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Status of the Major Oyster Diseases in Virginia 2003 A Summary of the Annual Monitoring Program

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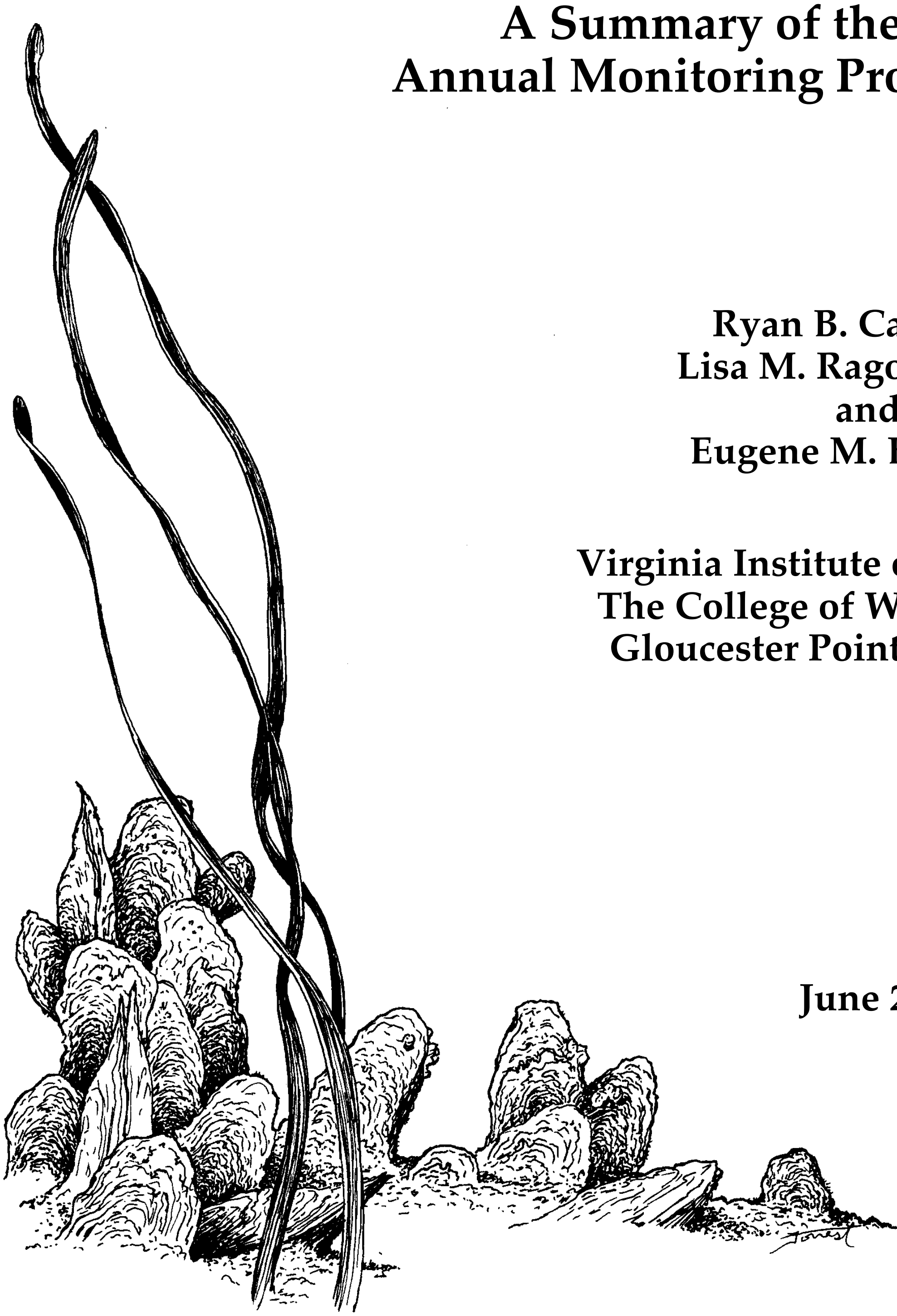
A Summary of the Annual Monitoring Program



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Executive Summary

Measured at Richmond, Virginia, 2003 was the wettest year of the last 114, and, after 1889, the second wettest ever recorded. Persistent snow and rain throughout the mid-Atlantic region caused heavy streamflows in the major tributaries of the Chesapeake, and depressed salinities throughout the lower Bay. Maximum measured salinities were generally 6-12‰ lower than in the previous year. Water at upriver oyster beds, such as Deepwater Shoal in the James River, was very nearly fresh for much of the year. Water temperatures were generally lower as well. In 2002, water temperature at Gloucester Point on the York River never fell below 5.5°C. In 2003, it was below 5°C for seven weeks beginning in mid-January, and below 2°C for two weeks in late January-early February. Late spring water temperatures were also notably cool, with temperatures more than 2°C below average for three weeks beginning in mid-May.

Low temperatures and salinities brought abatement in the oyster diseases caused by *Perkinsus marinus* (Dermo) and *Haplosporidium nelsoni* (MSX) for the first time since 1998. In the James River, *P. marinus* prevalences were the lowest they had been since 1998. In summer and fall, when *P. marinus* is normally most prevalent, it was found in a maximum of 72% of oysters at Wreck Shoal and in less than half the oysters at Horsehead Rock and Point of Shoals. Advanced infections were very rare. *Haplosporidium nelsoni* had disappeared completely from quarterly James River samples by July.

Fall Survey samples similarly revealed a withdrawal of *H. nelsoni* from most of the oyster bars in lower Bay tributaries, and a reduction in the disease impact caused by *P. marinus. Haplosporidium nelsoni* was found at only three survey locations—Aberdeen Rock in the York River, Hog House Rock in the Rappahannock, and Fleet Point in the Great Wicomico—at prevalences below 20%, and all infections were only light in intensity. *Perkinsus marinus* persisted at every oyster bar, but not in every oyster, and at relatively lower infection intensities. The general absence of *H. nelsoni*, and reduction in prevalence and intensity of *P. marinus*, suggests that mortality due to these parasites in tributaries of the lower Chesapeake Bay was probably at its lowest level in several years.

Introduction

The protozoan parasites *Haplosporidium nelsoni* ("MSX") and *Perkinsus marinus* ("Dermo") are serious pathogens of oysters in the Chesapeake Bay. *Haplosporidium nelsoni* 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 once-productive 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* in Virginia was limited to the lower river areas, 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, with its increase in abundance and distribution, *P. marinus* is now a more important oyster pathogen than *H. nelsoni*. Most *P. marinus*-associated mortality occurs during late summer and early fall, but it may begin as early as June following warm winters that allow more infections to persist through the winter.

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 at salinities < 12 ppt.

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 2003 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 and oyster reefs.

Tray Samples. Oysters are collected from the upper Rappahannock River at Ross Rock each April or May and held in trays in the lower York River. Ross Rock oysters are highly susceptible to diseases caused by *H. nelsoni* and *P. marinus* and serve as excellent sentinels for the assessment of annual variability in disease pressure.

Prior to deploying 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 Ross Rock during April, but in some years *P. marinus* has been present at low (< 10%) prevalence. At least 300 oysters are placed in each of two trays in the York River around 1 May each year. Each month from May through October, mortality is calculated and samples of 25 oysters are examined histopathologically for disease.

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

New trays are established each May to provide a record of disease prevalence and intensity for each year. Because sentinel oysters have been held at the same location each year since 1960, we have a long-term database on *H. nelsoni* and *P. marinus* abundance. It is possible to compare parasite prevalence and infection intensity between 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 (n=25) are collected in the fall from most major public harvesting areas in Virginia. From 1987 to 2001 the upper James River has been intensively monitored. Each month, samples of 25 oysters were collected from Wreck Shoal, Point of Shoals, Horsehead Rock, and Deep Water Shoal. In 2002, samples were collected from these four locations monthly from January through May and then again in July and October. In 2003, samples were collected in January, March, July, and October.

Private Oyster Grounds and Oyster Reefs. Occasionally 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.

In the last several years VMRC along with other entities have been pursuing oyster reef restoration as a resource management strategy. Periodically, samples of oysters from the reefs have been submitted for disease analysis. These samples are identified as reef samples in the results of this report.

Diagnostic Techniques

Prevalence (percent of population infected) 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. Weighted prevalence, a measure of average infection intensity, was determined by assigning scores of 1, 3, and 5 to light, moderate and heavy infection intensity ranks, summing the scores of all individuals in a sample, and dividing the total score by the total number of individuals in a sample.

Environmental Parameters

Water temperature for the determination of long-term averages and yearly anomalies was 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 was obtained during visits to the collection sites. River flow data for the James River and Rappahannock River were obtained from the United States Geological Survey (USGS; http://waterdata.usgs.gov/va/nwis/current/?type=flow).

Results

I. Environmental Conditions

Mean weekly water temperatures for 2003 were below the long-term average in 24 of the 37 weeks before Hurricane Isabel destroyed the monitoring station at the VIMS pier (Figure 1). The winter was cold, with water temperatures below 5°C for seven weeks beginning in mid-January, and below 2°C for two weeks in late January-early February. Late spring was cool, with temperatures more than 2°C below normal for three weeks from mid-May to early June. Summer water temperatures were typical.

2003 was a very wet year, breaking a low river flow (thus high salinity) trend that began in mid-1998 (Figures 2, 3). Measured in the James River at Richmond, streamflow was above average in every month except January. Average streamflow in the James River in both May and June was the second highest on record; in September and November, the third highest on record. The arrival of Hurricane Isabel on the night of 18 September resulted in a twenty-fold increase in streamflow over two days, with elevated flows persisting for two weeks. In the Rappahannock River, streamflow increased by a factor of sixteen over two days, and elevated flows lasted for twelve days. High streamflows over the course of the year in the major tributaries of the Chesapeake Bay depressed salinities throughout the lower Bay. In the James River, maximum measured salinities at Deepwater Shoal, Horsehead Rock, Point of Shoals, and Wreck Shoal were 7-11‰ lower than in 2002; minimum measured salinities were 5-9‰ lower (Table 1). During sampling in fall 2003 for the oyster survey, measured salinities were 6-10‰ lower in the James River, 6-12‰ lower in the York

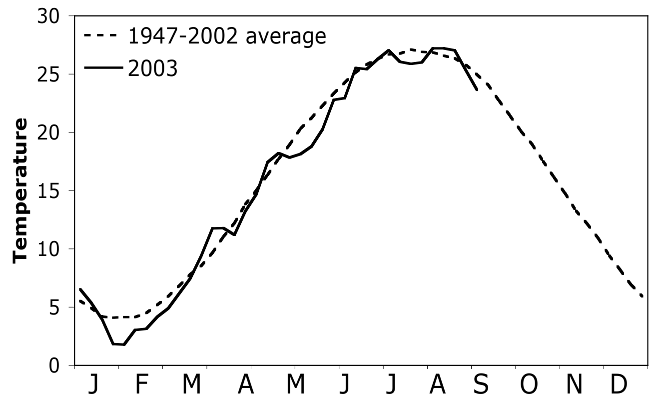

Figure 1. Average weekly water temperature (°C) in the York River at Gloucester Point in 2003 relative to the long-term weekly average.

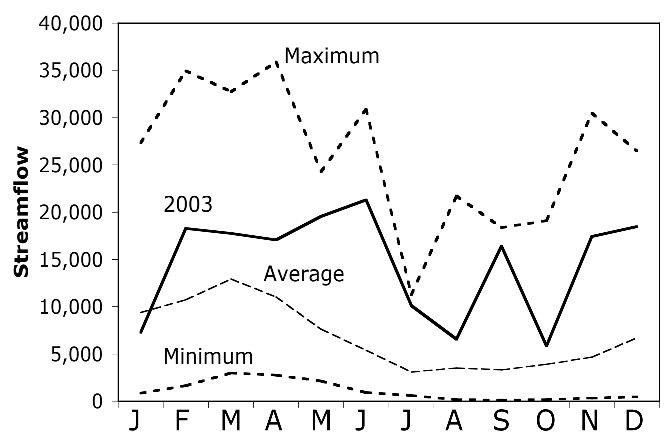

Figure 2. Average monthly streamflow (cu ft/sec) in the James River at Richmond in 2003 relative to the long-term (1935-2002) monthly average and all time maxima and minima.

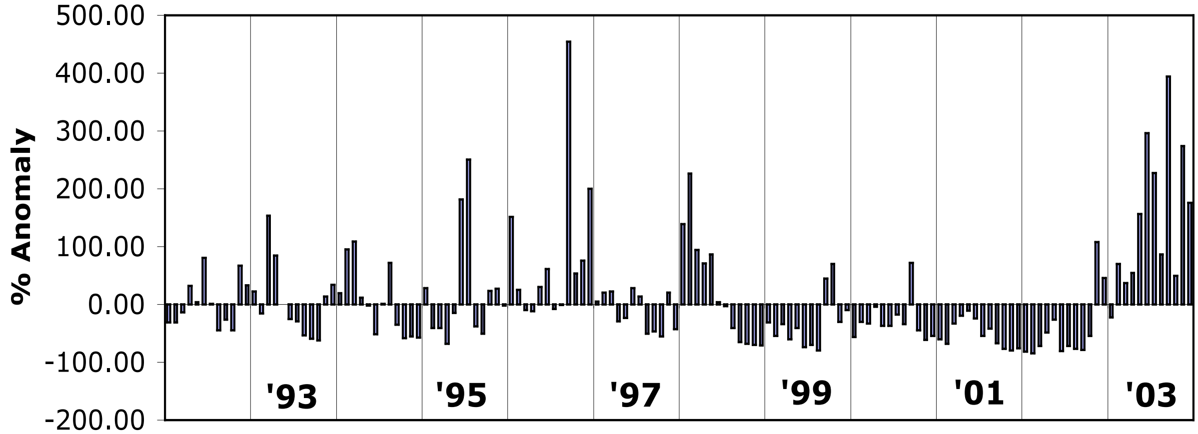

Figure 3. Average monthly streamflow anomaly in the James River at Richmond, 1992-2003. Expressed in terms of percentage (%) anomaly relative to long-term (1935-2002) average for each month.

River, 8-9‰ lower in the Piankatank River, 6-7‰ lower in the Rappahannock River, and 8‰ lower in the Great Wicomico River than in 2002 (Table 2).

II. James River Oyster Disease Monitoring

Perkinsus marinus (Dermo)

Prevalence and intensity of *P. marinus* in the upper James River in 2003 declined to levels not seen since 1996-98 (Figure 4). Prevalence at Deepwater Shoal, Horsehead Rock, Point of Shoals, and Wreck Shoal in January 2003 ranged from 38 to 76% (Table 1), relatively high for that time of year but consistent with high prevalences observed through 2002. Prevalence declined sharply through the spring and into summer. In July, *P. marinus* could not be detected at Deepwater Shoal or Horsehead Rock, and was present at only 3% prevalence at Point of Shoals. Prevalence at Wreck Shoal in July was a more typical 72%. October prevalences of 39% at Point of Shoals and 40% at Horsehead Rock and Wreck Shoal were the lowest observed since 1996. (At Deepwater Shoal, live oysters could not be found in October.)

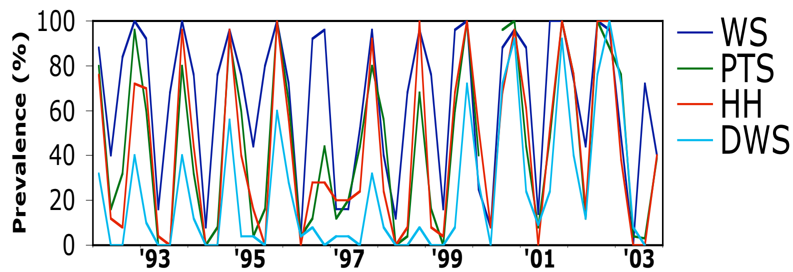

Figure 4. Quarterly prevalence of *P. marinus* in the James River at Wreck Shoal (WS), Point of Shoal (PTS), Horsehead Rock (HH), and Deepwater Shoal (DWS) from 1992-2003.

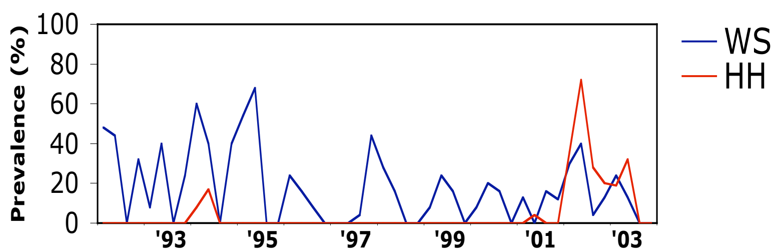

Figure 5. Quarterly prevalence of *H. nelsoni* in the James River at Wreck Shoal (WS) and Horsehead Rock (HH) from 1992-2003.

Intensity of *P. marinus* infections in the upper James River in 2003 was also lower than in 2002 (Table 1). In 2002, 75% of all *P. marinus* infections in July and October were at least "moderate" in intensity, with 24% "heavy"; just 25% of infections were "light". In 2003, 71% of infections were "light", and just a single heavily infected oyster was observed after January, in October at Wreck Shoal.

Haplosporidium nelsoni (MSX)

Haplosporidium nelsoni was moderately prevalent (19-28%) in the upper James River in January 2003 (Figure 5, Table 1). By March, *H. nelsoni* was undetectable at Deepwater Shoal, though still moderately prevalent (13-32%) at the other stations; by July, it had disappeared from Horsehead Rock, Point of Shoals, and Wreck Shoal as well, and would not be detected again in the James River in 2003. All observed *H. nelsoni* infections in the James River in 2003 were light in intensity.

III. Fall Oyster Disease Survey

The fall 2002 oyster disease survey was conducted from 22 September through 23 October. Thirty-one oyster populations were sampled for disease analysis. Oysters were collected from natural oyster reefs in tributaries of the western shore of the Chesapeake Bay, including the James River, York River, Mobjack Bay, Piankatank River, Rappahannock River, Corrotoman River, Great Wicomico River, and Potomac River; and from an artificial reef in the Elizabeth River. Results of this survey are presented in Table 2, and described for each tributary below.

James River

Nine James River oyster rocks were surveyed for disease in the fall of 2003 (a tenth, Deepwater Shoal, had no live oysters). *Perkinsus marinus* prevalences were generally much lower than in 2002. Prevalence fell by 21% (Dry Shoal) to 92% (Mulberry Point) at the eight oyster bars farthest upriver, ranging from 8-67%. The two downriver sites, Thomas Rock and Nansemond Ridge, were exceptional in having higher *P. marinus* prevalences (by 24 and 36%, respectively) than in 2002. At no sites were infection intensities more intense than in 2002. Only one "heavy" infection, at Wreck Shoal, was observed, and the average percentage of "moderate" to "heavy" infections fell from 55 to 21%.

Haplosporidium nelsoni, present at all James River survey sites in fall 2002 at prevalences ranging from 4-28%, was not observed at any James River site in fall 2003.

York River

Two locations were sampled in the York River—Aberdeen Rock and Bell Rock. *Perkinsus marinus* prevalence in fall 2003 was 88% at both locations, in each case 8% lower than in 2002 Far fewer heavy infections were observed—none (versus 3 in 2002) at Aberdeen Rock and 2 (versus 11 in 2002) at Bell Rock—and the percentage of moderate to heavy infections fell from 55 to 50% at Aberdeen Rock and 71 to 50% at Bell Rock.

In 2002, *Haplosporidium nelsoni* was found at Bell Rock (at 8% prevalence) but not at Aberdeen Rock. In 2003, *H. nelsoni* was found at Aberdeen Rock (16% prevalence) but not at Bell Rock. All infections were light.

Mobjack Bay

Oysters from only one site in Mobjack Bay, Tow Stake, were examined for disease. *Perkinsus marinus* prevalence fell from 96% in 2002 to 83% in 2003, with far more infections (70%, versus 0% in 2002) being only light in intensity. *Haplosporidium nelsoni* was not observed in Mobjack Bay.

Piankatank River

Three Piankatank River oyster rocks were sampled in the fall 2003—Ginney Point, Burton Point, and Palace Bar. *Perkinsus marinus* prevalence ranged from 88-92%, down from 96-100% in 2002. Fewer advanced infections were observed than in 2002: 1 fewer heavy infections at Burton Point (5) and 4 fewer at Palace Bar (0). The average percentage of moderate to heavy infections fell from 58 to 43%.

Haplosporidium nelsoni, present at all Piankatank River survey sites in fall 2002 at prevalences ranging from 4-16%, was not observed in the Piankatank River in fall 2003.

Rappahannock River

Oysters were sampled from nine Rappahannock River oyster reefs. *Perkinsus marinus* prevalence in 2003 was equal to prevalence in 2002 at the sites farthest upriver (Ross Rock, 8%) and downriver (Broad Creek, 100%). At sites in between, *P. marinus* prevalence was always lower in 2003, and with just one exception (Smokey Point) below 90%. In 2002, prevalence at all Rappahannock sites exceeded 90%. Heavy infections were restricted to the five sites farthest downriver, and the average percentage of moderate to heavy infections fell from 63 to 39%.

In 2002, *Haplosporidium nelsoni* had been found at all Rappahannock River stations except Morattico Bar, at prevalences from 4-28%. In 2003, only a single light infection was observed in the Rappahannock, at Hog House Rock.

Corrotoman River

Middle Ground was the only Corrotoman River location surveyed. *Perkinsus marinus* was slightly less prevalent than in 2002 (92%, versus 96% in 2002), but fewer oysters had advanced infections. Only one oyster had a heavy infection, and the percentage of moderate to heavy infections fell from 75 to 60%. *Haplosporidium nelsoni* was not observed in the Corrotoman River.

Great Wicomico River

Three Great Wicomico oyster bars were sampled in the fall of 2003—Fleet Point, Haynie Bar, and Whaley's. *Perkinsus marinus* prevalences of 84% and 88% at Whaley's and Fleet Point, respectively, were unchanged since 2002; prevalence of 80% at Haynie Bar was 12% lower. Only a single heavy infection was observed, at Haynie Bar, and the average percentage of moderate to heavy infections fell from 49 to 41%.

A light *Haplosporidium nelsoni* infection was observed in a single Fleet Point oyster.

Other areas

Two additional locations were surveyed in fall 2003—Nomoni, in the Potomac River, and the West Branch shell plant reef in the Elizabeth River. *Perkinsus marinus* prevalence was 100% at the West Branch shell plant (with most infections moderate in intensity), but only 16% at

Nomoni (with three of four infections light). *Haplosporidium nelsoni* was not observed at either site.

IV. VIMS Tray Samples

In order to assess inter-annual variation in disease pressure, a tray of Ross Rock, Rappahannock River oysters was established in the lower York River at VIMS on 28 April 2003 and subsequently monitored for disease until early September. No infections of *H. nelsoni* or *P. marinus* were detected in oysters sampled at the time of transplantation. The number of live and dead oysters in each tray was assessed monthly from June to September; the resulting determinations of percent monthly and percent cumulative mortalities are shown in Table 3. Relative to 2002, mortality was delayed by a month and increased more gradually in 2003 to a September level 25% lower than a year earlier. Cumulative mortality was low (< 5%) through early July, but increased to 19.6% in August and 64.0% in September.

Samples for disease diagnoses were also taken monthly. *Perkinsus marinus* was not observed in the transplanted oysters until early August, a month later than in 2002. Prevalence of *P. marinus* at that time was a relatively low 32%, but rapidly increased to 92% by early September. Infections were generally less intense than in 2002. In 2002, the proportion of moderately to heavily infected oysters rose from 68% in August to 71% in September and 91% in October. By the end of the 2003 trial in September, only 50% of *P. marinus* infections were moderate to heavy.

The first 2003 observation of *Haplosporidium nelsoni*, in August, was also a month later than in 2002. The prevalence of *H. nelsoni* upon its initial discovery in the York River in 2003 was 92%, identical to its prevalence upon discovery in 2002; prevalence in the second month (September, 69%) was also about the same, as were the distributions of infection intensities during the first two months of the disease event (2002: 12 heavy/4 moderate/7 light, then 5 heavy/9 moderate/3 light; 2003: 13 heavy/3 moderate/10 light, then 5 heavy/5 moderate/8 light).

Discussion

Perkinsus marinus was distributed no less widely in lower Chesapeake Bay in 2003 than in 2002. With salinity depressed throughout the lower Bay and its tributaries, however, its prevalence and its disease impact abated, especially in the upper reaches of the major rivers. Prevalence at most sites declined to levels not seen since 1998 or earlier, and heavy, advanced infections were relatively scarce. Figure 2 illustrates quarterly *P. marinus* prevalences at four James River oyster bars from 1992-2003. During a period of reduced rainfall and streamflow and thus higher salinities from mid-1998 through 2002, the maximum annual prevalence of *P. marinus* converged at 100% at all four oyster bars. In 2003, however, prevalence peaked at 72% at Wreck Shoal in July, and prevalence was ≤ 40% at Wreck Shoal, Point of Shoal, and Horsehead Rock in October.

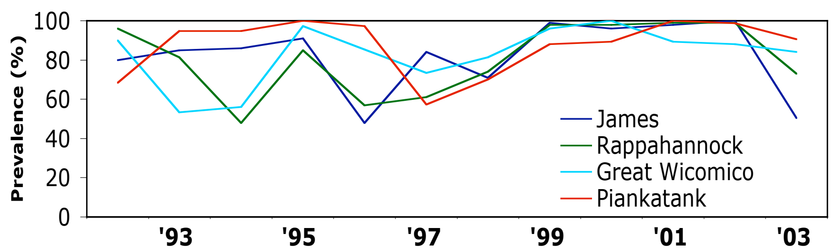

Figure 5. Mean maximum annual prevalence of *P. marinus* at oyster bars in four Chesapeake Bay tributaries, 1992-2003.

Perkinsus marinus prevalence in the other rivers followed a similar trend. Figure 5 shows average maximum annual prevalence from 1992-2003 at four oyster bars in the James River (Wreck Shoal, Point of Shoal, Horsehead Rock, and Deepwater Shoal), five in the Rappahannock River (Broad Creek, Parrot Rock, Long Rock, Bowlers Rock, and Ross Rock), three in the Great Wicomico River (Fleet Point, Whaley's, and Haynie Bar), and three in the Piankatank River (Palace Bar, Burton Point, and Ginney Point). As in the James River, *P. marinus* prevalence in the Rappahannock, Great Wicomico, and Piankatank Rivers surpassed 85% in 1999 and remained high through 2002 before decreasing somewhat, particularly in the larger James and Rappahannock Rivers, in 2003.

The mean maximum annual percentage of more advanced, moderate to heavy infections is another indicator of the intensity of *P. marinus* activity. As *P. marinus* prevalence increased at oyster bars in lower Chesapeake Bay tributaries from 1998-2002, so did the proportion of moderate to heavy infections (Figure 6). Generally, 60-80% of all oysters carried advanced *P. marinus* infections between 2000-2002. In 2003, advanced infections became more scarce (≤ 40%) in all the tributaries, and were restricted to higher salinity waters closer to the main stem of Chesapeake Bay.

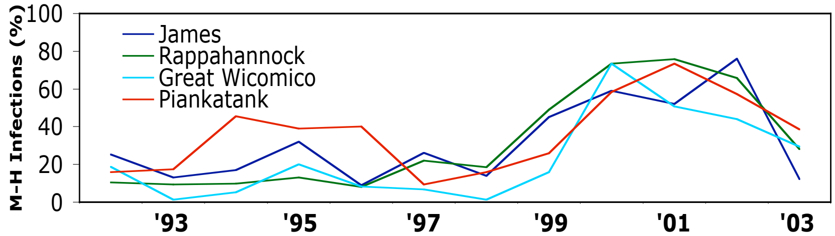

Figure 6. Mean maximum annual percentage of more intense, moderate to heavy *P. marinus* infections at oyster bars in four Chesapeake Bay tributaries, 1992-2003.

Haplosporidium nelsoni was affected more dramatically than *P. marinus* by 2003's extended period of increased river flows and depressed salinities. At the end of 2002, *H. nelsoni* was ubiquitous and probably causing intense disease in most of the oyster bars in Virginia. The parasite continued to be very prevalent in the James River in January 2003. However, *C. virginica* can purge *H. nelsoni* infections at salinities below 10‰. Salinities this low were probably widespread in lower Bay tributaries from spring into summer 2003; salinity at Point of Shoal in the James River, for example, was ≤ 8‰ from mid-May through August. By the end of 2003, *H. nelsoni* appeared to have retreated from most of the oyster bars it colonized during four and a half years of drought. Only a few light *H. nelsoni* infections were observed anywhere, and the parasite was undetected in the James, Elizabeth, Piankatank, and Potomac Rivers as well as Mobjack Bay.

Salinity at Deepwater Shoal in the upper James River was too low even for the oysters, none of which could be found surviving by October.

While *P. marinus* activity may have been reduced in 2003 by an extended period of low salinities, this does not necessarily bode well for 2004; infection prevalence and intensity of *P. marinus* will be strongly influenced by water conditions this summer. *Perkinsus marinus* persists in every bar oyster surveyed, and while overwintering, January 2004 prevalences were low (0-20% in the James River) and intensities uniformly light, an extended period of very warm water and high salinities would result in intense disease activity by late summer. A cooler, rainier summer, on the other hand, would probably result in another year of relatively low *P. marinus* activity. It is somewhat more certain that *H. nelsoni* activity will be light, at least in late spring. Observed prevalence and infection intensity of *H. nelsoni* normally peak once in spring, as late summer-acquired, overwintering infections develop into advanced cases with resulting mortality, and again in late summer-early fall, as spring-acquired infections become advanced. With overwintering infections largely non-existent (*H. nelsoni* was not observed in the James River in January 2004), oyster mortality in the spring should be low. The only other year in the last twelve in which *H. nelsoni* was not observed in January is also the only year in which spring infections were absent. In 1997, overwintering *H. nelsoni* infections were undetectable in the James River, and the parasite did not appear until July that year at any oyster bar in the James.

Acknowledgments

This work would not have been possible without the assistance of many people. Among them, Captain Paul Harvey operated the vessels collecting quarterly James River oyster samples and the Rappahannock River spring imports; the Virginia Marine Resources Commission collected oysters for the Fall Survey; Rita Crockett, Susan Denny, and Martin Wunderly performed all the histological processing and RFTM culturing, and read the slides; and Corinne Audemard and Melissa Southworth (VIMS Molluscan Ecology program) shared their James River salinity data.

References

Andrews, J. D. 1988. Epizootiology of the disease caused by the oyster pathogen *Perkinsus marinus* and its effects on the oyster industry. Am. Fish. Soc. Spec. Pub. 18: 47-63.

Ford, S. E., and M. R. Tripp. 1996. Diseases and defense mechanisms. Pages 581-660 in V. S. Kennedy, R. I. E. Newell, and A. F. Eble (eds.). The Eastern Oyster *Crassostrea virginica*. Maryland Sea Grant Program, College Park, Maryland.

Haskin, H. H., and J. D. Andrews. 1988. Uncertainties and speculations about the life cycle of the eastern oyster pathogen *Haplosporidium nelsoni* (MSX). Am. Fish. Soc. Spec. Pub. 18: 5-22.

Table 1.

Monthly survey of prevalence and intensity of *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo) in oysters from James River harvesting areas in 2003. Inf/Ex = number infected/number examined. Infection intensity was ranked as heavy (H), moderate (M), and light (L) (presented as H-M-L).

				H. nelsoni			*P. marinus*		
Location	Date	Temp	Sal	Inf/Ex	Prev	Intensity	Inf/Ex	Prev	Intensity
Deepwater Shoal									
	13 Jan	5	0	5/25	20	0-0-5	18/25	72	1-3-14
	24 Mar	15	0	0/25	0	0-0-0	2/25	8	0-0-2
	24 Jul	28	2	0/15	0	0-0-0	0/15	0	0-0-0
	22 Oct	17	4	No live oysters					
Horsehead Rock									
	13 Jan	5	3	4/21	19	0-0-4	8/21	38	0-5-3
	25 Mar	14	2	8/25	32	0-0-8	0/25	0	0-0-0
	24 Jul			0/25	0	0-0-0	0/25	0	0-0-0
	23 Oct	17	10	0/25	0	0-0-0	10/25	40	0-2-8
Point of Shoals									
	13 Jan	5	2	7/25	28	0-0-7	19/25	76	0-10-9
	19 Mar	10	4	7/24	29	0-0-7	1/24	4	0-0-1
	24 Jul	27	4	0/30	0	0-0-0	1/30	3	0-0-1
	23 Oct	17	9	0/23	0	0-0-0	9/23	39	0-2-7
Wreck Shoal									
	13 Jan	5	5	6/25	24	0-0-6	12/25	48	1-2-9
	19 Mar	10	10	3/24	13	0-0-3	0/25	0	0-0-0
	24 Jul		14	0/25	0	0-0-0	18/25	72	0-8-10
	23 Oct	16	14	0/25	0	0-0-0	10/25	40	1-6-8

Table 2.

Fall survey of prevalence and intensity of *Haplosporidium nelsoni* and *Perkinsus marinus* in oysters from Virginia oyster populations in 2003. Inf/Ex = number infected/examined. Infection intensity as heavy (H), moderate (M), and light (L) (H-M-L).

				H. nelsoni			*P. marinus*		
Location	Date	Temp	Sal	Inf/Ex	Prev	Intensity	Inf/Ex	Prev	Intensity
James River									
Deepwater Shoal	23 Oct	16.5	7						
Horsehead Rock	23 Oct	16.5	10	0/25	0	0-0-0	10/25	40	0-2-8
Swash	23 Oct	16.5	12	0/25	0	0-0-0	15/25	60	0-7-8
Mulberry Point	23 Oct	16.5	10	0/24	0	0-0-0	2/24	8	0-0-2
Point of Shoals	23 Oct	16.5	9	0/23	0	0-0-0	9/23	39	0-2-7
Long Shoal	23 Oct	16.0	12	0/25	0	0-0-0	12/25	48	0-1-11
Dry Shoal	23 Oct	16.0	11	0/24	0	0-0-0	16/24	67	0-4-12
Wreck Shoal	23 Oct	16.0	14	0/25	0	0-0-0	10/25	40	1-1-8
Thomas Rock	23 Oct	17.0	15	0/25	0	0-0-0	14/25	56	0-2-12
Nansemond Ridge	23 Oct	17.0	13	0/25	0	0-0-0	12/25	48	0-4-8
Elizabeth River									
West Branch Shell Plant	23 Oct			0/23	0	0-0-0	23/23	100	0-17-6
York River									
Aberdeen Rock	22 Oct	18.5	17	4/25	16	0-0-4	22/25	88	0-11-11
Bell Rock	22 Oct	18.0	13	0/26	0	0-0-0	22/25	88	2-9-11
Mobjack Bay									
Tow Stake	17 Oct	20.0	17	0/25	0	0-0-0	20/24	83	0-6-14
Piankatank River									
Ginney Point	16 Oct	20.0	11	0/24	0	0-0-0	23/25	92	1-6-16
Burton Point	16 Oct	18.5	12	0/25	0	0-0-0	22/25	88	5-10-7
Palace Bar	16 Oct	19.0	12	0/25	0	0-0-0	23/25	92	0-7-16
Rappahannock River									
Ross Rock	21 Oct	18.0	6	0/24	0	0-0-0	2/25	8	0-0-2
Bowlers Rock	21 Oct	18.0	9	0/25	0	0-0-0	8/25	32	0-1-7
Long Rock	21 Oct	18.0	9	0/25	0	0-0-0	18/25	72	0-4-14
Morattico	21 Oct	18.0	10	0/25	0	0-0-0	22/25	88	0-4-18
Smokey Point	21 Oct	18.0	11	0/25	0	0-0-0	23/25	92	3-14-6
Drumming Ground	21 Oct	18.0	12	0/25	0	0-0-0	22/25	88	1-13-8
Hog House Rock	21 Oct	18.0	13	1/25	4	0-0-1	19/25	76	2-9-8
Parrot Rock	21 Oct	20.0	13	0/25	0	0-0-0	22/25	88	2-10-10
Broad Creek	16 Oct	20.0	13	0/25	0	0-0-0	25/25	100	1-10-14
Corrotoman River									
Middle Ground	21 Oct	18.0	12	0/25	0	0-0-0	23/25	92	1-13-9
Great Wicomico River									
Haynie Bar	15 Oct	20.0	13	0/25	0	0-0-0	20/25	80	1-5-14
Whaley's	15 Oct	19.0	13	0/25	0	0-0-0	21/25	84	0-9-12
Fleet Point	13 Oct	19.5	13	1/25	4	0-0-1	22/25	88	0-11-11
Potomac River									
Nomoni	14 Oct			0/25	0	0-0-0	4/25	16	0-1-3

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, 2003. Inf/Ex = number infected/examined. Infection intensity as heavy (H), moderate (M), and light (L) (H-M-L).

	Monthly	Cumulative		*H. nelsoni*			*P. marinus*	
Date	mortality-%	mortality%	Inf/Ex	Prev	Intensity	Inf/Ex	Prev	Intensity
28 Apr			0/25	0	0-0-0	0/25	0	0-0-0
5 Jun	1.72	1.72	0/25	0	0-0-0	0/25	0	0-0-0
1 Jul	0.30	2.02	0/25	0	0-0-0	0/25	0	0-0-0
2 Aug	17.93	19.60	26/28	92	13-3-10	9/28	32	0-2-7
3 Sep	55.23	64.04	18/26	69	5-5-8	24/26	92	4-8-12