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The Impact of Low Salinities on James River Oyster Populations 1979-1980

Dexter S. Haven
Virginia Institute of Marine Science

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ABSTRACT

During the fall, winter and spring of 1979-1980 there was an extensive and prolonged mortality of the 1979 set of oysters in the James River, Virginia. Yearling oysters died at lesser rates, with mortalities starting in mid-winter. Small oysters showed moderate to 100% mortalities at two locations. Market-sized oysters showed the lowest mortality. Deaths were associated with prolonged periods of low salinity.

INTRODUCTION

During much of 1979 and 1980 salinities in the James River, Virginia seed area were far below normal. A brief summary of events follows:

1. Salinities were below average during much of 1979 and through March 1980;
2. There was an excellent set over most of the seed area by late September 1979;
3. There was a subsequent heavy mortality of the 1979 set over wide areas; and,
4. There was a moderate to high mortality at several locations of yearlings (1978 set) and small oysters.

The seed area was sampled with an oyster dredge on six occasions from 20 September 1979 to 28 January 1980 (Table 1). Additionally, four series of samples were obtained from 10 April 1980 to 7 May 1980 (Table 2). Summaries of both periods, respectively, are shown in Tables 3 and 4. Data on numbers of oysters in the various size classes in Tables 1-4 shows considerable variation, as might be expected from dredged samples. However, the conclusions reached in this paper are based largely on trends and to a lesser extent on the absolute values.

Quality of James River Seed in 1979

In September of 1979 in the James River the quality of seed (total numbers of all sized oysters per bushel) was high. A summary

Table 1

1979-80 Survey of Oyster Rocks in the James River, Virginia. Data Shows Numbers of Oysters Per Bushel of Unculled Dredged Bottom Materials.[1, 2] The Period Covered is From 20 September 1979 to 28 January 1980.

Rock	9/20	10/15	1979 10/24	11/15	12/4	1980 1/28	Avg.
SPAT							
Deep Water Shoal	380	420	65	--	50	34	42
Horsehead Shoal	95	175	80	--	62	36	49
Point of Shoals	535	195	--	--	118	72	95
Wreck Shoal, Offshore	260	590	935	368	372	354	365
Wreck Shoal, Inshore	--	--	--	546	--	378	462
White Shoal	325	400	--	272	--	108	276
Brown Shoal	--	110	--	110	--	--	110
YEARLINGS							
Deep Water Shoal	305	140	240	--	144	362	238
Horsehead Shoal	185	215	100	--	144	174	164
Point of Shoals	340	185	--	--	84	94	176
Wreck Shoal, Offshore	505	555	520	362	324	354	437
Wreck Shoal, Inshore	--	--	--	502	--	450	476
White Shoal	245	195	--	196	--	142	194
Brown Shoal	--	85	--	116	--	--	100
SMALL OYSTERS							
Deep Water Shoal	260	385	590	--	586	288	422
Horsehead Shoal	525	400	730	--	330	356	468
Point of Shoals	270	440	--	--	298	304	328
Wreck Shoal, Offshore	385	480	370	422	436	464	426
Wreck Shoal, Inshore	--	--	--	466	--	456	461
White Shoal	285	300	--	300	--	268	288
Brown Shoal	--	185	--	160	--	--	172
MARKET OYSTERS							
Deep Water Shoal	0	0	10	--	52	4	13
Horsehead Shoal	30	45	50	--	56	56	47
Point of Shoals	40	125	--	--	70	76	78
Wreck Shoal, Offshore	155	55	95	84	88	104	97
Wreck Shoal, Inshore	--	--	--	90	--	94	92
White Shoal	75	95	--	86	--	150	101
Brown Shoal	--	115	--	184	--	--	149

Table 1 (Contd.)

[1]Samples from September 20, 1979 to October 24, 1979 based on 1/5 bushel; those collected later based on 1/2 bushel.

[2]Averages for spat (only) from November 15, 1979 to January 28, 1980 for all but White and Brown Shoals.

Table 2

1980 spring survey of oyster rocks in the James River, Virginia. Data show number of oysters per bushel of unculled dredged bottom material.[1]

Rock	4/10/80	4/24/80	5/2/80	5/7/80	Avg.
SPAT					
Deep Water Shoal	12	--	--	4	8
Horsehead Shoal	52	--	--	46	49
Point of Shoals	84	--	--	76	80
Wreck Shoal, Offshore	264	232	--	242	246
Wreck Shoal, Inshore	--	--	252	248	250
White Shoal	--	--	--	24	24
Brown Shoal	--	--	--	--	--
YEARLINGS					
Deep Water Shoal	224	--	--	146	185
Horsehead Shoal	144	--	--	140	142
Point of Shoals	104	--	--	98	101
Wreck Shoal, Offshore	330	318	--	340	239
Wreck Shoal, Inshore	--	--	440	404	422
White Shoal	--	--	--	108	108
Brown Shoal	--	--	--	--	--
SMALL OYSTERS					
Deep Water Shoal	244	--	--	200	222
Horsehead Shoal	334	--	--	342	338
Point of Shoals	320	--	--	308	314
Wreck Shoal, Offshore	442	456	--	456	451
Wreck Shoal, Inshore	--	--	414	462	438
White Shoal	--	--	--	362	362
Brown Shoal	--	--	--	--	--
MARKET					
Deep Water Shoal	2	--	--	2	2
Horsehead Shoal	52	--	--	48	50
Point of Shoals	72	--	--	80	76
Wreck Shoal, Offshore	98	108	--	106	104
Wreck Shoal, Inshore	--	--	152	102	127
White Shoal	--	--	--	78	78
Brown Shoal	--	--	--	--	--

[1]Data based on 1/2 bushel samples.

Table 3

Summary of fall and winter surveys public oyster rocks in the James River, Virginia. The data shows average numbers of oysters in one bushel of unculled bottom material. The period covered is September 20, 1979 to January 28, 1980[1] for market, small and yearlings. Data derived from Table 1.

Station	No. of Samples	Spat	Yearlings	Small	Market	Total Seed	% Boxes		Drills, Drilled spat or Drill eggs
							Total	Recent	
Nansemond Ridge	1	46	120	102	158	426	11	2	None
Brown Shoal	2	110	100	172	149	531	10	3	None
Naseway Shoal	1	361	184	223	75	843	3	2	None
Thomas Rock	1	262	280	224	166	934	2	1	None
Gun Rock	3	142	222	188	126	678	2	1	None
White Shoal	3	276	194	288	101	859	5	3	None
Wreck Shoal, Inshore	2	462	476	461	92	1491	4	3	None
Wreck Shoal, Offshore	6	365	437	426	97	1325	11	4	None
Point of Shoals	4	95	176	328	78	677	7	4	None
Horsehead Shoal	5	49	164	468	47	728	2	1	None
Deep Water Shoal	5	42	422	238	13	715	10	3	None

[1]The number of spat shown above for Deep Water Shoal, Horsehead Shoal, Point of Shoals and Wreck Shoals (inshore and offshore) are those collected from November 15, 1979 to January 28, 1980. This was after the initial freshwater mortality (see Table 1).

Table 4

Summary of 1980 spring survey of public oyster rocks in the James River, Virginia. The data shows average number of oysters in one bushel of unculled dredged bottom material. The period covered is from 10 April 1980 to 2 May 1980. Data derived from Table 2.

Station	Spat	Yearlings	Small Oysters	Market Oysters	Total Seed	% Boxes[1]		Drills, Drilled spat or Drill eggs
						Total	Recent	
Nansemond Ridge	--	--	--	--	--	--	--	--
Brown Shoal	--	--	--	--	--	--	--	--
Naseway Shoal	--	--	--	--	--	--	--	--
Gun Rock	--	--	--	--	--	--	--	--
White Shoal	24	108	362	78	572	4.2	1.8	None
Wreck Shoal, Inshore	250	422	438	127	1237	6.6	5.4	None
Wreck Shoal, Offshore	246	239	451	104	1040	8.9	7.0	None
Point of Shoals	80	101	314	76	571	5.0	4.3	None
Horsehead Shoal	49	142	338	50	579	5.4	4.4	None
Deep Water Shoal[1]	8	185	222	2	417	33.1	31.5	None

[1]Includes yearling boxes; the many spat boxes and scars not included!

of the 20 September 1979 to 28 January 1980 surveys showed totals ranging from 426 to 1491 oysters per bushel, with the highest counts in mid-river at Wreck Shoal (Table 3).

Spatfall and Mortality

A moderate to heavy spatfall occurred during July, August and early September 1979. It was river-wide, but was highest in the mid-seed area. At Wreck Shoal, a maximum of 935[1] spat per bushel was recorded on 24 October 1979 (Table 1).

Spat mortality seemed to begin between 15 and 24 October 1979 at Deep Water Shoal, Horsehead and perhaps slightly later at Point of Shoals. At Wreck Shoals and White Shoals it began gradually and later in the season, probably during late January 1980 (Table 1). It continued at all the preceding stations throughout the winter and into May 1980 (Table 2).

Table 5 (based on Tables 1 and 2) summarizes spat mortalities from the fall of 1979 through May 1980. In the 15 October 1979 to 28 January 1980 period mortalities of spat ranged from 89% at Deep Water Shoal to 14% at Wreck Shoal. By May 1980 mortality ranged from 98% at Deep Water Shoal to 42% at Wreck Shoal.

Spat mortalities did not decline in a regular manner in a downriver direction since a 93% mortality was observed at White Shoal.

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[1]This figures (935) may not represent a real increase over the 590 spat shown on 10/15/79, but may simply be variation due to sampling (see text on page 14 on termination of set).

Table 5

Average spat density on bottom cultch associated with low salinities in the James River, Virginia. Data shown are for number of spat per bushel of unculled dredged bottom material.[1]

Station	Average Spat Count			Cumulative % Mortality to:	
	9/20/79 to 10/15/79	11/15/79 to 1/28/80	4/10/80 to 5/7/80	1/28/80	5/7/80
Deep Water Shoal[2]	400	42	8	89	98
Horsehead Shoal	135	49	49	64	64
Point of Shoal	365	95	80	74	78
Wreck Shoal, Offshore	425	365	246	14	42
Wreck Shoal, Inshore	--	462	250	--	46
White Shoal	362	190	24	48	93

[1]Data derived from Tables 1 and 2. This tabulation omits data for 10/24/79 since it is a mid-point in the mortality.

[2]A study on 6/9/80 showed all oysters dead at Deep Water Shoal.

Depth in relation to salinity is probably a factor. White Shoal is located at about 6 ft MLW and Wreck Shoal at about 14 ft MLW. However, acclimation in relation to the magnitude of the salinity change may also be involved.

On 9 June 1980 oysters at Deep Water Shoal were examined again. Oysters in all size classes had died. An inspection of oysters from Horsehead to White Shoal on this date showed all were growing (new bills) with few if any recent mortalities.

Mortalities of Yearlings, Small Oysters and Market Oysters

Yearling oysters showed substantial mortalities at Deep Water Shoals, Horsehead, Point of Shoals, Wreck Shoals and at White Shoals. The variation in numbers of oysters per bushel with season does not permit stating the exact period when mortalities began. However, an inspection of Tables 1 and 2 suggests its onset was very gradual and that it may have began in late December 1979 or during January or February 1980. By May 7, 1980 average mortality from Deep Water Shoals to White Shoals ranged from 11% to 45% (Table 6). Again, as for spat there was no obvious pattern to those mortalities in respect to their location in the estuary (up or downriver).

Small oysters showed the delayed mortality pattern exhibited by yearling oysters. However, mortalities were high at only two upriver stations (Deep Water Shoals and Horsehead Shoals). These mortalities were respectively 47% and 28%. Downriver there was no evidence of a mortality (Table 6).

Table 6

Mortalities of small, juvenile and market oysters in the James River, Virginia. Data are calculated from Tables 1 and 2.

Station	Average Counts of Oysters/Bu 9/20/79 to 1/28/80	4/10/80 to 5/7/80	% Change
	YEARLINGS		
Deep Water Shoal	238	185	-22
Horsehead Shoal	164	142	-13
Point of Shoals	176	101	-43
Wreck Shoal, Offshore	437	239	-45
Wreck Shoal, Inshore	476	422	-11
White Shoal	194	108	-44
	SMALL OYSTERS		
Deep Water Shoal	422	222	-47
Horsehead Shoal	468	338	-28
Point of Shoal	328	314	- 4
Wreck Shoal, Offshore	426	451	+ 6
Wreck Shoal, Inshore	461	438	- 5
White Shoal	288	362	+20
	MARKET OYSTERS		
Deep Water Shoal	13	2	-85
Horsehead Shoal	47	50	+ 6
Point of Shoals	78	76	- 2
Wreck Shoal, Offshore	97	104	+ 7
Wreck Shoal, Inshore	92	127	+38
White Shoal	101	78	-23

Market oysters by May 7, 1980 showed an 85% average mortality at Deep Water Shoal; all sizes were dead by 9 June 1980. Other stations showed no evidence of mortality.

Box Counts as Indicators of Mortality

During the winter and spring months visual observation showed that spat scars and spat boxes were numerous especially at Deep Water Shoal and Horsehead. However, quantitative data were not obtained.

Number of yearlings, small oysters, and market oysters boxes was observed during the 20 September 1979 to 28 January 1980 period. Percent boxes ranged from 2 to 11%. Later, from 10 April 1980 to 2 May 1980 box counts (with one exception) ranged from 4.2 to 8.9%. Only at Deep Water Shoal were they high at 33.1% (Tables 3 and 4). The reason for these low numbers in relation to mortalities based on numbers of live oysters is not apparent, but the small juvenile boxes probably separated prior to being sampled.

Size of Spat and Yearling Oysters

Because of low salinities the 1979 set had not grown very large by the 20 September to 24 October 1979 period (Table 7). An inspection of these data show little difference in size from Deep Water Shoal to Brown Shoal. The modal size of all areas was in the 6 to 10.9 mm size interval; mean length ranged from 9.7 to 10.8 mm. By the 10 April to 7 May 1980 period the 1979 spat averaged about 6 mm larger than in late fall 1979 (Table 8). Most were in the 16 to

Table 7

Size frequency, mean size and % total of spat and yearling oysters collected from 20 September 1979 to 24 October 1979 from various oyster rocks in the James River, Virginia.

Length Interval mm	Station: Deep Water Shoal		Horsehead Shoal		Point of Shoals		Wreck Shoal, Offshore		White Shoal		Brown Shoal		Total All Sizes		% Total All Sizes	
	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr
0- 5					2		8				1		11		3.8	
6-10	33		25		35		43		34		11		181		62.2	
11-15	13		13		9		17		14		9		75		25.8	
16-20	4		6		4		7		2		1		24		8.2	
21-25								4						4		5.3
26-30		11		12				7						30		40.0
31-35		14		12				12						38		50.7
36-40				1				2						3		4.0
41-45																
46-50																
51-55																
56-60																
Total	50	25	44	25	50	--	75	25	50	--	22	--	291	75	--	--
Mean	10.1	29.3	10.8	30.1	9.8	--	9.7	30.1	9.8	--	10.2	--	10.0	30.2	--	--

Table 8

Size frequency, mean size and percent total of spat and yearling oysters collected from 10 April 1980 to 7 May 1980[1] from various oyster rocks in the James River, Virginia.

Length in mm	Station: Deep Water Shoal		Horsehead Shoal		Point of Shoals		Wreck Shoal, Offshore		Wreck Shoal, Inshore		White Shoal		Brown Shoal		Total-All Lengths		% Total All Lengths	
	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr	Sp	Yr
0- 5																		
6-10	1		3				1		12		5		--	--	22		15.7	
11-15			7		9		8		13		6		--	--	43		30.7	
16-20	1	1	13		11		12		19		1		--	--	57	1	40.7	0.6
21-25		5	3	2	5		4		6			2	--	--	18	9	12.9	5.3
26-30		8		5		8		6		10		6	--	--		43		25.3
31-35		9		13		8		10		16		13	--	--		69		40.6
36-40		2		4		8		7		11		4	--	--		36		21.2
41-45				1		1		2		7			--	--		11		6.5
46-50										1			--	--		1		0.6
51-55																		
56-60																		
No. Measured	2	25	26	25	25	25	25	25	50	45	12	25	--	--	140	170	--	--
Mean Size	13.3	29.4	16.1	31.9	16.8	32.8	16.9	33.6	15.0	35.4	12.1	31.8	--	--	15.6	32.9	--	--

[1] Data on lengths in raw data file collected in December 1979; January 1980 are not shown in this table since they represent a mid-period in the mortality.

20.9 mm size interval; mean size for the stations ranged from 12.1 to 16.8 mm.

In the fall of 1979 the modal length of yearling oysters was in the 31-35.9 mm size interval; mean lengths at the various stations ranged from 29.3 to 30.2 mm (Table 7). By the spring of 1980 little growth had occurred. Modal length was still in the 31-35.9 mm interval; mean length ranged from 29.4 to 35.4 mm (Table 8).

In almost all instances juveniles were separable from the 1979 set on the basis of size. The yearlings were small for their age and if measurements had not been made over a long period they could easily be confused with the 1979 set.

Salinity

Salinities (surface and bottom) were collected at intervals over the principle oyster rocks from 7 March 1979 to 9 June 1980 (Table 9). The salinity measurements were made, (in some instances) a month or more apart and there is a possibility of higher or lower values occurred during the interval. The consistancy of occurrence of low salinities, however, suggests that values did remain low over most of the period.

In discussing these salinities it is recognized that oysters show little feeding activity or growth below 5.0 ppt.

Salinities in the James River were already at record low levels by 3 March 1979 when this study began. Water temperatures were low, however, and the oysters were not active. By 16 May 1979 when

Table 9

James River salinities over the oyster bars from March 7, 1979 to May 2, 1980.[1]

	1979												
Tidal Stage	3/7 Ebb	4/12 Fl.	5/16 Fl.	6/14 Ebb	8/3 --	9/20 Fl.	9/26 Fl.	10/2 Ebb	10/10 --	10/15 Ebb	10/22 Fl.	10/24 Fl.	10/30 Ebb
Deep Water Shoal													
Surface	0.1	--	--	--	--	3.5	--	0.1	--	0.4	--	1.4	2.7
Bottom	0.1	--	--	--	--	3.6	--	0.4	--	0.4	--	1.7	3.2
Horsehead Shoal													
Surface	0.1	3.0	1.7	0.5	7.8	5.0	0.1	--	--	1.4	--	3.6	3.4
Bottom	0.1	3.4	2.1	0.6	8.1	5.2	--	--	--	3.3	--	4.4	5.0
Point of Shoals													
Surface	0.1	4.0	1.9	0.5	7.7	6.3	0.2	--	--	1.2	--	--	3.7
Bottom	0.1	4.2	1.9	0.5	9.0	6.7	--	--	--	1.2	--	--	3.7
Wreck Shoal													
Surface	0.2	9.2	7.0	4.2	11.0	10.7	1.2	1.9	1.5	1.7	--	9.2	7.4
Bottom	0.2	11.1	7.3	4.4	12.7	14.9	--	7.2	2.0	3.5	--	10.4	8.8
White Shoal													
Surface	0.7	10.3	8.2	6.3	13.5	10.4	--	--	--	2.2	--	--	8.4
Bottom	0.7	12.0	9.2	6.5	13.6	10.8	--	--	--	9.3	--	--	12.6
Brown Shoal													
Surface	--	--	--	--	--	--	1.5	6.6	--	5.0	6.8	--	--
Bottom	--	--	--	--	--	--	--	7.4	--	8.6	--	--	--

Table 9 (Contd.)

Data on salinity in the James River 1979-80.

	12/10	1/17	1/28	2/14	3/19	4/10	4/23	5/2	6/9
Tidal Stage	Low Slack	Late Flood	Ebb	Ebb	Late Ebb	Ebb	Ebb	Flood	Ebb
Deep Water Shoal									
Surface	0.1	3.4	0.6	--	--	0.1	--	--	2.5
Bottom	0.1	3.9	0.7	--	--	0.2	--	--	2.6
Horsehead Shoal									
Surface	1.4	6.2	0.9	8.4	0.9	0.5	--	1.9	6.0
Bottom	1.7	6.3	1.8	10.4	1.1	0.5	--	2.3	7.9
Point of Shoals									
Surface	1.1	6.2	0.4	7.9	2.3	0.6	--	1.5	6.8
Bottom	1.4	6.3	0.4	9.2	2.3	0.6	--	1.9	8.7
Wreck Shoal									
Surface	1.9	10.6	4.7	13.2	7.9	3.3	1.5	6.3	6.9
Bottom	11.5	12.2	4.8	14.0	7.9	10.9	7.1	10.3	13.5
White Shoal									
Surface	5.7	10.3	--	13.3	9.0	4.2	--	5.9	11.9
Bottom	5.9	15.0	--	13.3	9.1	6.2	--	8.8	14.4
Brown Shoal									
Surface	--	--	--	--	--	--	--	--	--
Bottom	--	--	--	--	--	--	--	--	--

[1]Titrated by Department of Ecology-Pollution.

oysters are normally fully active, the bottom salinities were 2.1 °/oo or lower at Deep Water Shoal, Horsehead Shoal and Point of Shoals.

Sometime after 14 June 1979 and prior to 3 August 1979 there was an increase in salinities to slightly less than the normal seasonal average, as evidenced by the samples collected on 3 August and 20 September 1979. Therefore, it may be speculated that setting of spat on bottom shell occurred after 14 June 1979. Between 20 and 26 September another major influx of freshwater caused a second major decline in salinities. Bottom salinities fell to 0.1 °/oo at Deep Water Shoal and only 7.4 °/oo at Brown Shoal (on October 2). This event initiated the major spat mortality described in this report; in all probability it terminated setting for the year.

By October 1979 bottom salinities increased from Wreck Shoal to Brown Shoal to levels which permitted normal activity for extended periods. However, upriver (except for increases in January and February 1980) they continued at very low levels (0.1 °/oo to 2.3 °/oo) to May 1980.

SUMMARY

1. There was a mortality of oysters in the James River due to low salinities which was related to size (age). At the stations below Deep Water Shoal the size (age) relation was most apparent. For example, spat mortality by May 1980 was 64% at Horsehead, 78% at Point of Shoals, and 93% at White Shoals. In contrast, yearling mortalities at these three stations was respectively, 13%, 43% and 45%. Mortality was complete at Deep Water Shoal for all size classes by 9 June 1980.
2. A major aspect documented by this study was the long period oysters may survive under salinity conditions which are usually considered lethal.
3. The seasonal set by October 1979 (prior to the mortality) was in the upper 10% of all James River sets since 1960. It occurred during a year of very marginal salinities. An inspection of Table 9 shows that salinities were "average" for the river during August and September 1979. Data are lacking for July but salinity was probably low for at least a portion of this month.
4. A major point shown by this study is that the exceptional 1979 set was preceeded by very marginal salinities as early as March 1979.
5. Spat and yearlings grew little during the low salinity period.
6. The percent mortality based on the combined box counts, of yearlings, small oysters and market oysters was never high except at Deep Water Shoal. This low percent mortality was probably due to the quick break up of yearling boxes.