviations used are: VIMS - Virginia Institute of Marine Science; CBL - Chesapeake Biological Laboratory, Solomons, Maryland; CLEAR - Center for Lake Erie Research; SAI - Steimle and Associates, Inc. In the following list, we record species name, number of larvae examined (N), institutional source, collection locale, date of collection, and length range of specimens examined (measured with an ocular micrometer and reported in mm SL): *Morone saxatilis*, N = 20, VIMS, York R., Virginia, spring, 1980, 11.3 - 17.1; *Morone saxatilis*, N = 20, CBL, Potomac R., Maryland, spring, 1980, 10.4 - 14.5; Morone americana, N = 50, VIMS, York R., Virginia, spring 1980, 10.8 - 20.0; Morone mississipiensis, N = 28, SAI, river systems in southern Louisiana, spring 1976-1979, 10.0 -16.1; Morone chrysops, N = 25, SAI, river systems in the southern Louisiana, spring 1976-1979, 9.9 - 19.4; Morone chrysops, N = 40, CLEAR , Lake Erie, spring 1974, 11.6 - 19.6.

Larvae were cleared and stained following the methods of Dingerkus and Uhler (1977) and examined in 50% glycerin under a binocular microscope. Predorsal bone (or cartilage) and dorsal or anal pterygiophore interdigitation were determined following the methods of Potthoff (1975, 1980) and Houde and Potthoff (1976). The number and position of these elements relative to interneural or interhaemal spaces (Fig. 1) were recorded for each specimen and digit sequences were later analysed using computer pattern recognition. Occasionally, the proximal tip of an anal or dorsal pterygiophore would coincide closely with the distal tip of its associated neural or haemal spine. In these instances, the position of the fin element was difficult to determine but recorded in the anterior-most interneural or interhaemal space.

RESULTS

Dorsal Fin Pterygiophores

The position of the first dorsal-spine bearing pterygiophore and the presence or absence of a pterygiophore in interneural space 10 or 11 (INS 10 or INS 11) are characters which delimit the larvae of Morone saxatilis, M. chrysops, M. americana, and M. mississippiensis

(Fig. 1). In larvae of M. saxatilis, the first dorsal pterygiophore is most frequently positioned in INS 4, posterior to the third neural spine (Fig. 1; Fritzsche and Johnson 1980). This element is anterior to the third neural spine in larvae of M. americana, M. chrysops and M. mississipiensis, and most frequently occupies INS 3 together with the third (or most posterior) predorsal bone (or cartilage). In our sample of 185 specimens, 12 patterns of predorsal and pterygiophore interdigitation were observed within interneural spaces 1-6 (Table 1). Of the four patterns observed in larvae of M. saxatilis, three were characteristic of striped bass only and occurred in 87.5% (35/40) of the sample. Only one pattern (of 9 observed) was common in larvae of M. chrysops, M. americana and M. mississippiensis (Table 1), occurring in percent frequencies of 78%, 84% and 77%, respectively.

The absence of a pterygiophore in INS 10 or INS 11 is a useful character identifying larval white perch and yellow bass (Fig. 1, Table 2). In our sample, eleven patterns of pterygiophore interdigitation were observed within interneural spaces 10-13 (Table 2). Patterns without blank interneural spaces characterized all larvae of M. saxatilis and M. chrysops and only 2.5% (2/80) of the combined sample of M. americana and M. mississippiensis larvae. The absence of a pterygiophore in INS 10 was the predominant pattern in larvae of white perch and yellow bass, occurring in 89% (71/80) of our combined sample (Table 2). Since pterygiophores of the soft dorsal fin first appear as cartilage (Fritzsche and Johnson 1980), the absence of a pterygiophore in INS 10 is diagnostic of Morone larvae in early stages of development (Fig. 2). Although incompletely developed, M. saxatilis flexion larvae 8.5 - 9.0 mm SL/NL are recognizable since the ventral tips of the proximal radial (Fig. 2, PR2) supporting the second soft ray lies anterior to the vertical plane extended from the tip of the eleventh neural spine (Fig. 2), 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. Although not figured, these characters separate early larvae of M. chrysops and M. mississippiensis as well.

Excluding three predorsal elements, Morone larvae in our sample possessed 19-23 total dorsal pterygiophores (Table 3). As detailed by Fritzche and Johnson (1980), the anterior eight pterygiophores support 10 spines of varying lengths. The remaining elements support soft rays (Fig. 1). Although total counts overlapped among the four species, M. chrysops larvae possessed modal counts which exceeded those of all other species (Table 3).

Anal Fin Pterygiophores

The number and positon of pterygiophores within interhaemal spaces 12-15 separate larvae of M. saxatilis and M. chrysops from M. americana and M. mississippiensis (Table 4, Fig. 1). In our sample of 185 larvae, 17 patterns of interdigitation were observed (Table 4) and, with the exception of five specimens, pattern overlap between the above-named species pairs did not occur. Six patterns within interhaemal spaces 12-15 occurred in larval striped bass and white bass and were characterized by the absence of the anterior spine-bearing pterygiophore in interhaemal space 12 (IHS 12). This element was most frequently positioned together with the first soft ray-bearing pterygiophore in IHS 13. In larval white perch (as well as yellow bass), the first anal pterygiophore is notably longer and more massive than in striped bass and this relative difference becomes exaggerated with growth (Fritzsche and Johnson 1980). As a result, greater variability in interdigitation patterns was observed in _M. americana_ larvae (Table 4) since the proximal tip of this stout element often extended into IHS 12.

In our sample, specimens possessed 9-14 total anal pterygiophores. The first anal element supports three spines with succeeding pterygiophores supporting soft rays (Fig. 1). Larvae of _M. chrysops_ were distinguishable from those of _M. americana_ and _M. mississippiensis_ by virtue of total counts (Table 3). In addition, total anal element counts of striped bass exceeded those of yellow bass.

DISCUSSION

The diagnostic potential of pterygiophore interdigitation patterns in the genus _Morone_ was first recognized by Woolcott (1957) in an examination of adult osteology. Although unable to detect useful anal pterygiophore patterns, Woolcott (1957) demonstrated differences in total dorsal pterygiophore counts and the location of certain elements in relation to neural spines. It is not surprising, therefore, that our results and those of Fritzche and Johnson (1980) illustrate the utility of this suite of characters in identifying young stages of American *Morone* species. Indeed, the number and position of anal and dorsal pterygiophores in relation to vertebrae are characters which have been successfully used to delimit larval scombrids (Matsui 1967; Potthoff 1974, 1975), larval sparids (Houde and Potthoff 1976) and larval coryphaenids (Potthoff 1980). An important consideration in these studies, however, is the extent to which natural variability affects character utility. Previous investigations (Matsui 1967; Potthoff 1974, 1975; Houde and Potthoff 1976) have emphasized variability (expressed as percent occurrence) of a particular pterygiophore number in a single interhaemal or interneural space. Our data indicate that patterns of interdigitation (ie, sequence of pterygiophore numbers in more than one space), when judiciously chosen, exhibit less variability and are more useful as diagnostic characters.

Throughout our examination, we could not find interdigitation patterns which would delimit the larvae of white perch and yellow bass and total element overlap was great. Woolcott (1957) was unable to separate *M. mississippiensis* and *M. americana* adults using a variety of osteological characters but Whitehead and Wheeler (1966) delimit the species based on dorsal spine length and adult pigmentation. The extent to which these nominal species are sympatric is unknown, however current distributional data (Lee et al. 1978) do not indicate geographic overlap.

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FOOTNOTES

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Table 1. Patterns of predorsal and pterygiophore interdigitation within interneural spaces 1-6 in a sample of 185 Morone larvae. Abbreviations used are: P - predorsal bone (or cartilage), MS - M. saxatilis, MC - M. chrysops, MA - M. americana, MM - M. mississippiensis.

INTERNEURAL SPACE						PATTERN FREQUENCY			
1	2	3	4	5	6	MS	MC	MA	MM
P	P	P	2	1	2	19			
P	P	P	2	2	1	15			
P	P	P	1	2	2	1			
P	P	P+1	1	2	1	5	51	42	23
P	P	P+1	2	1	1		5	4	4
P	P	P+2	1	2	1		5		
P	P	P+2	2	1	1		2		
P	P	P+1	1	1	2		1		
P	0	PP+1	1	2	1		1		
P	PP	1	1	2	1			3	2
P	PP	1	2	1	1			1	
P	P	P+1	3	1	1				1
					TOTAL	40	65	50	30

Table 2. Patterns of pterygiophore interdigitation within interneural spaces 10-13 in a sample of 185 *Morone* larvae. Abbreviations used are MS - *M. saxatilis*, MC - *M. chrysops*, MA - *M. americana*, MM - *M. mississippiensis*.

INTERNEURAL SPACE				PATTERN FREQUENCY			
10	11	12	13	MS	MC	MA	MM
1	1	1	2	34	52	2	
1	1	2	1	3			
1	1	1	3	1	11		
1	1	2	2	2	1		
2	1	1	2		1		
1	0	2	2			17	2
1	0	1	2			16	6
1	0	2	1			14	15
0	1	1	2			1	3
0	1	2	1				3
1	0	1	3				1
			TOTAL	40	65	50	30

Table 3. Frequency of total dorsal and anal pterygiophores in a sample of 185 *Morone* larvae. Total dorsal element counts exclude predorsal bones.

	ANAL FIN						DORSAL FIN				
Total Pterygiophores	9	10	11	12	13	14	19	20	21	22	23
M. saxatilis			3	37			6	32	2		
M. chrysops				10	52	2		3	45	15	2
M. americana		33	17				5	45			
M. mississippiensis	3	27					69	11			

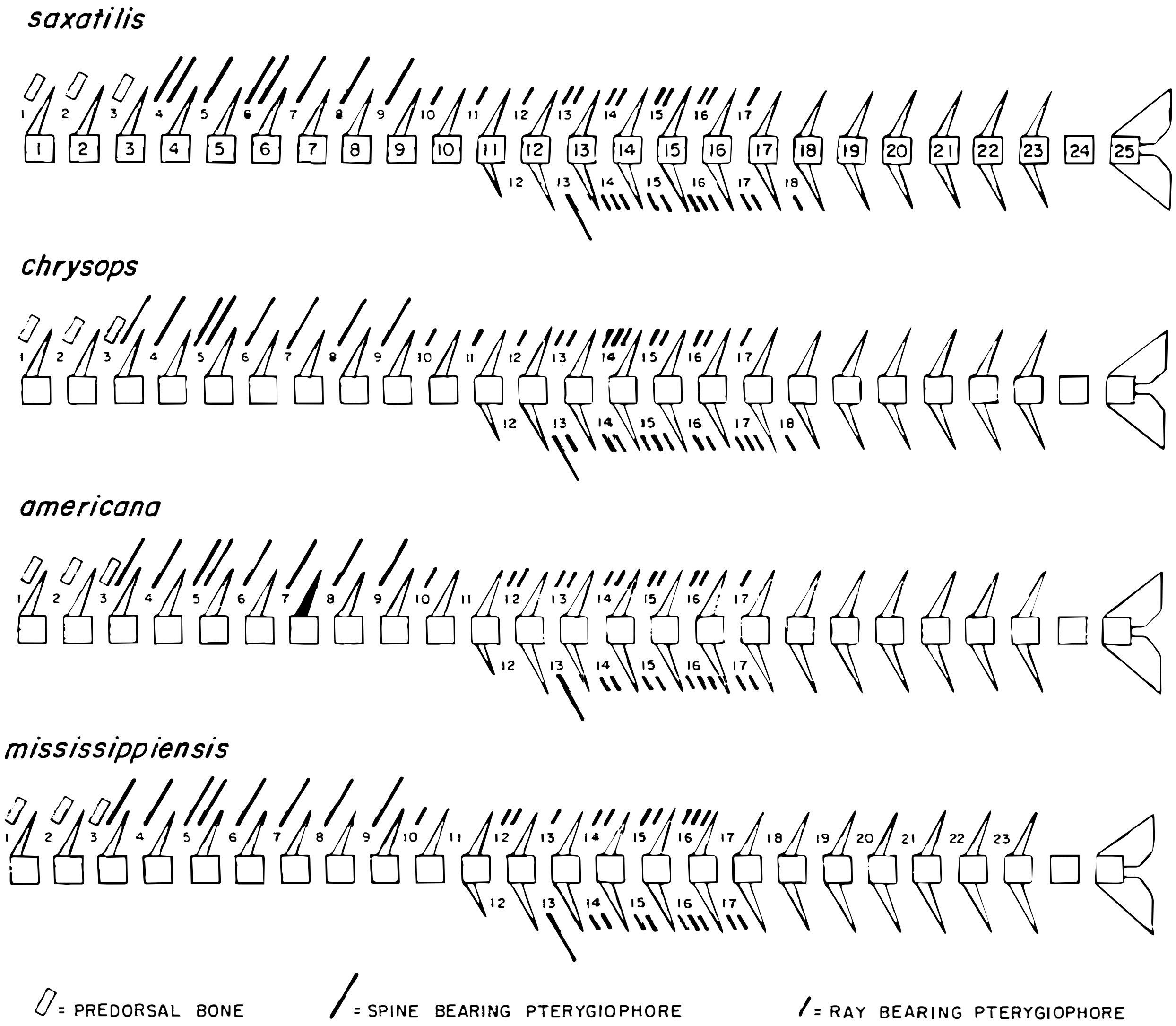
Table 4. Patterns of pterygiophore interdigitation within interhaemal spaces 12-15 in a sample of 185 *Morone* larvae. Abbreviations used are MS - *M. saxatilis*, MC - *M. chrysops*, MA - *M. americana*, MM - *M. mississippiensis*.

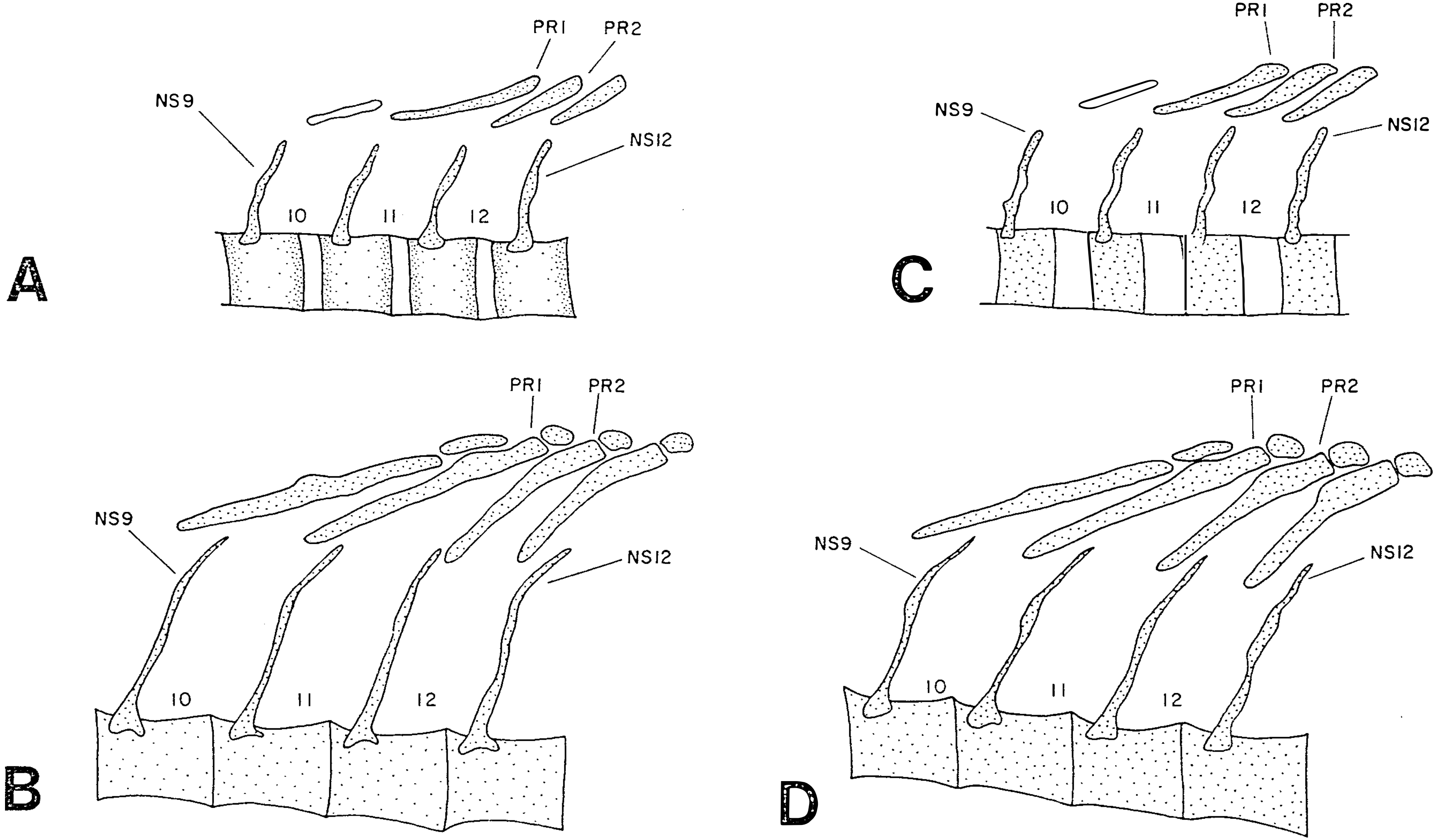
INTERHAEMAL SPACE				PATTERN FREQUENCY			
12	13	14	15	MS	MC	MA	MM
0	1	3	2	16	1	1	2
0	2	2	3	12	32		
0	2	2	2	8	31		
0	1	3	3	2			
0	2	3	2		1		
0	1	2	3	2		6	7
0	1	2	2			28	17
1	0	2	2			7	
1	1	1	3			1	2
1	1	2	2			1	1
0	1	1	3				1
0	1	0	3			1	
0	1	1	2			1	
1	0	2	3			1	
1	0	3	2			1	
1	1	1	2			1	
0	2	1	2			1	
			TOTAL	40	65	50	30

FIGURE CAPTIONS

Figure 1. Diagramatic representation of the most frequently observed patterns of predorsal, dorsal and anal pterygiophore interdigitation in four species of *Morone.* Larger numerals indicate vertebral number. Smaller numerals indicate interneural or interhaemal space designation.

Figure 2. The arrangement of neural spines and dorsal pterygiophores in *Morone americana* (A-8.5 mm SL; B-11.2 mm SL) and *M. saxatilis* (C-8.5 mm SL; D-11.1 mm SL). Abbreviations used are NS9-neural spine of ninth vertebra; NS12 - neural spine of 12th vertebra; PR1 - proximal radial supporting the first soft ray of the second dorsal fin; PR2- proximal radial supporting the second soft ray of the second dorsal fin; numerals indicate respective interneural space designations. Stippling indicates positive stain reactions (Alcian Blue or Alizarin Red).


saxatilis
chrysops
americana
mississippiensis
= PREDORSAL BONE
= SPINE BEARING PTERYGIOPHORE
= RAY BEARING PTERYGIOPHORE


A
PR1
PR2
NS9
NS12
10
11
12
C
PR1
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10
11
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B
PR1
PR2
NS9
NS12
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D
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