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Status of the Major Oyster Diseases in Virginia 1998 A Summary of the Annual Monitoring Program

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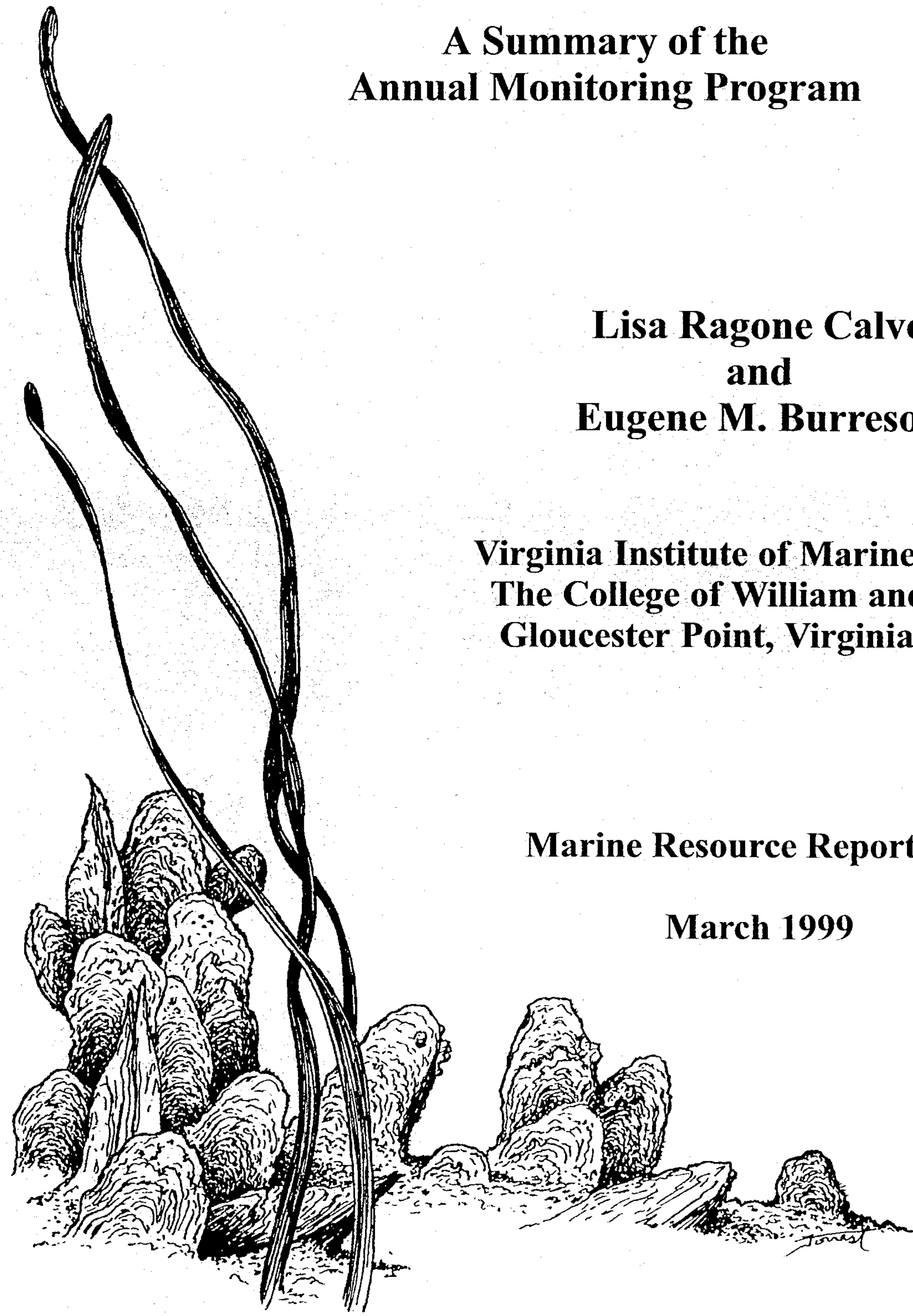

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EXECUTIVE SUMMARY

Environmental Factors. Unusually warm temperatures were observed throughout 1998 and this was reflected by weekly averages in water temperature recorded at our lower York River monitoring station. Weekly averages in water temperature exceeded long-term averages by 1-6.0°C for all but two weeks in the year. During the winter months weekly average water temperature did not decline below 5°C. Based on the long-term average, water temperatures at the site typically remain below 5°C for a period of 8 weeks. Extremely warm temperatures were also observed in the summer as weekly average water temperature above 27°C was recorded for 8 weeks. Generally such high temperatures occur for only 1 week.

The Chesapeake Bay region experienced exceptionally high streamflows during the first five months of 1998. The US Geological Survey reported that total flow for the Chesapeake Bay in January was the second highest on record at 224% of the long-term average while total flow in February was the highest on record at 220% of the long-term average. Similarly in the James River, record high streamflows were recorded for February and above average streamflows were recorded for January and March through May. The high streamflows resulted in exceptionally low salinities in the upper James River oyster seed areas during the spring. Oysters located at the bars furthest upriver experienced fresh or near-fresh water for 10-12 weeks. The dry summer and fall reversed the high flow pattern and streamflows progressively decreased and were below average levels the remainder of the year. As streamflow declined during the summer and fall salinity in the upper James River increased to levels conducive to the proliferation and spread of oyster disease.

***Perkinsus marinus* (Dermo).** In the upper James River, *P. marinus* prevalences declined to exceptionally low levels during the late winter and spring (0-12%). At Wreck Shoal prevalence sharply increased from 12% to 68% in July and then gradually increased to a fall maximum of 100% in November. Prevalences at Point of Shoals and Horsehead Rock remained low (<8%) through August but ultimately increased to fall maximums of 68 and 100%, respectively. At Deepwater Shoal prevalence remained at 0% from March through September. Few infections were noted at the site during the fall and the maximum monthly prevalence recorded was 16%. Since becoming established at Deepwater Shoal in the late 1980s, annual maximums of *P. marinus* prevalence have generally ranged from 36-88%. Thus, an appreciable decrease in the abundance of the parasite occurred at the site in 1998.

Our fall survey of Virginia oyster bars indicated that *P. marinus* was present at nearly all western shore oyster bars surveyed. Prevalences were generally higher than 1996-1997 levels. In the Rappahannock River no infections were observed at Ross Rock; however, an atypically high prevalence (88%) was observed just down river at Bowlers Rock. Prevalences at bars located further down river ranged from 48-100% and advanced infections (moderate to heavy intensity) were common. Prevalence at Broad Creek, which is located at the mouth of the river was relatively low (64%) for the second year in a row. Middle Ground in the Corrotoman River had a prevalence of 100%.

In the Piankatank River prevalences ranged from 52-88% with approximately 20% of the sampled oysters harboring advanced infections. Prevalences in the Great Wicomico River were also relatively high (72-88%); however, infections were light in intensity. A rather extensive survey of Tangier Sound indicated a very high abundance of the parasite in the area. Prevalences of 96-100% and high infection intensities were observed at 4 of the 5 Tangier Sound areas that were sampled.

***Haplosporidium nelsoni* (MSX).** *Haplosporidium nelsoni* prevalences in the James River were relatively high at Wreck Shoal at the beginning of the year; however, the infections were expulsed during the spring and the parasite did not reappear again until December. No infections were observed at Horsehead Rock.

In the fall low prevalences of *H. nelsoni* were observed in the Piankatank River at Ginney Point (8%), in Mobjack Bay at Pultz Bar (12%), in the Great Wicomico River at Whaley's East (8%) and Fleeton Point (8%), at Parker Rock in Pocomoke Sound (16%), and at various areas in Tangier Sound (8-12%). No infections were detected in the Rappahannock River, which had relatively high prevalences in 1997. Prevalence in susceptible oysters that were transplanted to the lower York River at VIMS in May reached 90% in mid-summer and ranked as one of the highest prevalences on record for our spring import monitoring tray oysters.

INTRODUCTION

The protozoan parasites *Haplosporidium nelsoni*, popularly known as MSX, and *Perkinsus marinus*, popularly known as Dermo, are serious pathogens of oysters in the Chesapeake Bay. MSX first appeared in Chesapeake Bay in 1959 and in the early 1960s killed millions of bushels of oysters on lower Bay oyster grounds. The continued presence of the parasite has discouraged use of these prime growing areas since that time.

The infection period for *H. nelsoni* begins in early May each year with peak mortality in the lower Bay from these early summer infections occurring during August and September. However, infections acquired during late summer and fall may overwinter if salinity remains high and develop as soon as water temperature increases in early spring. These overwintering infections may cause oyster mortality as early as June. In the major tributaries, normal spring runoff usually causes expulsion of overwintering *H. nelsoni* infections by May, but the pathogen may reinvade an area by fall if salinity is favorable during summer. Oyster mortality is reduced under these circumstances because *H. nelsoni* is present mainly during winter when cold water temperature slows development of the parasite.

Historically, *P. marinus* has been present at low levels in the lower portions of all Virginia rivers, but the parasite increased in abundance and spread throughout all public oyster beds during the late 1980s. Until that time *P. marinus* was not as serious a pathogen as *H. nelsoni* because *P. marinus* spread slowly within an oyster bed and between adjacent beds, and required three years to cause significant mortality. However, because of the increase in the distribution and abundance of *Perkinsus*, this parasite is now more important than *H. nelsoni* as an oyster pathogen in the Bay. The population dynamics of *P. marinus* are complex and not entirely understood. Most mortality occurs during late summer and early fall, but it may begin as early as June following warm winters that allow more overwintering infections.

The distribution and pathogenicity of both diseases are limited by salinity and, in a very general sense, neither parasite causes serious mortality in areas where the salinity remains below 12 ppt. *Haplosporidium nelsoni* is eliminated from oysters after about 10 days below 10 ppt; however, *P. marinus* may persist for years at low salinity although it is not pathogenic.

Because of the detrimental effect of these diseases on the Virginia oyster industry, the Virginia Institute of Marine Science has been monitoring the prevalence of both parasites since 1960. Information on disease severity and distribution each year is provided to management agencies and the oyster industry through publications and special advisories of the Marine Advisory Service office. The results of disease monitoring for the calendar year 1998 are presented in this report.

METHODS

Sampling.

The oyster disease monitoring program consists of three different sample types—tray samples, native oyster samples and samples provided from private oyster grounds.

Tray Samples. In late April each year, oysters are dredged from Ross Rock in the upper Rappahannock River, and placed in 2-foot by 4-foot legged trays in the York River at Gloucester Point. Oysters from the upper Rappahannock River are known to be highly susceptible to *H. nelsoni* , thus they serve as excellent indicators of annual abundance of this parasite when placed in an endemic area such as the lower York River just prior to the normal infection period for *H. nelsoni* that begins in May and continues through July. Historically, *P. marinus* has never invaded the trays during the first year of monitoring so the trays were a good measure of mortality resulting from MSX alone. However, because of the dramatic increase in *P. marinus* dance since 1987, oysters in the monitoring trays become infected with this pathogen each year. The presence of both *H. nelsoni* and *P. marinus* in the trays has made interpretation of the cause of mortality difficult. In addition, because of its widespread distribution, oysters from the upper Rappahannock River may now be infected with *P. marinus* when they are collected. Nonetheless, these oysters can still be used to monitor *H. nelsoni*, which normally does not occur in the upper reaches of the rivers.

Prior to establishing trays, a sample of 25 oysters is analyzed for *H. nelsoni* and *P. marinus* to determine the level of existing infections at the dredge site. No *H. nelsoni* infections have ever been encountered at these sites during April, but in some years *P. marinus* has been present at low prevalence (<10%). At least 300 oysters are placed in each of the two York River trays on 1 May each year. Trays are cleaned every week and counts are periodically made of live and dead oysters in each tray. Samples of 25 oysters are removed on about 1 July, 1 August, 1 September, and 1 October for disease determination; final counts are made about 1 December and trays are removed from the river at that time. New trays are established each May to provide a record of disease prevalence and intensity for each year. Because oysters from the same source have been held at the same location each year since 1960 we have a long-term database on *H. nelsoni* abundance and it is possible to compare years and to relate disease abundance and distribution to various environmental parameters.

Native Oyster Samples. In order to determine the annual distribution and severity of both *H. nelsoni* and *P. marinus;* samples of native oysters are collected periodically from most major public harvesting areas in Virginia. Samples of 25 oysters are collected from sites in Mobjack Bay, the Rappahannock River, the Great Wicomico River and from other tributaries of the western shore and the seaside of the Eastern Shore. Since 1987 a more intensive survey has been conducted in the James River— samples are collected monthly at Wreck Shoal, Horsehead Rock and Deep Water Shoal and Point of Shoal.

Private Oyster Grounds. Private oyster planters submit samples for disease diagnosis and the results are used to make planting and harvesting decisions. In this report these samples are identified by location only and cannot be separated from native oyster samples.

Diagnostic Techniques.
Prevalence of *H. nelsoni* was determined by histological analysis of paraffin–embedded tissue sectioned at 6 µm and stained with hematoxylin and eosin; prevalence of *P. marinus* was determined by thioglycollate culture of mantle, gill and rectal tissue.

Monthly mortality in tray samples was determined by dividing the number of dead oysters by the number of live and dead oysters in the tray. This result was divided by the period in days since the last count to yield percent dead per day. This value was then multiplied by 30 to yield monthly mortality. Cumulative mortality in each tray was calculated using a complex formula that accounts for live oysters removed for disease diagnosis.

Environmental Parameters.
Water temperature for the determination of long-term averages and yearly anomalies is obtained from a continuous monitor at the VIMS pier in the lower York River. Water temperatures were also recorded at the various collection sites on each sample date. Salinity data for the James River is obtained from a variety of sources. The State Water Control Board takes biweekly samples at Wreck Shoal and at Deep Water Shoal from May through October and monthly samples from November through April. The VIMS shellstring survey obtains weekly data at these locations from May through October and the VIMS oyster disease monitoring program obtains monthly samples throughout the year. Riverflow data for the James River and for the entire Chesapeake Bay are obtained from the U. S. Geological Survey.

RESULTS

Environmental Parameters.

Overall, 1998 was an unusually warm year and weekly average water temperatures at our lower York River site were generally above long-term averages (1947-1997) (Figure 1). During the winter

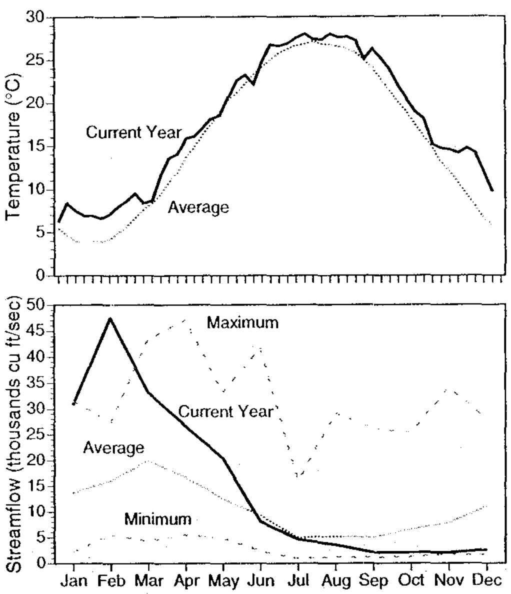

Figure 1. Average weekly water temperature at VIMS, Gloucester Point, VA (top) and monthly James River, VA streamflow (bottom). Long-term averages (dotted lines) are contrasted with 1998 values (solid lines). For streamflow long-term minimums and maximums are also shown. Long-term temperatures are for years 1947-1997 and long-term streamflows are for 1951-1997.

months average water temperatures exceeded the long-term average by approximately 1-3.5°C (Figure 1 and 2). Average weekly water temperatures remained above 5°C the entire winter (Figure 1). Normally average weekly water temperatures are below 5°C for a period of 8 weeks. Above average temperatures prevailed through most of the spring and early summer. The summer was relatively warm with average weekly temperatures exceeding 25°C for 14 weeks and 27°C for 8 weeks. Typically temperatures exceeding 25°C occur for only 10 weeks and temperatures above 27°C are recorded for only 1 week. Average weekly

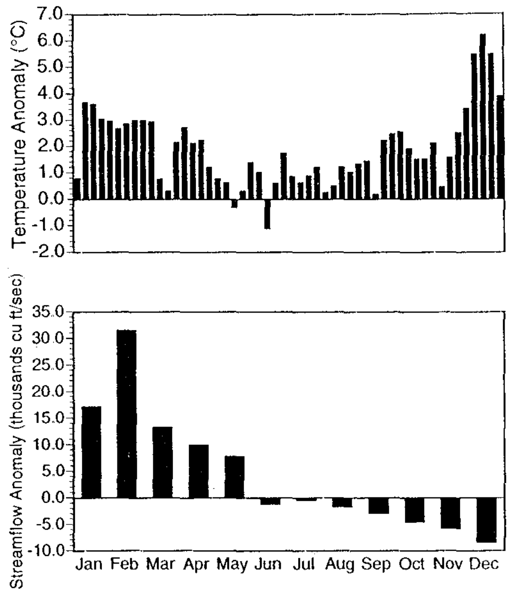

Figure 2. Weekly water temperature anomaly at the VIMS pier, Gloucester Point, VA based on average weekly water temperature from 1947-1997 (top) and monthly James River streamflow anomaly based on average discharge from 1951-1997 (bottom) for the calendar year 1998. Anomalies were calculated by subtracting the long term average from the value observed in 1998. Positive values represent above average measures (warmer/wetter conditions) and negative values represent below average measures (colder/drier conditions).

water temperatures remained from 1 to 6°C above average from October to December. Temperature anomalies (deviations from long-term average temperatures) for the years 1987-1998 are shown in Figure 3. In comparison to the previous 11 years, 1998 stands out as one of the warmest on record.

The Chesapeake Bay region experienced exceptionally high streamflows during the first five months of 1998. The US Geological Survey reported that total flow for the Chesapeake Bay in January was the second highest on record at 224% of the long-term average while total flow in February was the highest on record at 220% of the long-term average. Similarly in the James River record high streamflows were recorded for February and above average streamflows were recorded for January and March through May (Figure 1 and 2). The dry summer and fall reversed this pattern and streamflows progressively decreased and were below average levels the remainder of the year. While it's typical for streamflows to decline in the summer and early fall, they usually begin to rise again in the late fall. Streamflow anomalies for the years 1987-1998 are shown in Figure 3.

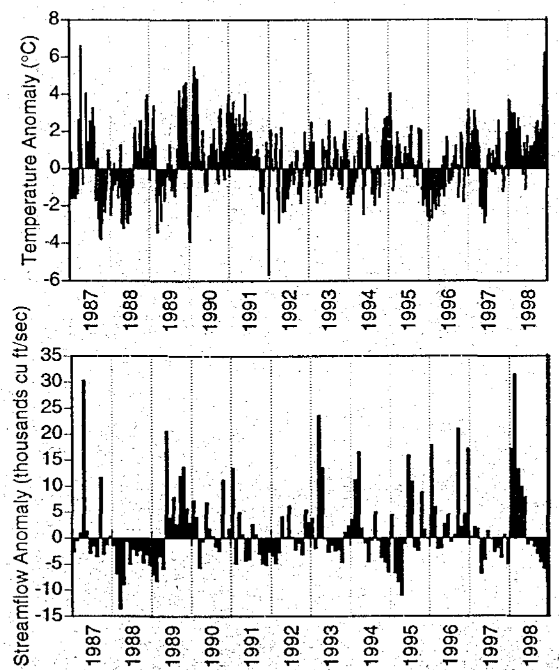

Figure 3. Mean weekly VIMS pier water temperature anomaly from long-term (1947-1997) average (top). Mean monthly James River streamflow anomaly from long-term (1951-1997) average (bottom).

***Perkinsus marinus* (Dermo).**

James River. Above average streamflows during the winter and spring of 1998 resulted in very low salinities in the upper James River from January through June. The oyster bars furthest up river, Point of Shoals, Horsehead Rock and Deepwater Shoals experienced freshwater conditions for a period of at least 10-12 weeks (Table 1). Slightly down river at Wreck Shoal salinities ranged from 2-9 ppt (Table 1). As a consequence *P. marinus* prevalences and infection intensities were greatly depressed at all four areas in the spring. While *P. marinus* abundances typically decline during this time of the year, the prevalences observed during the first five months of 1998 were exceptionally low. At Wreck Shoal a minimum spring prevalence of 12% was observed (Table 1, Figure 4). This low level was maintained from April through June. At the stations upriver from Wreck Shoal the parasite was absent (or undetectable) during most of the spring (Table 1, Figure 4). At Deepwater Shoal no infections were detected for the seven-month period spanning March through September. While it is common for prevalence to decline at Deepwater Shoal to 0% in the spring, it is unusual for prevalence to remain this low for such an extended period.

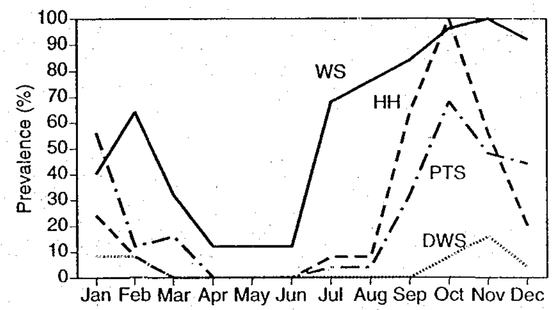

Figure 4. Prevalence of *P. marinus* in James River oysters from Wreck Shoal (WS), Horsehead Rock (HH), Point of Shoals (PTS) and Deepwater Shoal (DWS) in 1998.

Salinity in the upper James River progressively increased from June through November, presenting favorable conditions for the proliferation and spread of the disease (Table 1). However, despite above average water temperatures for nearly the entire year and relatively high fall salinities, the average *P. marinus* prevalence and intensity in the upper James River for the months of June through December were below average in comparison to the previous 10 years.

At Wreck Shoal prevalence sharply increased from 12% in June to 68% in July as water temperature exceeded 25°C and salinity increased to 13 ppt (Figure 5). Salinity continued to rise in late summer and ranged from 17-22 ppt the remainder of the year. *Perkinsus marinus* prevalence gradually increased to 84% in September. This increase was somewhat slower than

Table 1. Monthly survey of prevalence and intensity of *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* in oysters from James River harvesting areas in 1998. See accompanying figure for station locations. NA=not analyzed for MSX. H=number of heavy infections, M=moderate infections, L=light infections.

Location	Date	Temp. (°C)	Sal. (ppt)	MSX Infect./exam. -%infected	Infection Intensity H–M–L	*Perkinsus* Infect./exam. -%infected	Infection Intensity H–M–L
James River							
Deep Water Shoal	21 Jan	8.0	2.0	NA		2/25 (8%)	0-0-2
	17 Feb	7.0	0.0	NA		2/25 (8%)	0-0-2
	16 Mar	8.0	0.0	NA		0/25 (0%)	0-0-0
	14 Apr	17.5	0.0	NA		0/25 (0%)	0-0-0
	14 May			NA		0/25 (0%)	0-0-0
	16 Jun	27.5	2.0	NA		0/25 (0%)	0-0-0
	13 Jul	30.0	5.0	NA		0/25 (0%)	0-0-0
	13 Aug	30.0	5.5	NA		0/25 (0%)	0-0-0
	15 Sep	28.0	9.0	NA		0/25 (0%)	0-0-0
	15 Oct	22.5	12.0	NA		2/25 (8%)	0-0-2
	17 Nov	15.0	14.0	NA		4/25 (16%)	0-0-4
	10 Dec	16.0	10.0	NA		1/25 (4%)	0-0-1
Horsehead Rock	21 Jan	8.0	6.0	0/25 (0%)	0-0-0	6/25 (24%)	0-0-6
	17 Feb	7.0	0.0	0/25 (0%)	0-0-0	2/25 (8%)	0-0-2
	16 Mar	8.0	0.0	0/25 (0%)	0-0-0	0/25 (0%)	0-0-0
	14 Apr	17.0	0.0	0/25 (0%)	0-0-0	0/25 (0%)	0-0-0
	14 May			0/25 (0%)	0-0-0	0/25 (0%)	0-0-0
	16 Jun	27.0	4.0	0/25 (0%)	0-0-0	0/25 (0%)	0-0-0
	13 Jul	30.0	7.0	0/25 (0%)	0-0-0	2/25 (8%)	0-0-2
	13 Aug	30.0	8.0	0/25 (0%)	0-0-0	2/25 (8%)	0-0-2
	15 Sep	27.5	12.5	0/25 (0%)	0-0-0	16/25 (64%)	0-0-16
	15 Oct	21.5	14.0	0/25 (0%)	0-0-0	25/25 (100%)	0-0-25
	17 Nov	15.0	16.0	0/25 (0%)	0-0-0	14/25 (56%)	2-1-11
	10 Dec	15.0	13.0	0/25 (0%)	0-0-0	5/25 (20%)	1-0-4
Point of Shoals	21 Jan	8.0	4.0	NA		14/25 (56%)	0-0-14
	17 Feb	7.0	0.0	NA		3/25 (12%)	0-0-3
	16 Mar	8.5	0.0	NA		4/25 (16%)	0-0-4
	14 Apr	17.0	0.0	NA		0/25 (0%)	0-0-0
	14 May			NA		0/25 (0%)	0-0-0
	16 Jun	27.0	6.0	NA		0/25 (0%)	0-0-0
	13 Jul	29.5	8.0	NA		1/25 (4%)	0-0-1
	13 Aug	30.0	8.5	NA		1/25 (4%)	0-0-1
	15 Sep	27.0	13.5	NA		8/25 (32%)	0-1-7
	15 Oct	22.0	14.0	NA		17/25 (68%)	1-1-15
	17 Nov	16.0	16.0	NA		12/25 (48%)	0-0-12
	10 Dec	14.5	15.0	NA		11/25 (44%)	0-0-11
Wreck Shoal	21 Jan	7.5	14.0	7/25 (28%)	0-2-5	10/25 (40%)	1-1-8
	17 Feb	7.0	2.0	6/25 (24%)	0-0-6	16/25 (64%)	2-1-13
	16 Mar	8.0	6.0	17/25 (68%)	0-1-16	8/25 (32%)	0-0-8
	14 Apr	15.0	5.0	4/25 (16%)	0-0-4	3/25 (12%)	0-0-3
	14 May	18.5		0/25 (0%)	0-0-0	3/25 (12%)	0-0-3
	16 Jun	27.5	9.0	0/25 (0%)	0-0-0	3/25 (12%)	0-0-3
	13 Jul	29.0	12.0	0/25 (0%)	0-0-0	17/25 (68%)	1-0-16
	13 Aug	29.5	11.5	0/25 (0%)	0-0-0	19/25 (76%)	4-4-11
	15 Sep	27.0	16.0	0/25 (0%)	0-0-0	21/25 (84%)	1-7-13
	15 Oct	21.0	20.0	0/25 (0%)	0-0-0	24/25 (96%)	4-5-15
	17 Nov	15.0	20.0	0/25 (0%)	0-0-0	25/25 (100%)	4-3-18
	10 Dec	14.0	18.0	1/25 (4%)	0-0-1	23/25 (92%)	5-2-16

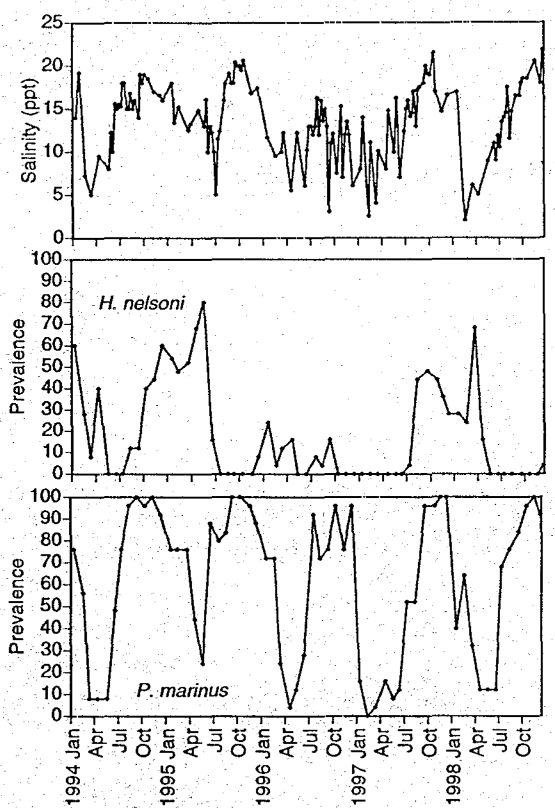

Figure 5. Salinity (top) and prevalence of *P. marinus* (bottom) and *H. nelsoni* (middle) at Wreck Shoal, James River, VA for the years 1994-1998.

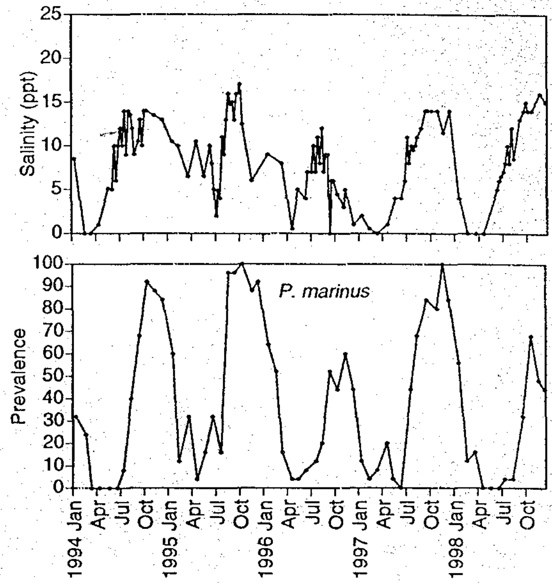

Figure 6. Salinity (top) and prevalence of *P. marinus* (bottom) at Point of Shoals, James River, VA for the years 1994-1998.

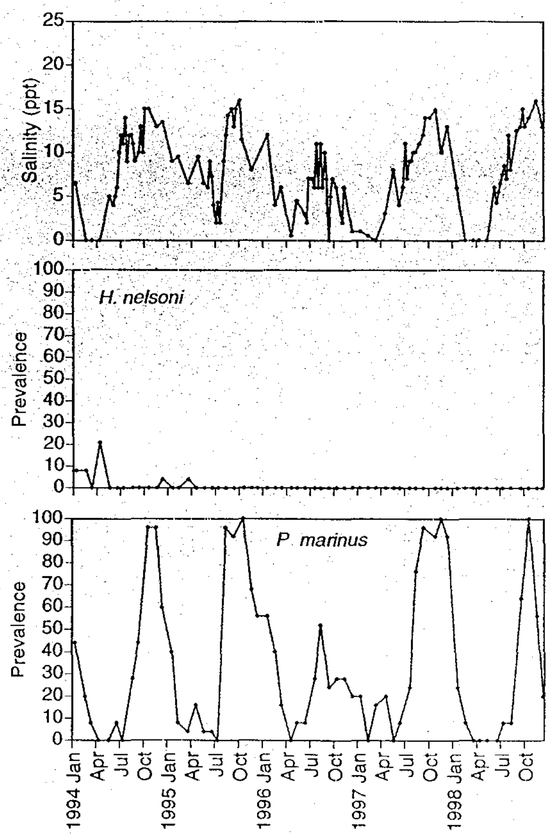

Figure 7. Salinity (top) and prevalence of *P. marinus* (bottom) and *H. nelsoni* (middle) at Horsehead Rock, James River, VA for the years 1994-1998.

typical, but by November prevalence was 100%. During the months of October through December infection intensities were relatively high; 28-36% of the oysters sampled had moderate to heavy infections.

At Point of Shoals (Figure 6) and Horsehead Rock (Figure 7) prevalence remained below 8% through August as salinity remained below 12 ppt. As salinity consistently exceeded 12 ppt during the late summer and fall prevalence increased to an annual maximum in October of 68% at Point of Shoals and 100% at Horsehead Rock. The average prevalence at Point of Shoals for the months of June through December was the lowest observed since 1989. Infection intensities were relatively low at both Point of Shoals and Horsehead Rock (Table 1).

At Deepwater Shoal salinity gradually increased during the summer and ranged from 8-15 ppt in the fall (Figure 8). *Perki-*

nus marinus reappeared in October at 8% prevalence but prevalence remained low (<16%) through December. Since 1990 there has only been one other year in which a lower maximum annual prevalence has been observed at Deepwater Shoal. Maximum annual prevalences for all other years since 1990 have ranged from 36-88%.

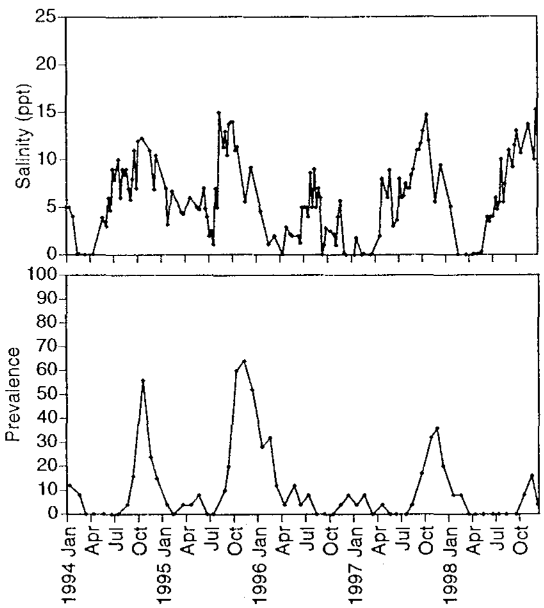

Figure 8. Salinity (top) and *P. marinus* prevalence (bottom) at Deepwater Shoal, James River, VA for the years 1994-1998.

Fall Survey Stations. Twenty-six oyster bars, including sites in the James, York, Piankatank, Rappahannock, Corrotoman, Great Wicomico Rivers, Mobjack Bay and Tangier Sound were surveyed for oyster disease in the fall of 1998 (Table 2). *Perkinsus marinus* prevalences were generally higher than 1996-1997 levels. The parasite was present at all sampled bars except for Ross Rock, which is located in the upper Rappahannock River and Bell Rock, which is located in the upper York River. With the exception of the most up river oyster bars, our survey areas at the time of sampling had salinities greater than 15 ppt and *P. marinus* prevalences higher than 75%. Moderate and heavy infection intensities were abundant at most of these areas.

In the Piankatank River prevalences were about 20% higher than last year. At Burton Point prevalence was 88% (Table 2). This prevalence was consistent with 1991-1996 prevalences, which ranged from 88-100%. Despite the high prevalence observed in 1998, infection intensities were relatively light as only 16% of the oysters had advanced infection intensities. Prevalence at Ginney Point was 52% (Table 2), remaining much lower than 1989-1996, which ranged from 88-100%. As at Burton Point, only 16% of the oysters sampled had moderate to heavy infections. In previous years the proportion of Burton Point oysters having advanced infections has been as high as 52%.

In the Great Wicomico River prevalences were 12 to 20% higher than 1997, but still remained moderate compared to other years. Prevalences at Haynies Bar, Whaley's East and Fleeton Point ranged from 72-84% and nearly all infections were of light intensity (Table 2). Typically, few advanced infections are observed in oysters sampled from these three bars. At the time of collection, salinity ranged from 16-17 ppt.

In the Rappahannock River at Ross Rock *P. marinus* was not detected for the second year in a row. Seven additional Rappahannock River oyster bars, located down river of Ross Rock, were also sampled in the fall. The bars, which were located along a salinity gradient, had salinities at the time of collection ranging from 12-18 ppt. *Perkinsus marinus* prevalences ranged from 48-100% (Table 2). Prevalence and intensity at Bowlers Rock, Smokey Point, and Parrot Rock ranked among the top three highest observed for these areas since 1989. Prevalence at Bowlers Rock increased 36% since last year and prevalence at Smokey Point increased 55%. In contrast prevalences and infection intensities at Morratico Bar, Long Rock and Broad Creek were relatively low compared to most other years since 1989. Advanced infections were observed at all sites where the parasite was present and were quite

Table 2. Fall survey of prevalence and intensity of *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* in oysters from Virginia oyster beds in 1998. See accompanying figures for station locations. NA=not analyzed for MSX. H=number of heavy infections, M=moderate infections, L=light infections.

Location	Date	Temp. (°C)	Sal. (ppt)	MSX Infect./exam. -%infected	Infection intsity H–M–L	*Perkinsus* Infect./exam. -%infected	Infection intensity H–M–L
James River							
Deep Water Shoal	15 Oct	22.5	12.0	NA		2/25 (8%)	0-0-2
Horsehead Rock	15 Oct	21.5	14.0	0/25 (0%)	0-0-0	25/25 (100%)	0-0-25
Point of Shoals	15 Oct	22.0	14.0	NA		17/25 (68%)	1-1-15
Wreck Shoal	15 Oct	21.0	20.0	0/25 (0%)	0-0-0	24/25 (96%)	4-5-15
York River							
Bell Rock	19 Oct	20.2	15.5	0/23 (0%)		0/25 (0%)	0-0-0
Mobjack Bay							
Pultz Bar	20 Oct		21.0	3/25 (12%)	0-0-3	2/25 (8%)	0-0-2
Piankatank River							
Ginney Point	23 Oct	17.9	16.7	2/25 (8%)	0-1-1	13/25 (52%)	1-3-9
Burton's Point	23 Oct	18.2	17.5	0/25 (0%)	0-0-0	22/25 (88%)	1-3-18
Rappahannock River							
Ross Rock	22 Oct	17.6	9.8	0/25 (0%)	0-0-0	0/25 (0%)	0-0-0
Bowlers Rock	21 Oct	17.8	11.8	0/25 (0%)	0-0-0	22/25 (88%)	1-2-19
Long Rock	21 Oct	18.0	13.4	0/25 (0%)	0-0-0	12/25 (48%)	1-2-9
Marratico Bar	21 Oct	18.2	14.1	0/25 (0%)	0-0-0	15/25 (60%)	1-0-14
Smokey Point	22 Oct	18.8	15.8	0/25 (0%)	0-0-0	18/23 (77.4%)	2-3-13
Drummond Ground	22 Oct	19.3	17.3	0/25 (0%)	0-0-0	23/23 (100%)	5-7-11
Parrot Rock	21 Oct	18.8	17.0	0/25 (0%)	0-0-0	23/24 (96%)	7-3-13
Broad Creek	23 Oct	16.8	17.5	0/25 (0%)	0-0-0	16/25 (64%)	0-2-14
Corrotoman River							
Middle Ground	22 Oct	19.0	16.0	0/25 (0%)	0-0-0	25/25 (100%)	2-5-18
Great Wicomico River							
Haynies Bar	2 Nov	16.2	16.8	0/25 (0%)	0-0-0	22/25 (88%)	0-0-22
Whaley's East	23 Oct	16.0	16.5	2/25 (8%)	0-2-0	18/25 (72%)	0-1-17
Fleeton Point	23 Oct	16.5	16.9	2/25 (8%)	0-2-0	21/25 (84%)	0-0-21
Tangier Sound							
Hurley's Rock	17 Sept		17.0	2/21 (9.5%)	0-0-2	16/21 (76%)	2-1-13
Johnson Rock	21 Sept			2/25 (8%)	0-1-1	25/25 (100%)	5-6-14
California Rock	17 Sept			0/25 0%)		25/25 (100%)	3-6-16
Thoroughfare	17 Sept		17.0	3/25 (12%)	2-0-1	24/25 (96%)	6-6-12
Cod Harbor	21 Sept	25.8	17.5	0/24 (0%)	0-0-0	24/24 (100%)	6-4-14
Pocomoke Sound							
Parker's Rock	17 Sept	24.7	17.8	4/25 (16%)	1-2-1	9/25 (36%)	1-0-8

abundant at Smokey Point, Drummond Ground and Parrot Rock. As last year the prevalence among bars was variable in that a consistent progressive increase was not observed as one moves down river along the salinity gradient.

Five oyster bars were sampled in Tangier Sound (Table 2). The parasite was found at all bars. Prevalences at Hurley's Rock, Johnson Rock, California Rock, Thoroughfare and Cod Harbor ranged from 76-100% and advanced infections were abundant at all 5 areas. Prevalence was only 36% at Parker Rock, Pocomoke Sound and infections were primarily light intensity.

***Haplosporidium nelsoni* (MSX).**
Haplosporidium nelsoni prevalences in the James River were relatively low in 1998 (Table 1 and Figure 9). For the third consecutive year the parasite was absent from Horsehead Rock (Figure 7). At Wreck

secutive year the parasite was absent from Horsehead Rock (Figure 7). At Wreck Shoal *H. nelsoni* was observed during the months of January through April at prevalences ranging from 16-68%, but was not found again until December when only a single infected oyster was observed (Table 1, Figure 5 and 9). The maximum fall prevalence of *H. nelsoni* observed at Wreck Shoal typically ranges from 16-48% (Figure 5).

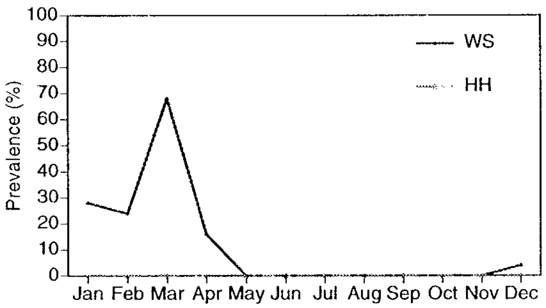

Figure 9. Prevalence of *H. nelsoni* (MSX) (bottom) in James River oysters from Wreck Shoal (WS) and Horsehead Rock (HH) in 1998.

Fall prevalences of *H. nelsoni* in Virginia's other major tributaries were also relatively low (Table 2). In 1998, *H. nelsoni* was not detected in the Rappahannock River, but was observed at prevalences less than 8% at Ginney Point in the Piankatank River and at Whaley's East and Fleeton Point in the Great Wicomico River. It is common for *H. nelsoni* to be absent from the oyster bars located in the upper portions of these tributaries but in most years the parasite is observed at locations located further down river. In Mobjack Bay *H. nelsoni* prevalence was 16% at Pultz Bar. The distribution of *H. nelsoni* in Tangier Sound was patchy with prevalences ranging from 0-16%. In most areas prevalences were reduced in comparison to 1997, which ranked as one of the highest years for abundance of the pathogen in the lower Chesapeake Bay. However, even in 1997, prevalences in these areas remained below 30%.

VIMS Tray Samples.

A tray of Ross Rock, Rappahannock River oysters was established at the VIMS, Gloucester Point, York River site on 29 April 1998. Analyses of a sample of the Ross Rock oysters prior to transplantation indicated that *P. marinus* prevalence was 0% and that the oysters were also free of detectable *H. nelsoni* infections. The number of live and dead oysters in each tray was assessed monthly from June to September and the resulting determinations of percent monthly and percent cumulative mortalities are shown in Table 3. Cumulative mortality was 71% by mid August. In September cumulative mortality increased to 87%; however, there was heavy sedimentation in the tray, which may have attributed to the oyster deaths. Samples for disease diagnoses were also taken monthly. *Haplosporidium nelsoni* was not detected in oysters sampled on 4 June or 9 July, but by 13 August prevalence was 90%. Thirty-two percent of the oysters sampled had moderate to heavy intensity infections. Prevalence was 76% in September. The acquisition of *H. nelsoni* was somewhat later than typically occurs but the maximum prevalence attained was the highest on record (Figure 10).

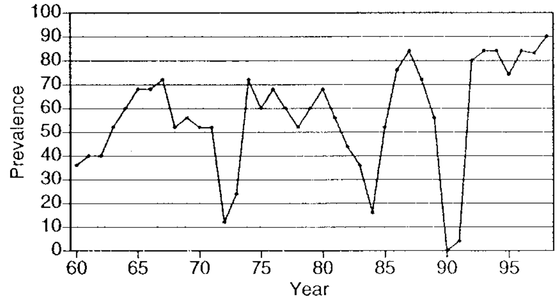

Figure 10. Maximum annual prevalence of *H. nelsoni* (MSX) in imported monitoring tray oysters at VIMS 1960-1998.

Perkinsus marinus infections first appeared in June at a prevalence of 4% (Table 3). Prevalence remained low through August, but sharply increased to 76% in September and continued to increase to 100% in October. As in 1997, the acquisition and proliferation of the pathogen was atypically late compared to other years. Given the fact that the onset of *P. marinus* infections was very late and prevalences of the parasite were relatively low through

Table 3. Mean mortality and disease prevalence in upper Rappahannock River oysters transplanted to trays at the lower York River, Gloucester Point, VA in April, 1998.

Date–1997	Monthly mortality–%	Cumulative mortality-%	*H. nelsoni* prevalence	Intensity H-M-L*	*P. marinus* prevalence	Intensity H–M–L*
29 Apr	0	0	0/25 (0%)	0-0-0	0/25 (0%)	0-0-0
4 Jun	10.1	11.5	0/25 (0%)	0-0-0	1/25 (4%)	0-0-1
9 Jul	3.7	15.9	0/25 (0%)	0-0-0	1/25 (4%)	0-0-1
13 Aug	46.9	70.5	18/20 (90%)	3-5-10	3/20 (15%)	0-0-3
1 Sep	24.6**	87.0**	19/25 (76%)	11-3-5	19/25 (76%)	6-0-13
1 Oct	8.9	94.7	9/13 (69%)	2-1-6	13/13 (100%)	3-5-5

*H = number of heavy infections, M = moderate infections, L = light infections.
** Some portion of mortality at this time may be related to heavy sedimentation in tray.

August, it is very likely that most of the mortality observed between June and August was associated with *H. nelsoni*.

DISCUSSION

Above average streamflows during the winter and spring of 1998 resulted in salinity decreases throughout the Chesapeake Bay Region. In the James River record high streamflows were recorded in February and streamflows remained above average through May. As a consequence spring prevalences and infection intensities of *P. marinus* were greatly depressed at all four of our regularly monitored James River oyster bars— Wreck Shoal, Point of Shoals, Horsehead Rock and Deepwater Shoals. While *P. marinus* abundances typically decline during this time of the year, the prevalences observed during the first five months of 1998 were exceptionally low. At Deepwater Shoal, the uppermost oyster bar, prevalence declined to 0% in March and remained at 0% through September. This represents the longest period in which the parasite was not observed at the site since 1990. Similarly, *P. marinus* was not detected at Horsehead Rock or Point of Shoals for several months during the spring and at Wreck Shoal a spring minimum of 12% was observed. As the high flow conditions observed early in the year reversed to drought conditions in the summer and fall, salinity increased to above average at all sites. High salinities combined with above average temperatures resulted in sharp increases in *P. marinus* prevalence at Horsehead Rock, Point of Shoals and Wreck Shoal. Infection intensities were for the most part light at Point of Shoals and Horsehead Rock; however, at Wreck Shoal moderate and heavy infections were numerous from August through December and it is likely that some oyster mortality resulted. This recurrence of the disease during the fall once again demonstrates how difficult it is to eradicate the pathogen from these areas. While the parasite reappeared at Deepwater Shoal in October it remained at very low prevalence (<16%) through the fall despite favorable temperature and salinity conditions.

The average annual *P. marinus* prevalences and intensities in the upper James River were below average in comparison to the previous 10 years. This can be attributed to the extremely high streamflows that occurred early in 1998. The prolonged low salinity conditions caused by the high streamflows resulted in a regression in parasite tissue burdens. The observed infection regression is probably related to an inability of *P. marinus* to tolerate prolonged exposure to extremely low salinity. Although it is clear that parasite numbers were reduced, our diagnostic assay is not sensitive enough to determine whether the parasite is truly absent. Hence it is important to keep in mind that 0% prevalence only means that the *P. marinus* was not detected. Most likely the sharp rises in prevalence that occurred in mid-summer at Wreck Shoal, Point of Shoals and Horsehead Rock reflect the proliferation of low intensity (undetectable) infections that persisted through the winter and spring, rather than the acquisition of new infections. The sharp rise in prevalence that was observed underscores how quickly an epizootic can occur given favorable environmental conditions. It is surprising that prevalence remained extremely low at Deepwater Shoal, given that salinity in the late summer and fall was favorable for *P. marinus* and that temperatures were atypically high. This is the third consecutive year in which prevalence remained relatively low in this area and it appears that the abundance of the parasite has been significantly reduced from 1990-1996 levels.

During the fall *P. marinus* was abundant on nearly all oyster beds sampled. Prevalences in the Piankatank and Great Wicomico Rivers were generally higher than 1996-1997 levels but moderate compared to levels observed in 1990-1995. In the Rappahannock River prevalences were variable—at Bowlers Rock, Smokey Point, and Parrot Rock prevalences ranked among the highest observed since 1989, while at Morratico Bar, Long Rock and Broad Creek prevalences were relatively low compared to most other years since 1989. The high prevalences may be a result of the transplantation of infected seed from the James River while the low prevalences may reflect the effect of diminishing oyster standing stocks on parasite dynamics or possibly the development of disease resistance in these oysters.

During 1993-1997, *H. nelsoni* persisted at record high prevalences and intensities in the James River at Wreck Shoal; in the down river populated beds of Virginia's other major western shore tributaries; and in the sounds of Virginia's Eastern Shore. *Haplosporidium nelsoni* prevalences in 1998 were relatively low in comparison. In the James River relatively high prevalences of the pathogen were observed early in the year; however, prevalence declined to 0% by May and the parasite was not observed again until December. Generally, *H. nelsoni* infections which were acquired the previous summer or fall persist through the winter and then are subsequently eliminated in spring. Since the parasite is intolerant of salinities at or below 10 ppt, the occurrence of high streamflows, which reduce salinity below 10 ppt usually result in parasite expulsion. In 1998 high streamflows were observed relatively early as the flow for February was the highest on record. Above average streamflows for the James River continued through May and as a result salinity remained below 10 ppt for the period of February through June. At Wreck Shoal salinities at or below 10 ppt occurred between February and June and conditions were unfavorable for the parasite during this time. Typically, the parasite reinvades the area during the summer and fall once salinity increases to greater than about 10 ppt. The pattern observed in 1998 was atypical in that this reinvasion was not observed until December and even then prevalence remained extremely low (4%). As a result of this reinvasion being late and low, the oysters in this area were not impacted by the disease.

Overall, in the other major tributaries fall prevalences and intensities of *H. nelsoni* were lower than usual. In the Piankatank and Great Wicomico Rivers prevalences were less than 8%. The parasite was not detected in the Rappahannock River. The parasite was detected in Mobjack Bay and in Tangier Sound, but only at low prevalences (<16%).

In contrast, Rappahannock River oysters transplanted to the York River exhibited relatively high levels of the disease. The susceptible oysters that were transplanted to VIMS in April 1998 exhibited the highest prevalence of *H. nelsoni* ever recorded at the site. No infections were detected in June and July but by August prevalence was 90%. *Haplosporidium nelsoni* infections were severe and caused extensive mortality of the transplanted oysters. Unlike the upper James River, salinity at the lower York River VIMS site does not decline below 10 ppt during the spring. Hence, conditions were favorable for the parasite to persist in the area through the winter and spring. It is difficult to explain why prevalence was relatively high in the York River but relatively low in other areas having similar salinity regimes. Certainly, caution must be used when comparing patterns observed in "resistant" native stocks and in highly susceptible transplanted stocks. The life cycle of this important parasite has not as yet been determined so we can not explain exactly how the parasite overwinters. It is believed that another organism may harbor the pathogen at some point during its life cycle.

ACKNOWLEDGMENTS

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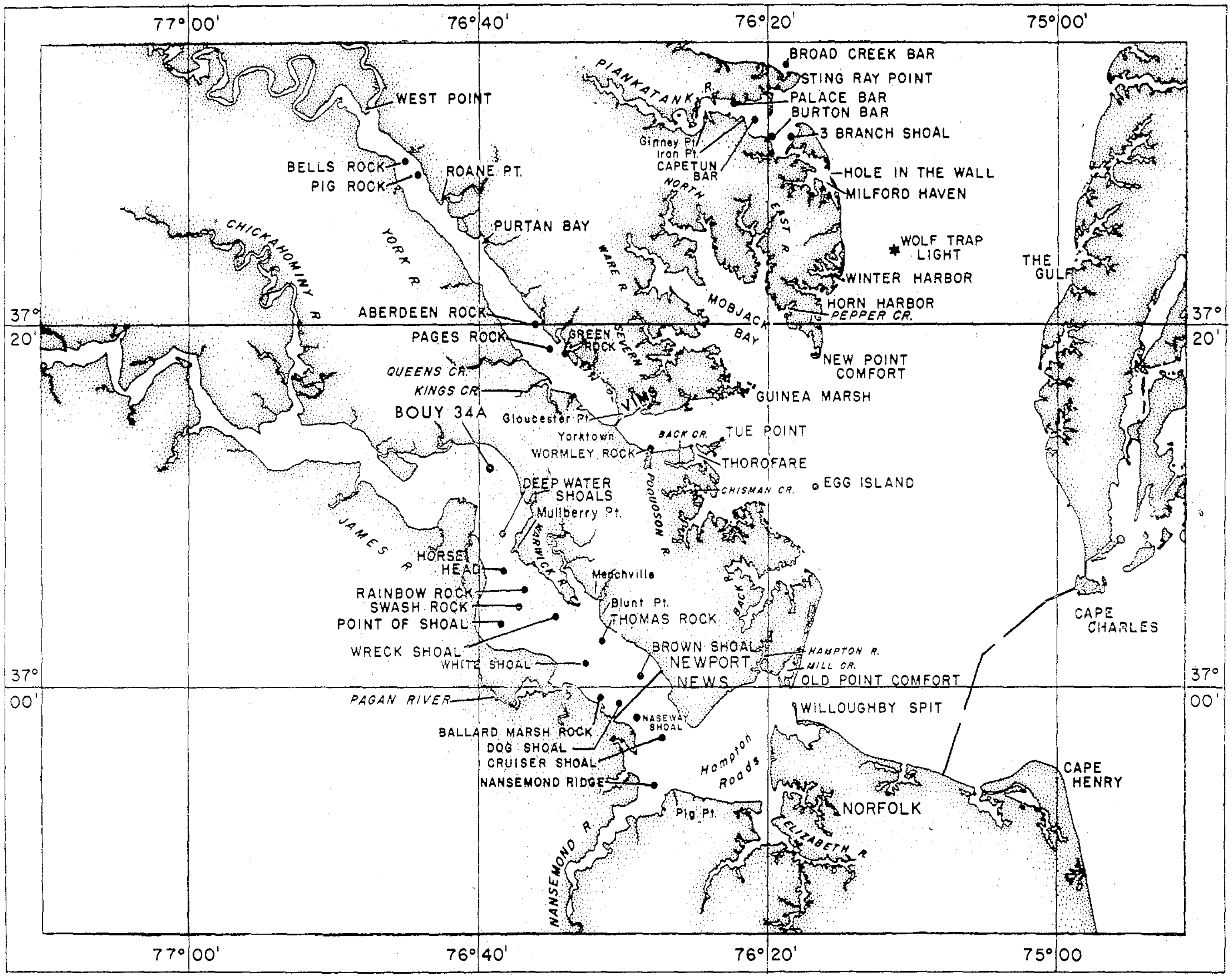
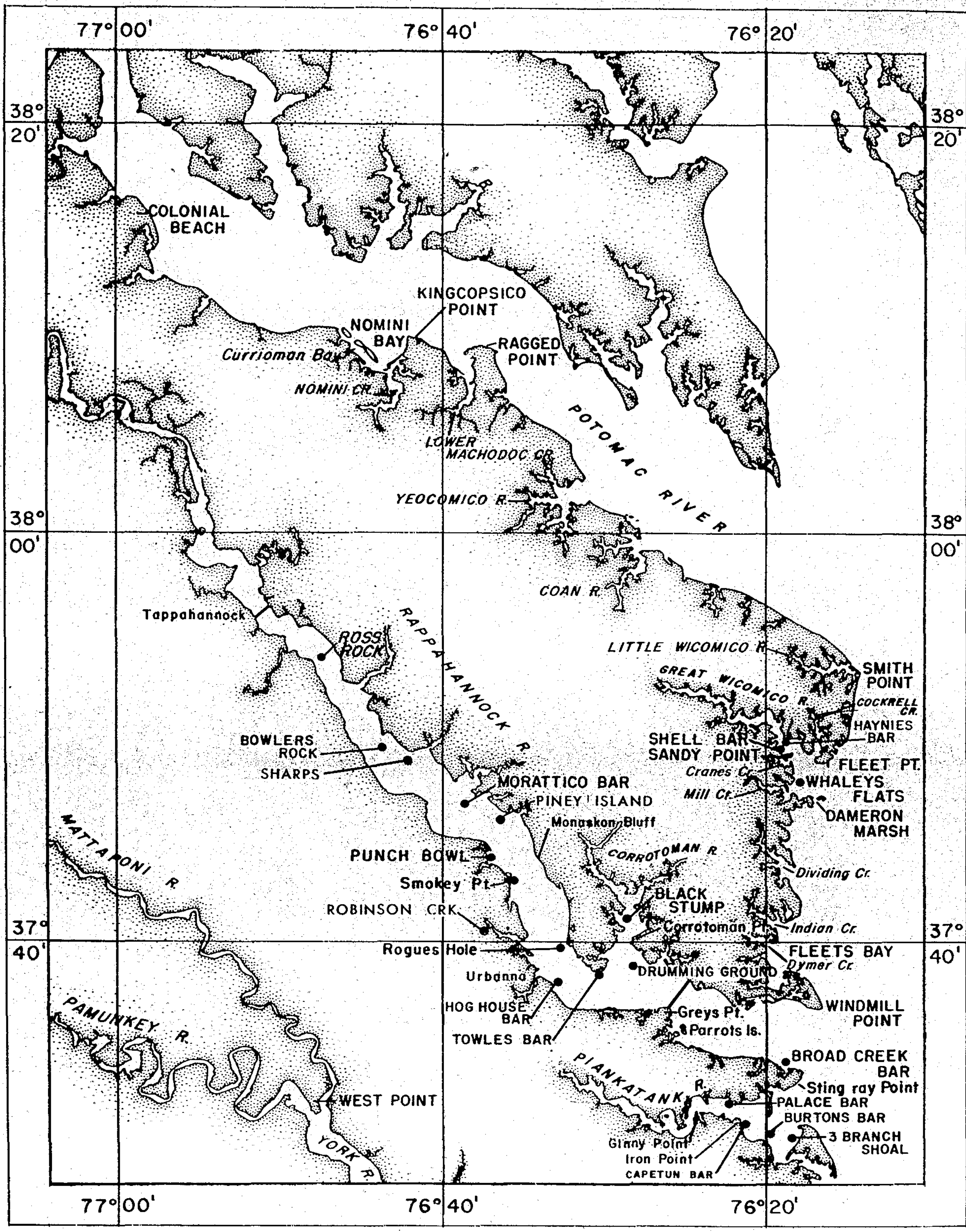
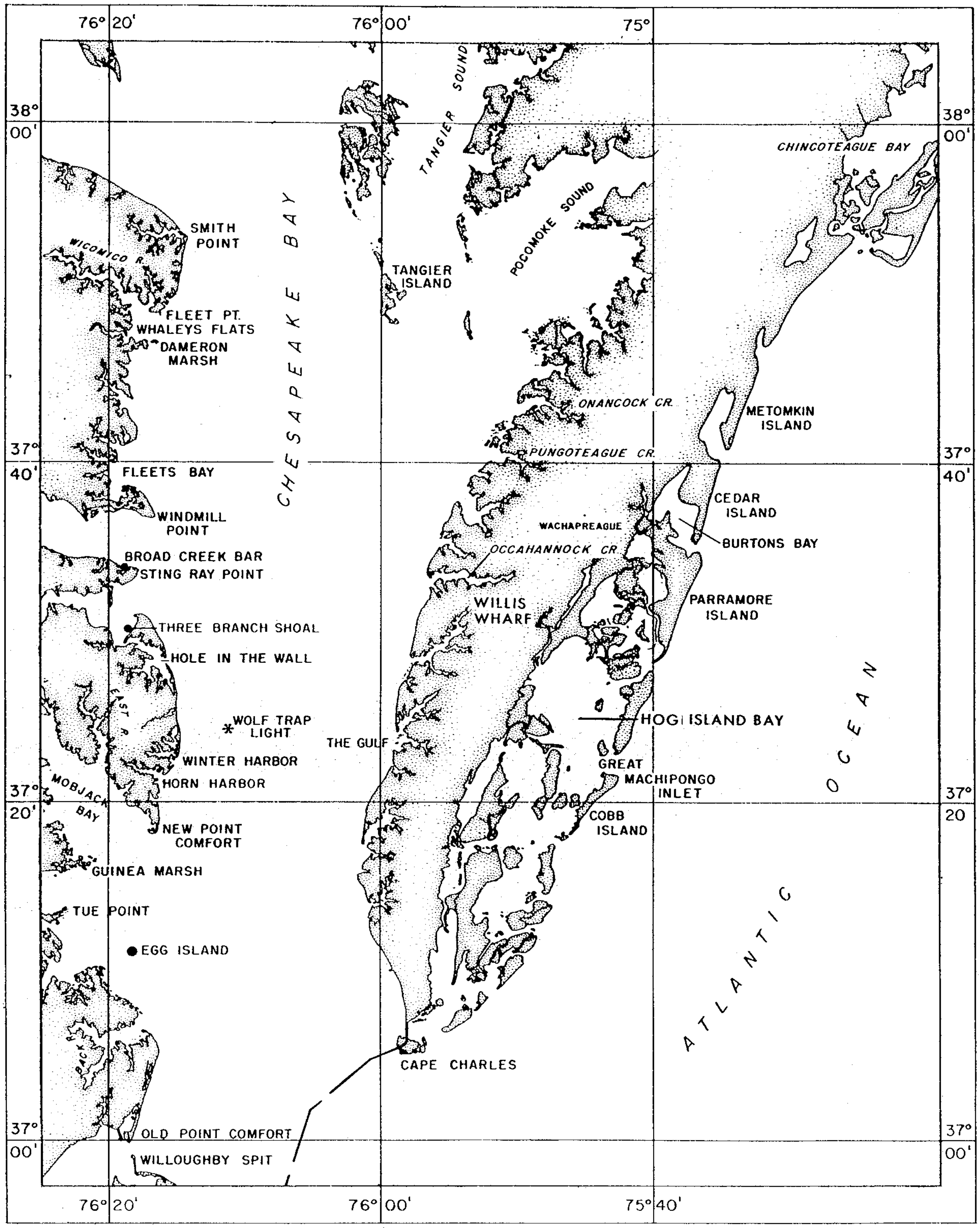


Names of oyster rocks, geographical points, towns and bodies of water in James and York rivers.



Names of oyster rocks, geographical points, towns and bodies of water in Rappahannock and Potomac rivers.



Names of oyster rocks, geographical points, towns and bodies of water on Eastern Shore of Virginia.