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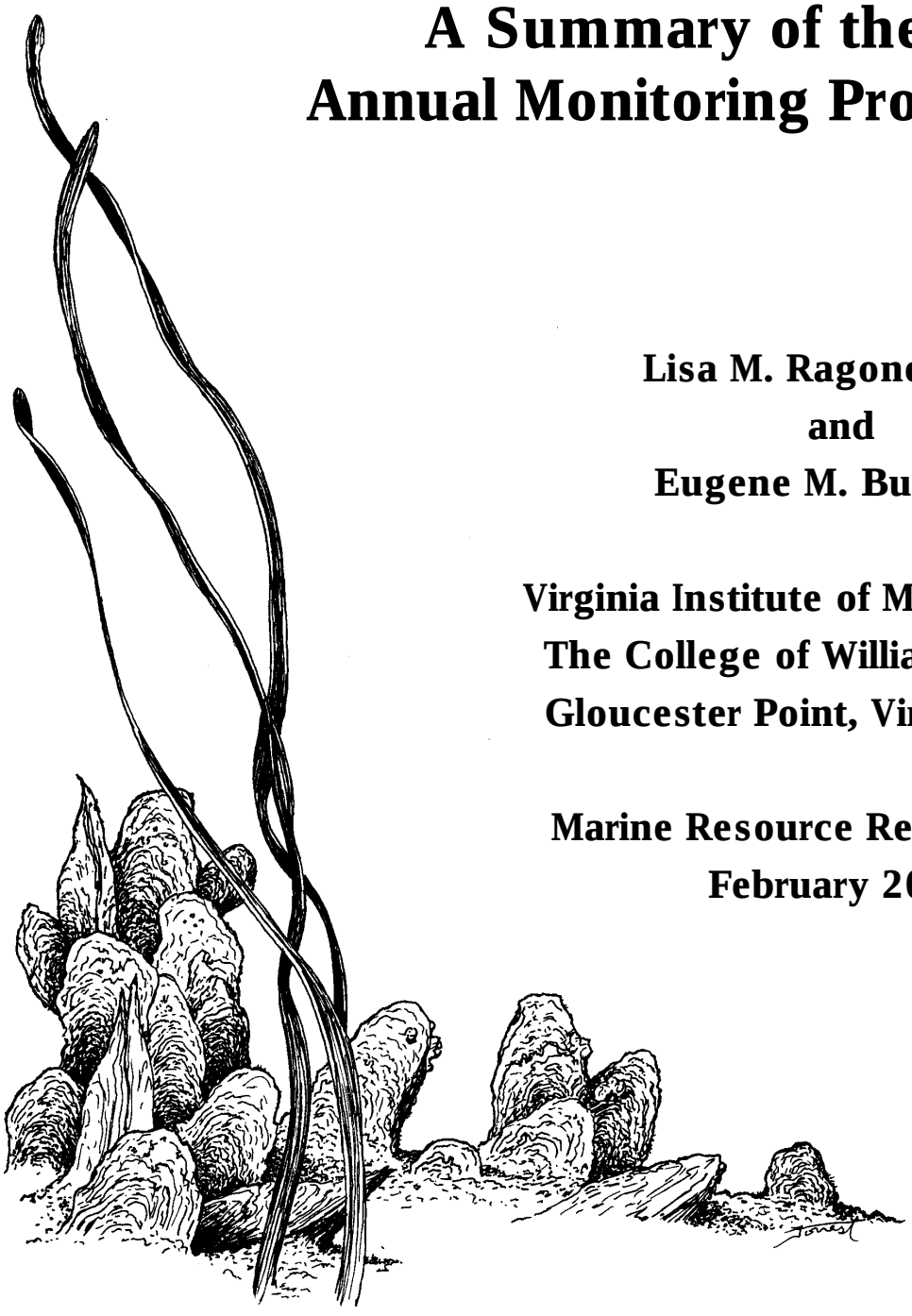

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Executive Summary

Relatively dry conditions prevailed through most of 2001 resulting in below average Chesapeake Bay streamflows. Streamflow in the James River was below average for the entire year. Similarly, salinities were elevated through out the other tributaries of the lower Chesapeake Bay, particularly during the fall 2001. Dry conditions and below average streamflows have been predominant in the Chesapeake Bay since summer 1998.

Water temperatures in late December 2000 and January 2001 consistently remained below 5°C for a seven-week period and were 1-3 °C below the long-term average. Following this initial cold spell, weekly water temperature was generally above average for the remainder of the year. November and December were particularly warm with some weekly temperature means exceeding long-term averages by 6°C. As a consequence of the relatively warm temperatures, high salinities, and high oyster parasite abundances in 2000, both *P. marinus* (Dermo) and *H. nelsoni* (MSX) were widely distributed throughout oyster populations in Virginia in 2001.

Our disease monitoring efforts once again included monthly assessments of oysters at four upper James River populations—Deepwater Shoal, Horsehead Rock, Point of Shoals, and Wreck Shoal. Prevalence of *P. marinus* followed a typical pattern declining during the winter and spring. Annual minimums in prevalence were observed in May and ranged from 0-4%. Salinity during mid to late summer and fall were exceptionally high ranging from 10-16 ppt at Deepwater Shoal, 14-20 ppt at Horsehead Rock, 15-18 ppt at Point of Shoals, and 16-22 ppt at Wreck Shoal. *Perkinsus marinus* abundance in the upper James River was at a record high level for the third consecutive year. Annual prevalence maximums exceeded 90% at all four sites. Advanced infections of *P. marinus* were most likely responsible for some mortality of oysters older than 1-2 years at all four of these locations.

Haplosporidium nelsoni persisted for nearly the entire year at Wreck Shoal; the parasite was detected in all months except April and June. The maximum prevalence observed at Wreck Shoal was only 24%, but given the presence of moderate and heavy intensity infections, the pathogen likely caused some mortality at this location in early summer. Prevalence of the parasite at Horsehead Rock was 4% in April. This was the only month during the period January to October in which the parasite was found. The high fall salinities promoted a reinvasion of *H. nelsoni* into this area in late fall and the parasite was observed at a prevalence of 16% in November and 36% in December. Thirty-six percent prevalence is a record high prevalence of the pathogen for Horsehead Rock.

Thirty-nine oyster populations were surveyed for disease in fall 2001. *Perkinsus marinus* was found in all areas sampled and prevalence exceeded 90% at all but 5 sample locations. In the James River *P. marinus* prevalence ranged from 88-100% at Deepwater Shoal, Horsehead Rock, Point of Shoals, Wreck Shoal, Mulberry Point, Swash, Long Shoal, and Dry Shoal. A lower prevalence was observed down river at Thomas Rock, 72%, and at Nansemond Ridge, 12%. The extremely low prevalence at Nansemond Ridge is likely age and density related; the oyster population was primarily comprised of spat; few small to market oysters were present at the site in October 2001.

In the Piankatank River *P. marinus* prevalence was 100% at all three sample locations, Ginney Point, Burton Point, and Palace Bar, and infection intensities were at a record high. In the Great Wicomico River *P. marinus* prevalence in the fall ranged from 84-100%, declining slightly from that observed in 2000, but still

remaining relatively high in comparison to previous years. *Perkinsus marinus* prevalence in the Rappahannock River continued to climb from the record high levels observed in 1999 and 2000. Once again the parasite was present on all of the eight oyster bars sampled including Ross Rock, the population located furthest up river. Prevalence at Ross Rock was 40%, the highest ever found at the site. Down river from Bowlers Rock to the mouth of the River at Broad Creek, with the exception of Hog House Rock, prevalences ranged from 96-100%. Prevalence at Hog House Rock was only 16%; this may reflect the low density of oysters, particularly market size oysters, at the site. *Perkinsus marinus* prevalence was 100% in: Nomini Creek, the Elizabeth River, on the bayside of the Eastern Shore in Pungoteague and Onancock Creeks, and at reef locations in the Coan and Yeocomico Rivers. In the York River at Aberdeen Creek prevalence was 92%. In Mobjack Bay at Pultz Bar and Tow Stake prevalences were 100 and 96%, respectively. Prevalence in Tangier Sound was 96-100%. Overall high infection intensities coincided with high prevalence. Samples from many locations had 20 to 44% prevalence of heavy infections and it is likely that the pathogen caused significant oyster mortalities in these areas.

Haplosporidium nelsoni was widely distributed in the fall. The parasite was found in October at Wreck Shoal, Long Shoal, Swash, Dry Shoal, Thomas Rock and Nansemond Ridge at prevalences ranging from 8-28%. Subsequent samples taken in December also revealed the parasite at a prevalence of 28-36% at Horsehead Rock and Point of Shoals. In the Rappahannock River *H. nelsoni* prevalence was 4% at Morattico Bar, Smokey Point, Parrot Rock, and Broad Creek. Higher prevalences were observed at Drumming Ground (16%) and Hog House Rock (40%). Prevalence in the Piankatank River was 12% at Ginney Point and 28% at Burton Point. *Haplosporidium nelsoni* prevalences in the Great Wicomico River ranged from 16 to 32%. The parasite was also detected at fairly low prevalences (<20%) at Aberdeen Rock in the York River, Yeocomico River Reef, Elizabeth River Reef, Pungoteague Creek Reef, Onancock Rock, Mobjack Bay at Pultz Bar and Tow Stake, and in Tangier Sound at California Rock, Hurley's Rock, and Byrd Rock. It is not unusual for MSX to be found at these moderate salinity areas.

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, the distribution of *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, *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 2001 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. Each year in April/May "disease free" oysters are collected from the upper Rappahannock River at Ross Rock and placed in trays located in the lower York River. Ross Rock oysters are highly susceptible to oyster disease and serve as excellent sentinels for the assessment of annual variability in disease pressure.

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 Ross Rock during April, but in some years *P. marinus* has been present at low prevalence (usually $< 10\%$). At least 300 oysters are placed in each of the two York River trays on about 1 May each year. Samples of 25 oysters are collected and examined for disease and counts of live and dead oysters are made monthly from May to October.

Monthly mortality rates are determined by dividing the number of dead oysters by the number of live and 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* 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 ($n = 25$) are collected in the fall from most major public harvesting areas in Virginia. Since 1987 the upper James River has been intensively monitored. Each month samples of 25 oysters are collected from Wreck Shoal, Point of Shoals, Horsehead Rock and Deep Water Shoal.

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 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.

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 tempera-

tures were also recorded at the various collection sites on each sample date. Salinity data for the James River was 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. River flow data for the James River and for the entire Chesapeake Bay are obtained from the U. S. Geological Survey.

Results

Environmental Parameters

Water temperatures in late December 2000 and in January 2001 were 1-3 °C below the long-term average and consistently remained below 5°C for a seven-week period (Figure 1 and 2). Average or above average temperatures persisted through the remainder of the winter, spring (Figure 2). The onset of temperatures > 20°C in late May was consistent with the timing for the long-term average and temperatures remained above 20°C for a typical 20 week period. Overall summer temperatures were at or above average; however, there were a few weeks in which below average temperature means were recorded (Figure 2). Water temperatures during November and December were extremely warm, with averages for some weeks approaching 6°C above average. A comparison of temperature anomalies for the years 1991-2001 is shown in Figure 3.

2001 was a very dry year and this was reflected in low streamflows throughout the Chesapeake Bay (USGS, see http://md.usgs.gov/monthly/bay.html). In the James River, streamflows remained below average for the entire year (Figure 1 and 2). On average, James River streamflows in 2001 were among the lowest recorded in the last decade, continuing a fairly consistent trend that began in mid-1998 (Figure 3). The low streamflow in the James River resulted in the occurrence of unusually high salinities in the upper portions of the tributary during much of the winter and fall.

James River Monthly Oyster Disease Monitoring

***Perkinsus marinus* (Dermo).** Prevalence and intensity of *P. marinus* in the upper James River in 2001 were high, but slightly lower than the record high prevalences observed in 1999 and 2000. Prevalences at Deepwater Shoal, Horsehead Rock, Point of Shoals, and Wreck

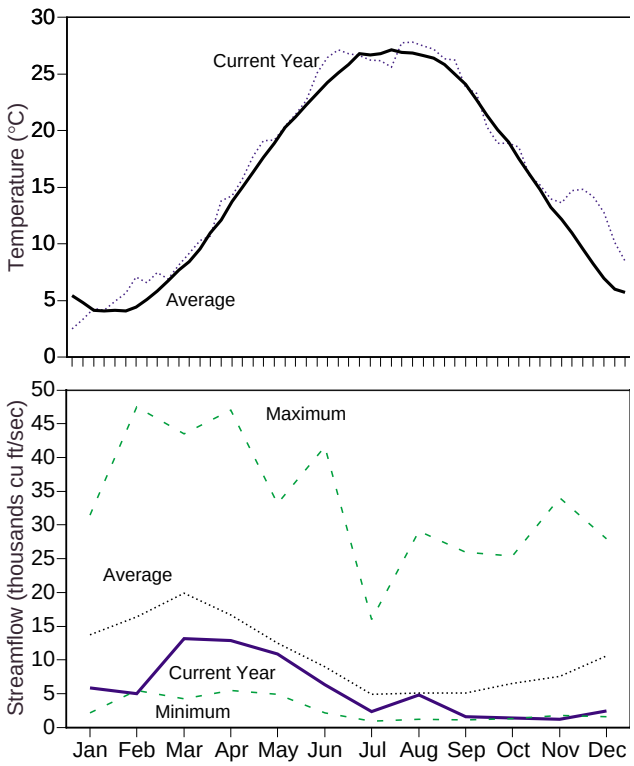


Figure 1. Average weekly water temperature at VIMS, Gloucester Point, VA (top) and monthly James River, VA streamflow (bottom). Long-term averages (dotted lines) are contrasted with 2001 values (solid lines). For streamflow long-term minimums and maximums are also shown. Long-term temperatures are for years 1947-2001 and long-term streamflows are for 1951-2000.

Shoal in January 2001 ranged from 24-88% and were well above the long-term monthly average for January (Table 1). Prevalence and intensity of the parasite followed a typical decline in the upper James River during the winter and spring. Annual minimums in prevalence ranging from 0-4% were observed in May (Figure 4). At Wreck Shoal a very sharp increase in prevalence from 0 to 64% was observed from May to June. A more gradual increase in prevalence was observed during the summer at stations upriver from Wreck Shoal—Point of Shoals, Horsehead Rock, and Deepwater Shoal. However, by late summer prevalences exceeding 90% were observed at all four stations. Maximum prevalences for the year were observed in October. High infection intensities were associated with the high prevalences and it is likely that *P. marinus* disease associated mortality occurred at Wreck Shoal from July through December and at the more upriver sites from September through December.

At Deepwater Shoal, the oyster bar located farthest upriver, record high prevalences and intensities of *P. marinus* were observed for the third year in a row (Figure 5). The high activity of the parasite at Deepwater Shoal during 1999-2001 is in sharp contrast to the preceding years 1996-1998, which had maximum prevalences ranging from only 4-36%. Although prevalence of the parasite in 2001 was slightly lower than in 1999 and 2000, the maximum once again exceeded 90%. More importantly, this high prevalence was associated with moderate and heavy infection intensities during the months September through December (Table 1). Prior to 1999 moderate and heavy intensity infections were rarely observed at this location. The increase in abundance in the last three years is associated with dry conditions that began in summer 1998 and fairly steadily persisted through December 2001. Although salinity in the spring 2001 declined to 0-8 ppt, salinity ranging from 10-17.5 ppt prevailed at

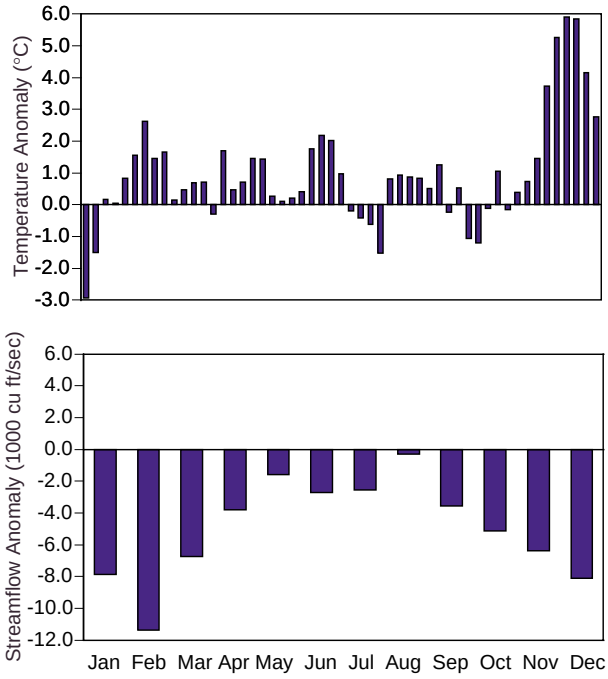


Figure 2. Weekly water temperature anomaly at the VIMS pier, Gloucester Point, VA based on average weekly water temperature from 1947-2001 (top) and monthly James River streamflow anomaly based on average discharge from 1951-2000 (bottom) for the calendar year 2000. Anomalies were calculated by subtracting the long-term average from the value observed in 2001. Positive values represent above average measures (warmer/wetter conditions) and negative values represent below average measures (colder/drier conditions).

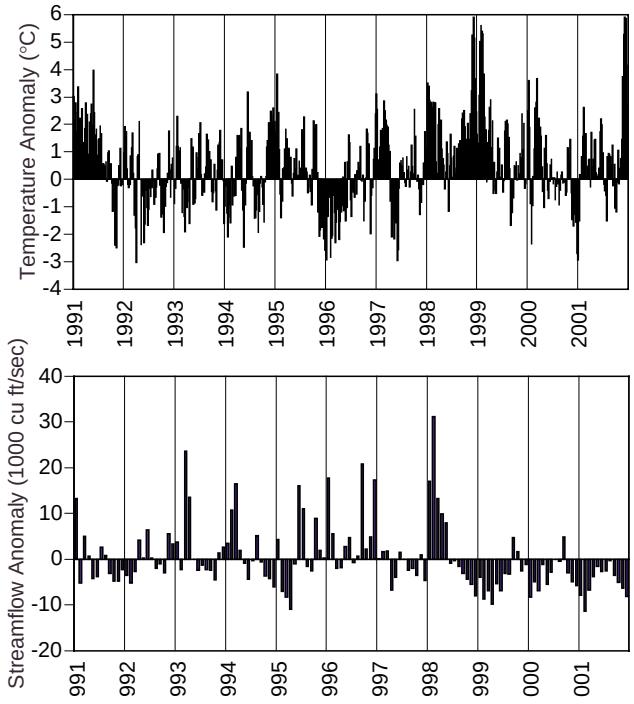


Figure 3. Mean weekly VIMS pier water temperature anomaly from long-term (1947-2001) average (top) and mean monthly James River streamflow anomaly from long-term (1951-2000) average (bottom).

Deepwater Shoal during the summer and fall creating conditions conducive to proliferation of the parasite.

At Horsehead Rock and Point of Shoals *P. marinus* prevalence and intensity declined over the winter and spring months to an annual low of 0% following a fairly typical annual pattern (Figure 4). Salinities at Horsehead Rock and Point of Shoals during this period ranged from 2-12 ppt and similar disease patterns were observed at the two sites (Figure 6 and 7). Prevalence remained low, < 8%, through June and then sharply increased to 48-52% in July. Prevalence continued to increase as the summer progressed ultimately reaching 100% in October. Late summer and fall salinities ranged from about 14-20 ppt at the two sites. This salinity range is extremely favorable for *P. marinus* as suggested by the high proportion of heavy and moderate intensity infections observed from September through December. In September 2001, the proportion of oysters having moderate or heavy intensity infections was 44% at Horsehead Rock and 40% at Point of Shoals (Table 1). While this is high, it is not as high as the intensities observed in 2000.

Farther down river at Wreck Shoal, spring salinity ranged from about 6 to 12 ppt (Figure 8). Prevalence gradually decreased from 88% in January to 0% in May. Prevalence increased from 0% in May to 64% in June. Salinity at this time ranged from 10-14 ppt, much lower than that observed at the same time in 2000 (14-21 ppt), but still relatively high for this time of the year. Prevalence continued to increase to 84% in July and ranged from 84-100% for the remainder of the year with a maximum of 100% occurring in October. Salinity ranged from 20-24 ppt through the fall. Advanced infections were numerous (Table 1). Given the high prevalence of advanced infections it is likely that *P. marinus* caused significant oyster mortalities of small and market size oysters at this location.

Average prevalence and intensity (weighted prevalence) of *P. marinus* at Deepwater Shoal, Horsehead Rock, and Wreck Shoal for the months July through December

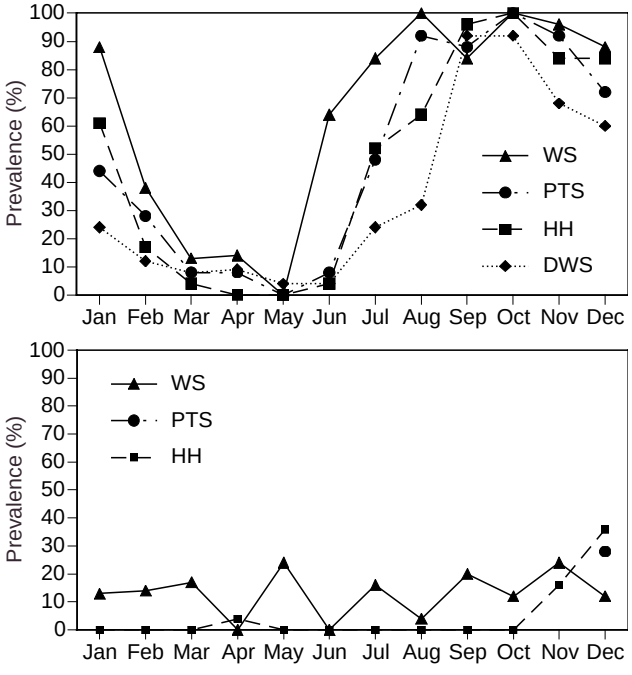


Figure 4. Prevalence of *P. marinus* (top) and *H. nelsoni* (MSX) (bottom) in James River oysters from Wreck Shoal (WS), Horsehead Rock (HH), Point of Shoals (PTS), and Deepwater Shoal (DWS) in 2001. DWS and PTS oysters were not analyzed for MSX.

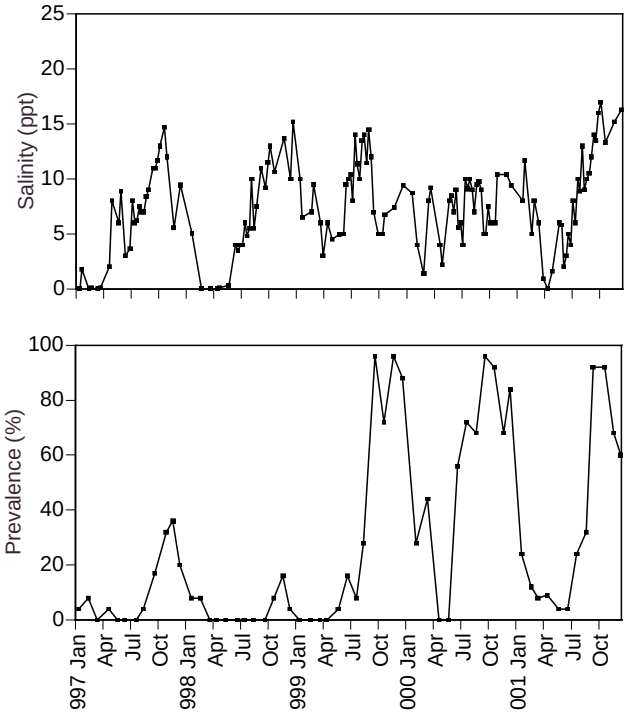


Figure 5. Salinity (top) and *P. marinus* prevalence (bottom) at Deepwater Shoal, James River, VA for the years 1997-2001.

Table 1. Monthly survey of prevalence and intensity of *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo) in oysters from James River harvesting areas in 2001. See accompanying figure for station locations. NA=not analyzed for MSX. Inf/Ex = number infected/number examined. Infection intensity was ranked as heavy (H), moderate (M), and light (L).

				H. nelsoni			*P. marinus*		
Location	**Date**	**Temp. (°C)**	**Sal. (ppt)**	**Inf/Ex**	**Prev.**	**Intensity H-M-L**	**Inf/Ex**	**Prev.**	**Intensity H-M-L**
Deep Water Shoal	17-Jan	6	8	NA			6/25	24	0-4-2
	19-Feb	7.5	5	NA			3/25	12	0-1-2
	14-Mar	11.5	6	NA			2/25	8	0-0-2
	12-Apr	19	0	NA			2/22	9	0-0-2
	15-May	21	6	NA			1/25	4	0-0-1
	15-Jun	27	5	NA			1/25	4	0-0-1
	16-Jul	28	10	NA			6/25	24	0-2-4
	15-Aug	29	12	NA			8/25	32	0-3-5
	13-Sep	29	14	NA			23/25	92	4-3-16
	16-Oct	21	14	NA			23/25	92	1-7-15
	15-Nov	15	16	NA			17/25	68	0-3-14
	12-Dec	13	15	0/25	0	0-0-0	15/25	60	2-1-12
Horsehead Rock	17-Jan	5	10	0/23	0	0-0-0	14/23	61	0-0-14
	19-Feb	7	8	0/24	0	0-0-0	4/24	17	1-0-3
	14-Mar	11.5	12	0/25	0	0-0-0	1/25	4	0-0-1
	12-Apr	19	2	1/25	4	0-0-1	0/25	0	0-0-0
	15-May	21	8	0/25	0	0-0-0	0/25	0	0-0-0
	15-Jun	27	8	0/25	0	0-0-0	1/25	4	0-0-1
	16-Jul	28	14	0/25	0	0-0-0	13/25	52	0-2-11
	15-Aug	29	13	0/25	0	0-0-0	16/25	64	0-6-10
	13-Sep	28	19	0/25	0	0-0-0	24/25	96	4-7-13
	16-Oct	20.5	18	0/25	0	0-0-0	25/25	100	1-10-14
	15-Nov	15	18	4/25	16	0-0-4	21/25	84	3-5-13
	12-Dec	13	20	9/25	36	1-2-6	21/25	84	1-3-17
Point of Shoals	17-Jan	5.5	12	NA			11/25	44	0-2-9
	19-Feb	7	10	NA			7/25	28	0-1-6
	14-Mar	11	8	NA			2/25	8	0-0-2
	12-Apr	18	2	NA			2/25	8	0-0-2
	15-May	22	8	NA			0/25	0	0-0-0
	15-Jun	26.5	8	NA			2/25	8	0-0-2
	16-Jul	28	15	NA			12/25	48	0-1-11
	15-Aug	28	15	NA			23/25	92	7-7-9
	13-Sep	28	15	NA			22/25	88	2-8-12
	16-Oct	20	18	NA			25/25	100	0-11-14
	15-Nov	14	17	NA			23/25	92	2-6-15
	12-Dec	13	18	7/25	28	4-1-2	18/25	72	2-5-11
Wreck Shoal	17-Jan	5.5	16	2/16	13	0-0-2	14/16	88	0-4-10
	19-Feb	6.5	11	3/21	14	0-0-3	8/21	38	1-0-7
	14-Mar	10.5	12	4/24	17	0-0-4	3/24	13	0-2-1
	12-Apr	17	6	0/7	0		1/7	14	0-0-1
	15-May	21	14	6/25	24	2-1-3	0/25	0	0-0-0
	15-Jun	25	11	0/25	0		16/25	64	0-6-10
	16-Jul	27	18	4/25	16	1-0-3	21/25	84	2-8-11
	15-Aug	28	20	1/25	4	0-0-1	25/25	100	10-6-9
	13-Sep	28	16	5/25	20	0-1-4	21/25	84	8-4-9
	16-Oct	19	20	3/25	12	0-0-3	25/25	100	4-15-6
	15-Nov	14	21	3/25	12	0-0-3	24/25	96	7-12-5
	12-Dec	13	22	6/25	24	1-1-4	22/25	88	5-10-7

and the years 1991-2001 are shown in Figures 9 and 10. At Deepwater Shoal, the average prevalences for the summer/fall of 2001 are lower than 1999 and 2000 but higher than all other years. Averages in prevalence and weighted prevalence at Horsehead Rock are well above average, but not as high as some other years. At Wreck Shoal the average summer/fall prevalence for 2001 is above average, but not that different from prior years; however, weighted prevalence for 2001 ranks as the second highest in the decade.

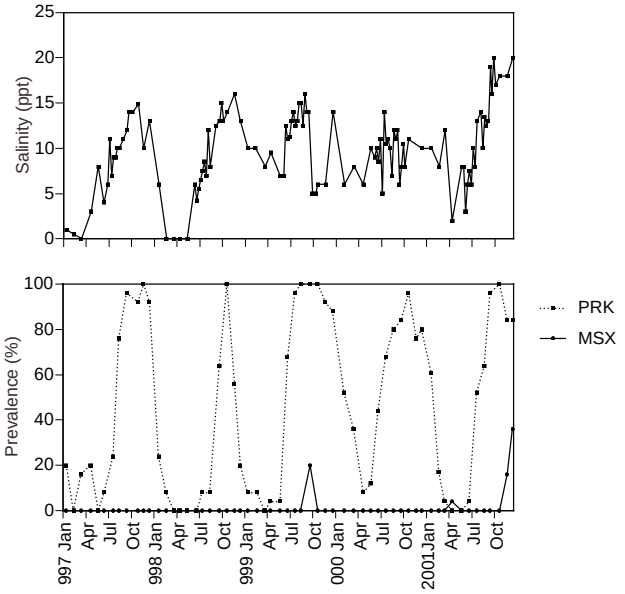


Figure 6. Salinity (top) and prevalence of *P. marinus* and *H. nelsoni* at Horsehead Rock, James River, VA for the years 1997-2001.

Haplosporidium nelsoni. *Haplosporidium nelsoni* prevalence in the upper James River at Wreck Shoal in 2001 was very similar to that in 1999 and 2000 remaining relatively low, < 24%, despite the consistent occurrence of high salinity (Table 1, Figures 4 and 8). The parasite was detected at this site in all months except April and June. The highest prevalences, 20-24%, were observed during the months May, September, and December. Generally, infection intensities of the parasite were light, however moderate and heavy infections were observed on three sample dates. Given the presence of heavy infections it is likely that the pathogen caused mortality in this area. *Haplosporidium nelsoni* was detected at Horsehead Rock in April, November, and December. The December sample had a prevalence of 36%, this is the highest that we have observed at this location since initiation of our monitoring program in 1987. The parasite was detected in December at Point of Shoals at a prevalence of 28%. No infections were observed up river at Deepwater

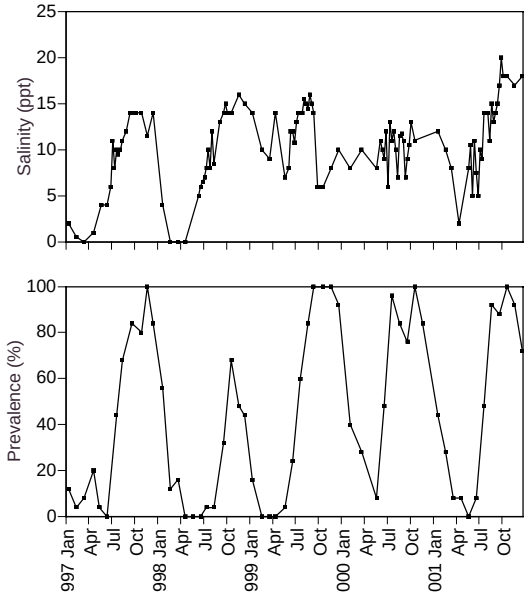


Figure 7. Salinity (top) and *P. marinus* prevalence (bottom) at Point of Shoals, James River, VA for the years 1997-2001.

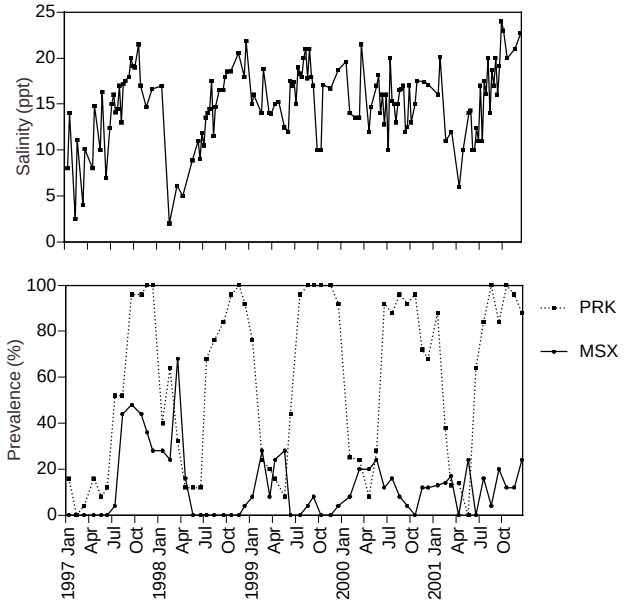


Figure 8. Salinity (top) and prevalence of *P. marinus* and *H. nelsoni* at Wreck Shoal, James River, VA for the years 1997-2001.

Shoal. December is the only month that oysters from Point of Shoals and Deepwater Shoal were examined for MSX.

Fall survey—*Perkinsus marinus*. For the third consecutive year *Perkinsus marinus* was widely distributed throughout the tributaries of the lower Chesapeake Bay and prevalences were at or near record high levels. In the Piankatank River *P. marinus* prevalence was 100% at all three sample locations (Ginney Point, Burton Point, and Palace Bar) and numerous advanced infections were observed (Table 2 and Figure 11). Similar prevalences have been observed in these areas in previous years; however, infection intensities in 2001 were at a record high. In the Great Wicomico River *P. marinus* prevalence in the fall ranged from 84 to 100%, declining slightly from that observed in 2000 (Table 2 and Figure 11), but still remaining relatively high in comparison to previous years. Numerous heavy infections were observed at the Great Wicomico stations sampled and it is likely that Dermo disease associated mortality occurred.

Prevalences of *P. marinus* in the Rappahannock River continued to climb from the record high levels observed in 1999 and 2000. Once again the parasite was present on all of the eight oyster bars sampled including Ross Rock, the oyster population located furthest up river, which had a record high prevalence of 40% (Table 2 and Figure 11). Down river from Bowlers Rock to the mouth of the River at Broad Creek, with the exception of Hog House Rock, prevalences ranged from 96-100%. Prevalence at Hog House Rock was only 16%. Oyster samples at all other stations downriver of Ross Rock had numerous individu-

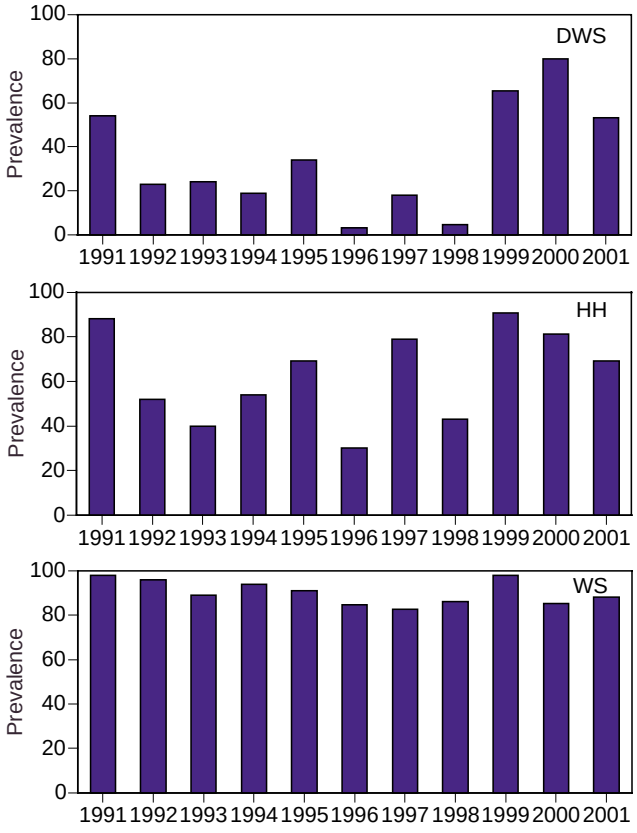


Figure 9. Annual comparison for years 1991-2001 of average summer/fall (July to December) prevalence *P. marinus* in the upper James River at Deepwater Shoal (DWS), Horsehead Rock (HH), and Wreck Shoal (WS).

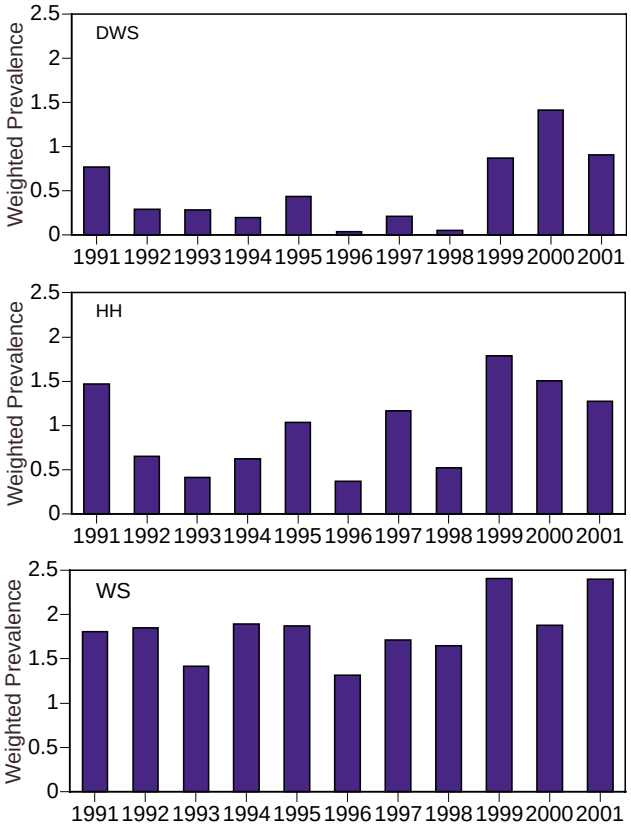


Figure 10. Annual comparison for years 1991-2001 of average summer/fall weighted prevalence of *P. marinus* in the upper James River at Deepwater Shoal (DWS), Horsehead Rock (HH), and Wreck Shoal (WS).

Table 2. Fall survey of prevalence and intensity of *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo) in oysters from Virginia harvesting and reef oyster populations in 2001. See accompanying figures for station locations. NA = not analyzed for MSX. Inf/Ex = number infected/number examined. Infection intensity was ranked as heavy (H), moderate (M), and light (L).

				H. nelsoni			*P. marinus*		
Location	**Date**	**Temp. (°C)**	**Sal. (ppt)**	**Inf/Ex**	**Prev.**	**Intensity H-M-L**	**Inf/Ex**	**Prev.**	**Intensity H-M-L**
James River									
Deepwater Shoal	15-Oct	21	14	NA			23/25	92	1-7-15
Horsehead Rock	15-Oct	20.5	18	0/25	0	0-0-0	25/25	100	1-10-14
Swash	24-Oct	18.4	16	7/25	28	1-0-6	25/25	100	6-11-8
Mulberry Point	24-Oct	18.7	15	0/25	0	0-0-0	22/25	88	0-8-14
Point of Shoals	15-Oct	20	18	NA			25/25	100	0-11-14
Long Shoal	24-Oct	18.8	15	2/24	8	0-1-1	24/25	96	3-11-10
Dry Shoal	23-Oct	18.9	16	2/25	8	1-0-1	24/25	96	1-9-14
Wreck Shoal	15-Oct	19	20	3/25	12	0-0-3	25/25	100	4-15-6
Thomas Rock	23-Oct	19.1	19	8/25	32	0-0-8	18/25	72	6-3-9
Nansemond Ridge	23-Oct	18.9	22	8/25	32	2-0-6	3/25	12	0-0-3
York River									
Aberdeen Rock	18-Oct	18	22	1/25	4	0-0-1	23/25	92	5-8-10
Mobjack Bay									
PultzBar	16-Oct	18	20	4/23	17	0-1-3	23/23	100	6-11-6
Tow Stake	16-Oct	18	20	1/24	4	0-0-1	23/24	96	9-7-7
Piankatank River									
Ginney Point	15-Oct	18.7	18	3/25	12	0-0-3	25/25	100	9-13-3
Burton Point	15-Oct	18	18	7/25	28	2-0-5	25/25	100	7-9-9
Palace Bar	15-Oct	18.7	18	0/25	0	0-0-0	25/25	100	5-12-8
Rappahannock River									
Ross Rock	22-Oct	17.8	11	0/25	0	0-0-0	10/25	40	1-0-9
Bowlers Rock	22-Oct	17.5	12	0/25	0	0-0-0	24/25	96	10-11-3
Long Rock	22-Oct	17.4	13	0/25	0	0-0-0	25/25	100	8-8-9
Morattico	22-Oct	17.5	15	1/24	4	0-0-1	25/25	100	12-8-5
Smokey Point	22-Oct	17.4	17	1/24	4	0-1-0	25/25	100	4-14-7
Drumming Ground	31-Oct	19	18	4/25	16	1-0-3	25/25	100	7-14-4
Hog House Rock	22-Oct	17.3	19	10/25	40	0-2-8	4/25	16	0-3-1
Parrot Rock	22-Oct	17.2	20	1/25	4	0-0-1	25/25	100	5-11-9
Broad Creek	15-Oct	18.2	20	1/24	4	0-0-1	24/24	100	13-9-2
Corrotoman River									
Middle Ground	22-Oct	19.7	14	4/25	16	0-0-4	25/25	100	5-6-14
Great Wicomico River									
Haynies Bar	17-Oct	18.1	18	4/25	16	0-0-4	21/25	84	3-8-10
Whaley's	17-Oct	17.7	19	5/25	20	2-2-1	23/25	92	5-9-9
Fleet Point	17-Oct	18	19	8/25	32	0-0-8	23/25	92	3-10-10
Shell Bar Reef	24-Sep	23	19	0/24	0	0-0-0	24/24	100	8-8-8
Coan River Reef	21-Sep	24	15	0/25	0	0-0-0	25/25	100	8-11-6
Yeocomico R. Reef	21-Sep	24	15	1/22	5	0-1-0	22/22	100	8-10-4
Nomini Creek	20-Sep	24	15	0/25	0	0-0-0	25/25	100	12-6-7
Elizabeth River Reef	3-Oct	24	19	5/25	20	0-0-5	25/25	100	7-13-5
Pungoteague Creek Reef	20-Sep	24	19	3/24	13	0-1-2	25/25	100	13-8-4
Onancock Rock	17-Sep	23	22	1/25	4	0-0-1	25/25	100	3-17-5
Tangier Sound									
California Rock	17-Sep	23	21	4/25	16	0-0-4	25/25	100	11-10-4
Hurley's Rock	17-Sep	23	21	4/25	16	0-0-4	24/25	96	1-12-11
Byrd Rock	17-Sep	23	21	1/25	4	0-1-0	24/25	96	4-8-12

als with moderate and heavy intensity infections. At most stations the proportion of heavy intensity infections was at a record high ranging from 16-52%. It is very likely that the parasite was responsible for significant oyster mortality in these areas. This is the second consecutive year in which a heavy intensity infection was observed at Ross Rock.

In the James River prevalences of *P. marinus* in the fall at locations upriver of Thomas Rock ranged from 88-100% (Table 2 and Figure 11). Parasite infection intensities were particularly high at Swash with 24% of the oysters having heavy intensity infection. Prevalence at Thomas Rock was lower, 72%; however, the proportion of heavy intensity infections was relatively high, 24%. Prevalence at Nansemond Ridge was very low, only 12%, and similar to that observed last year.

Most other tributaries had very high prevalences and infection intensities of *P. marinus*. *Perkinsus marinus* prevalence was 100% in Nomini Creek, on the bayside of the Eastern Shore in Onancock Creek, and at reef locations in Pungoteague Creek and the Elizabeth, Coan and Yeocomico Rivers (Table 2 and Figure 11). Moderate and heavy infections were found in oysters from all of these areas. In the York River at Aberdeen Creek prevalence was 92%, and in Mobjack Bay at Pultz Bar and Tow Stake prevalences were respectively, 100 and 96%. Heavy intensity infections were found in 24-36% of the Mobjack Bay oysters. In Tangier Sound at California Rock prevalence was 100% and 44% of the oysters sampled had heavy intensity infections. This is an extremely high intensity of the parasite for this location and it is likely that significant oyster mortality resulted as a consequence. Prevalence was 96% at Hurley's and Byrd Rock in Tangier Sound and intensities were slightly lower than at California Rock.

Haplosporidium nelsoni. The distribution of *H. nelsoni* in 2001 was similar to that observed in 2000 with some areas experiencing an increase in prevalence and others experiencing a decrease in prevalence. Overall a fairly wide distribution was observed; however, prevalence was generally fairly low in most areas (Table 2 and Figure 12). In the James River the parasite was present at prevalences of 8-12% at Long Shoal, Dry Shoal and Wreck Shoal and at significantly higher prevalences, 28-32%, at Swash, Thomas Rock and Nansemond Ridge (Table 2 and Figure 12). The parasite was also found in December at Horsehead Rock (36%) and Point of Shoals (28%). It is atypical for the parasite to be present at such high prevalence at Horsehead Rock.

In the Rappahannock River *H. nelsoni* prevalence was 4% at Morattico Bar, Smokey Point, Parrot Rock, and Broad Creek. Prevalence was 16% at Drumming Ground and significantly higher, 40%, at Hog House Rock (Table 2 and Figure 12). Prevalence in the Piankatank River increased from last year from 0 to 12% at Ginney Point and from 12 to 28% at Burton Point. In contrast prevalence at Palace Bar decreased from 16% in 2000 to 0% in 2001. *Haplosporidium nelsoni* prevalences in the Great Wicomico River at Whaley's Flat and Fleet Point were relatively high, 20 and 32% respectively. The parasite was also found at Haynies Bar at a prevalence of 16%.

Although prevalences were not high (< 20%, and in most cases 4-16%), *H. nelsoni* was detected in at least one site in most of the other creeks and tributaries sampled, specifically: Aberdeen Rock in the York River, Yeocomico River Reef, Elizabeth River, Pungoteague Creek, Onancock Rock, Mobjack Bay at Pultz Bar and Tow Stake, and in Tangier Sound at California Rock, Hurley's Rock, and Byrd Rock (Table 2 and Figure 12). It is not unusual for MSX to be found at these moderate salinity locations.

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 26 April 2000 and subsequently monitored for disease

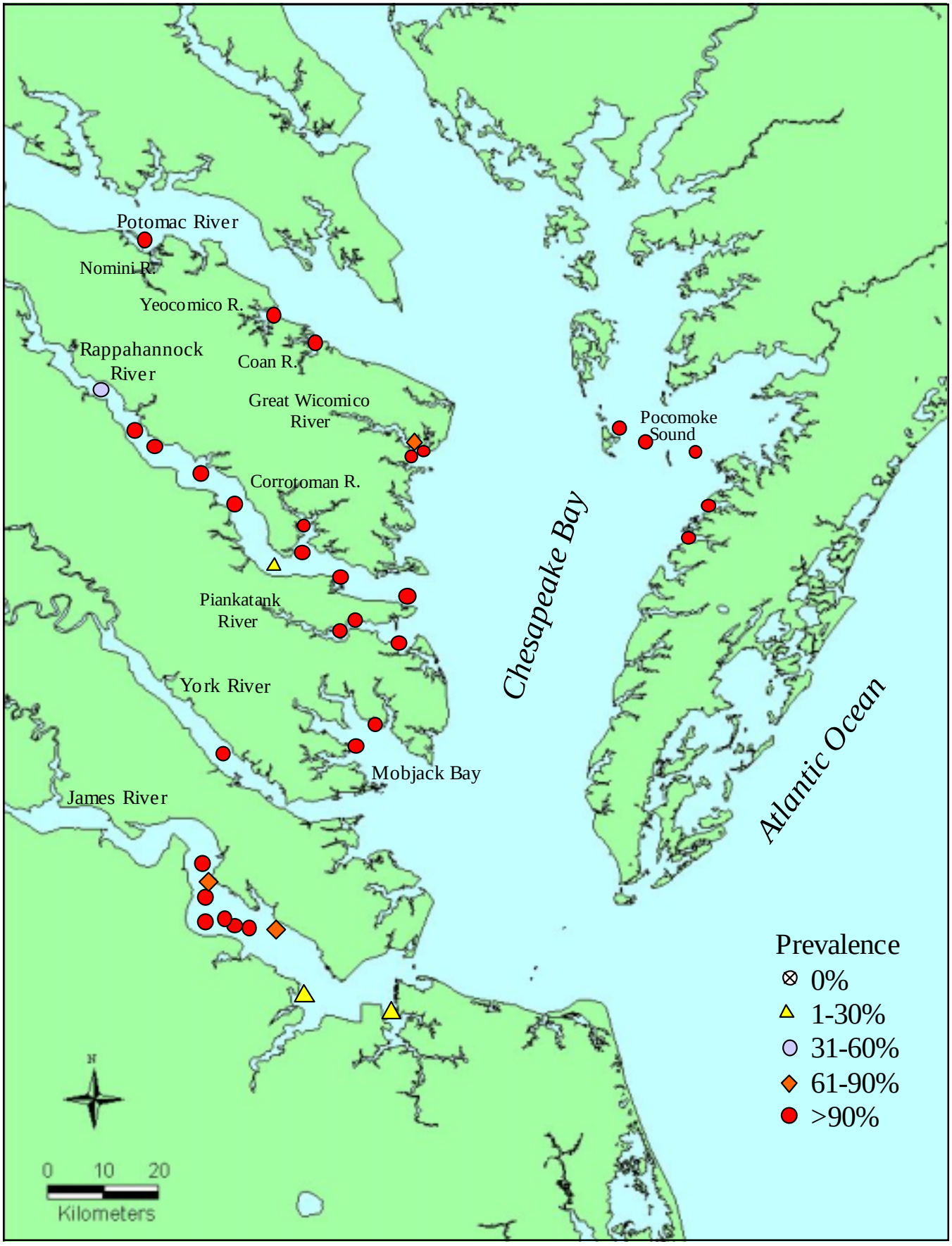


Figure 11. Distribution of *Perkinsus marinus* in Virginia in the fall of 2001.

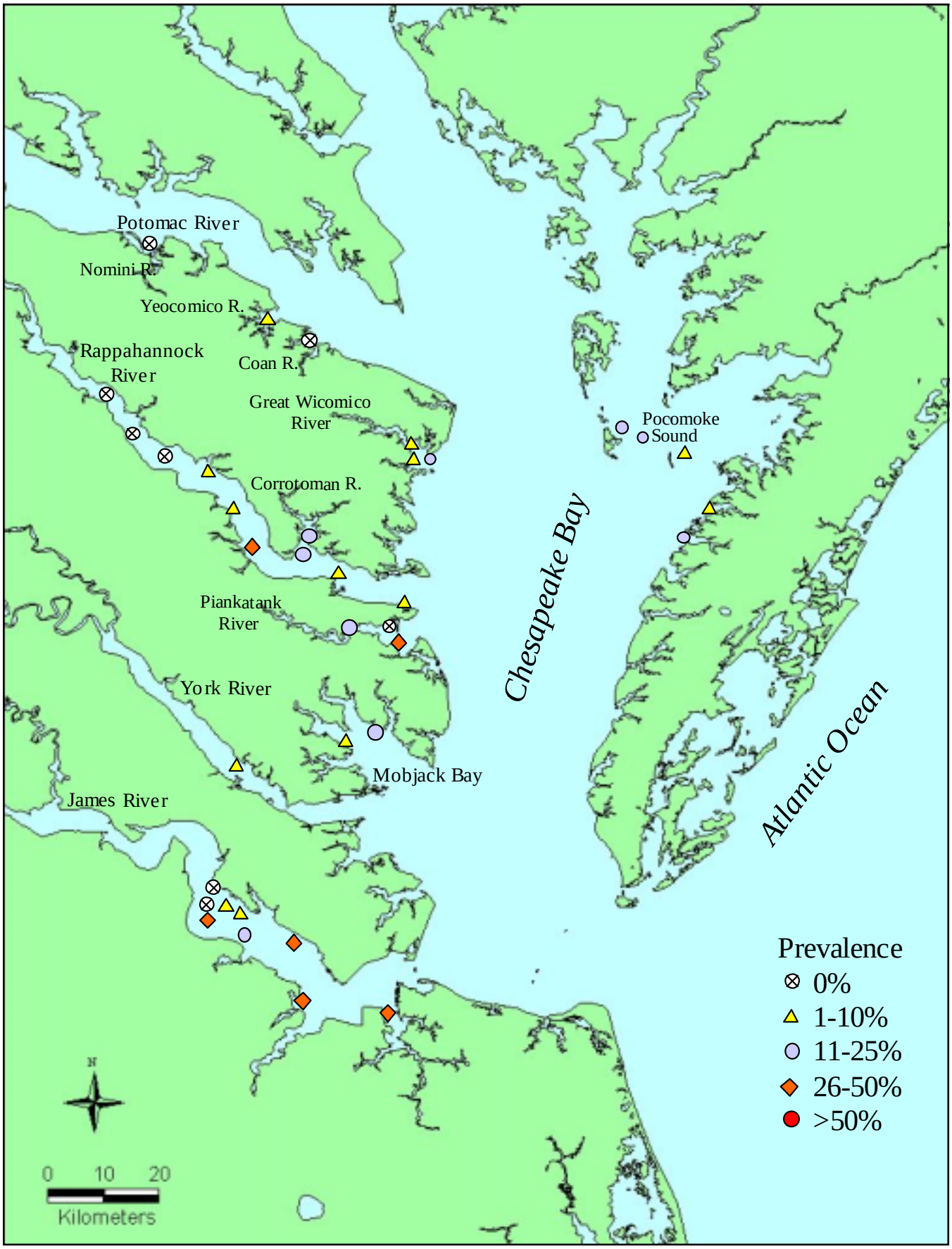


Figure 12. Distribution of *Haplosporidium nelsoni* in Virginia in the fall of 2001.

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, 2001. Inf/Ex = number infected/number examined. Infection intensity was ranked as heavy (H), moderate (M), and light (L).

			H. nelsoni			*P. marinus*		
Date	**Monthly mortality-%**	**Cummulative mortality-%**	**Inf/Ex**	**Prev.**	**Intensity H-M-L**	**Inf/Ex**	**Prev.**	**Intensity H-M-L**
26-Apr			0/25	0	0-0-0	0/25	0	0-0-0
8-Jun	1.58	2.2	0/25	0	0-0-0	2/25	8	0-0-2
9-Jul	7.48	9.7	19/24	79	8-5-6	1/25	4	0-0-1
8-Aug	54.47	64.2	17/25	68	9-3-5	24/25	96	8-5-11
5-Sep	30.14	91.3	12/23	52	4-3-5	23/25	92	13-6-4

through 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. Cumulative mortality was low (<10%) through early July, but sharply increased to 64% in August. In September cumulative mortality increased to 91% and so few animals remained that monitoring was terminated. Samples for disease diagnoses were also taken monthly. *Haplosporidium nelsoni* was not detected in oysters sampled on 8 June; however, by 9 July prevalence was 79%. This is a relatively high prevalence, particularly for this early in the summer. Thirty-two percent of the oysters sampled in July had heavy intensity infections. Prevalence declined to 68%, but the proportion of heavy intensity infections remained high. Prevalence of the parasite declined to 52% in September. Such an early onset of the disease is atypical; however, a peak prevalence of 79% while above average is not atypical. Higher prevalences were observed in last year's tray oysters (Figure 13).

Perkinsus marinus was first detected in the transplanted oysters in early June. Prevalence of *P. marinus* remained low, <10%, through early July and rapidly increased to 96% by early August. Prevalence of the parasite was 92% in September and nearly all of the infections were moderate to heavy intensity (Table 3). The sharp increase in *P. marinus* prevalence and intensity observed from early July to early August was atypical, generally, equivalent prevalences are not observed until September. It is possible that this early rise in *P. marinus* prevalence reflects an intensification of infections that were acquired in fall 2001, but were sub clinical when the oysters were examined for the disease at the time of transplantation in May. Typically *P. marinus* is not found at Ross Rock where the tray oysters were collected; however, in the fall of last year the parasite was detected at the site at a record high prevalence of 32%.

Mortality occurring in the tray oyster population between June and July can be attributed to MSX while mortality occurring between July and August was likely associated with both MSX and Dermo. Total cumulative mortality was relatively high in comparison to other years.

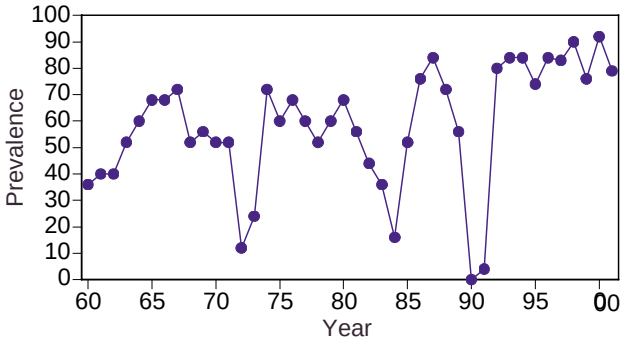


Figure 13. Maximum annual prevalence of *H. nelsoni* (MSX) in tray oysters monitored at VIMS 1960-2001.

Discussion

For the third consecutive year, both *P. marinus* and *H. nelsoni* were widely distributed throughout the tributaries of the lower Chesapeake Bay and epizootic oyster mortalities occurred in some areas in 2001. This wide parasite distribution is a consequence of the relatively warm temperatures and high salinities, which favored proliferation and spread of the parasites. Following a trend that was initiated in the summer of 1998, bay wide streamflows were relatively low. In the James River, streamflow was below average for most of the last 43 months. Likewise, above average temperatures have persisted for much of this time. Warm temperature and high salinity generally favor the spread and proliferation of both *P. marinus* and *H. nelsoni*. High parasite burdens in the fall of 1999 resulted in a relatively high abundance of overwintering parasites and a subsequent early intensification of parasite burdens in the summer months of 2000. This pattern was repeated in fall 2000 yielding the high disease pressure experienced in 2001.

In the upper James River at Deepwater Shoal prevalences and intensities of *P. marinus* slightly decreased from the record high levels observed in 2000. However, the parasite was detected at the site in all months of the year and heavy and moderate intensity infections were found in oysters sampled during the months September, October and December. Prevalences and intensities were also high down river at Horsehead Rock, Point of Shoals and Wreck Shoals. Advanced infections of *P. marinus* were most likely responsible for mortality of oysters older than 1-2 years at all four of these locations.

High salinities in the upper James River, which persisted through most of the year, resulted in the spread of *H. nelsoni* up river to Point of Shoals and Horsehead Rock. Both sites exhibited relatively high prevalences (28-36%) in December 2001. At Wreck Shoal salinities favorable to *H. nelsoni* persisted for nearly the entire year and the parasite was found in all months except for April and June. These two months represent the only months in which salinities less than or equal to 10 ppt occurred. Salinity in this range is unfavorable for the parasite and it is likely that infections were eliminated at least to sub clinical levels. The parasite reappeared as salinity increased above 10 ppt in the following months. Mid to late summer and fall salinities at Wreck Shoal ranged from 14 to 24 ppt and were well within the range favored by the parasite. Although MSX was consistently found from July through December, the maximum prevalence observed was relatively low, 24%. Higher prevalences in this area have been noted in previous years. *Haplosporidium nelsoni* was present at 32% prevalence at Thomas Rock and Nansemond Ridge locations down river from Wreck Shoal.

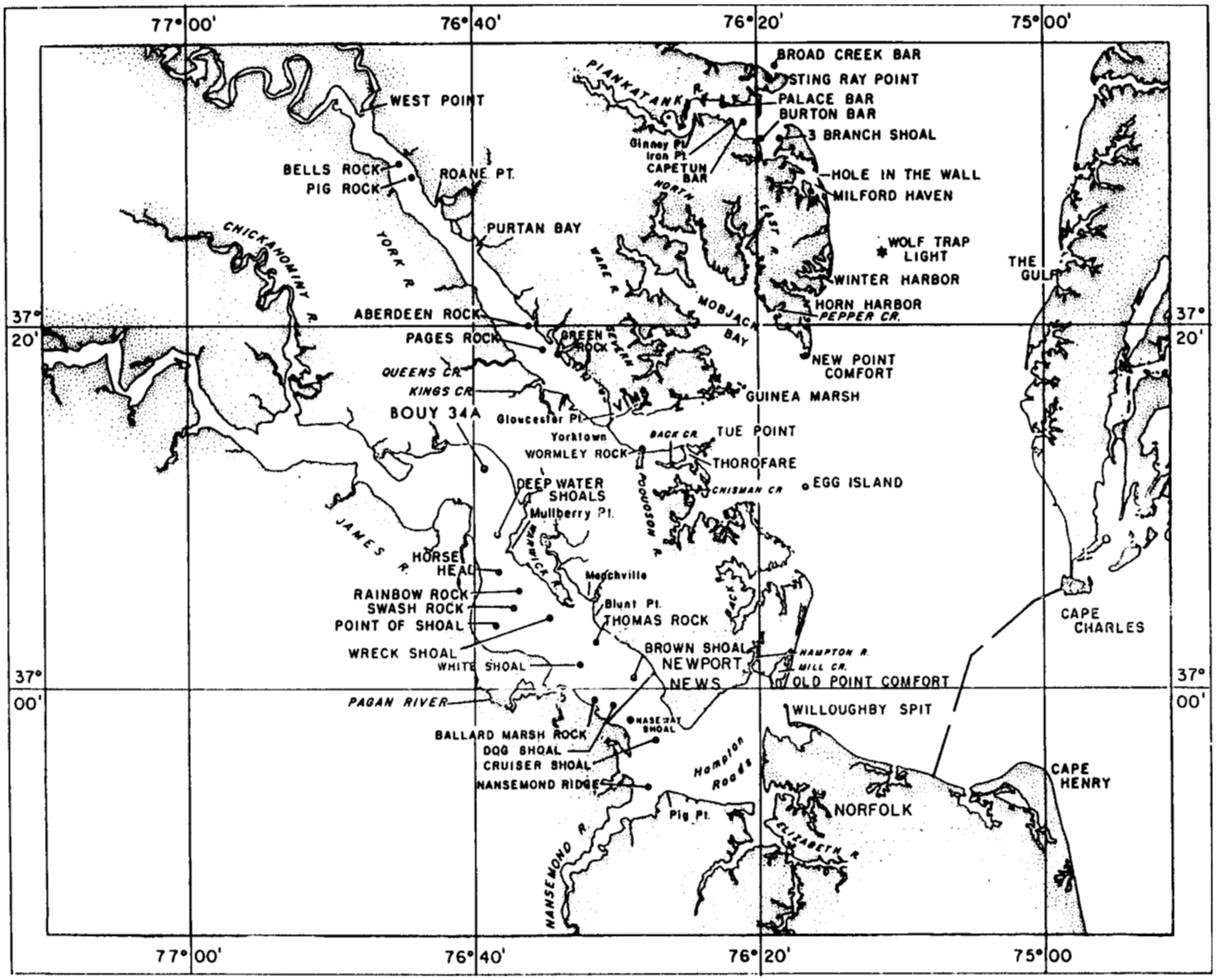
Relatively high levels of *P. marinus* and *H. nelsoni* were observed in the lower James River and in Virginia's other major tributaries. Exceptionally high *P. marinus* prevalences, > 90%, and intensities were observed at 31 of the 35 oyster populations sampled in the fall. In most of these areas salinities were atypically high and disease levels were similar to or exceeded the high or record high prevalences and intensities observed in the previous two years. Salinity at fall survey stations ranged from 11 to 24 ppt. The high proportion of heavy infections suggests that the high prevalences of *P. marinus* were associated with oyster mortality at most locations. Of the 35 oyster populations surveyed in the fall of 2001, only 4 had *P. marinus* prevalences less than 90%— Nansemond Ridge (16%) in the lower James River, Haynies Bar in the Great Wicomico River (84%) and Ross Rock (40%) and Hog House Rock (16%) in the Rappahannock River. The relatively low *P. marinus* prevalence observed at Ross Rock is related to low salinity. This oyster population represents the oyster population in the Rappahannock River that is located farthest up

river. Salinity at the site in the fall was 11 ppt, the lowest of all stations surveyed. In contrast Nansemond Ridge and Hog House Rock are located in the lower portions of the James and Rappahannock Rivers where higher salinities prevail. The extremely low *P. marinus* prevalence in these two areas is more likely a reflection of age and density of the particular oyster population. Prevalences and intensities of *P. marinus* are generally lower in 1-2 year old oysters than in older oysters. Furthermore population density is considered to be an important factor in transmission of the parasite. Fall stock assessments (dredge survey, M. Southworth personal communication) of the oysters in these two particular areas indicate that the population at Nansemond Ridge is primarily comprised of spat, while that at Hog House Rock has a very low density of oysters. Interestingly both sites had relatively high prevalences of *H. nelsoni*.

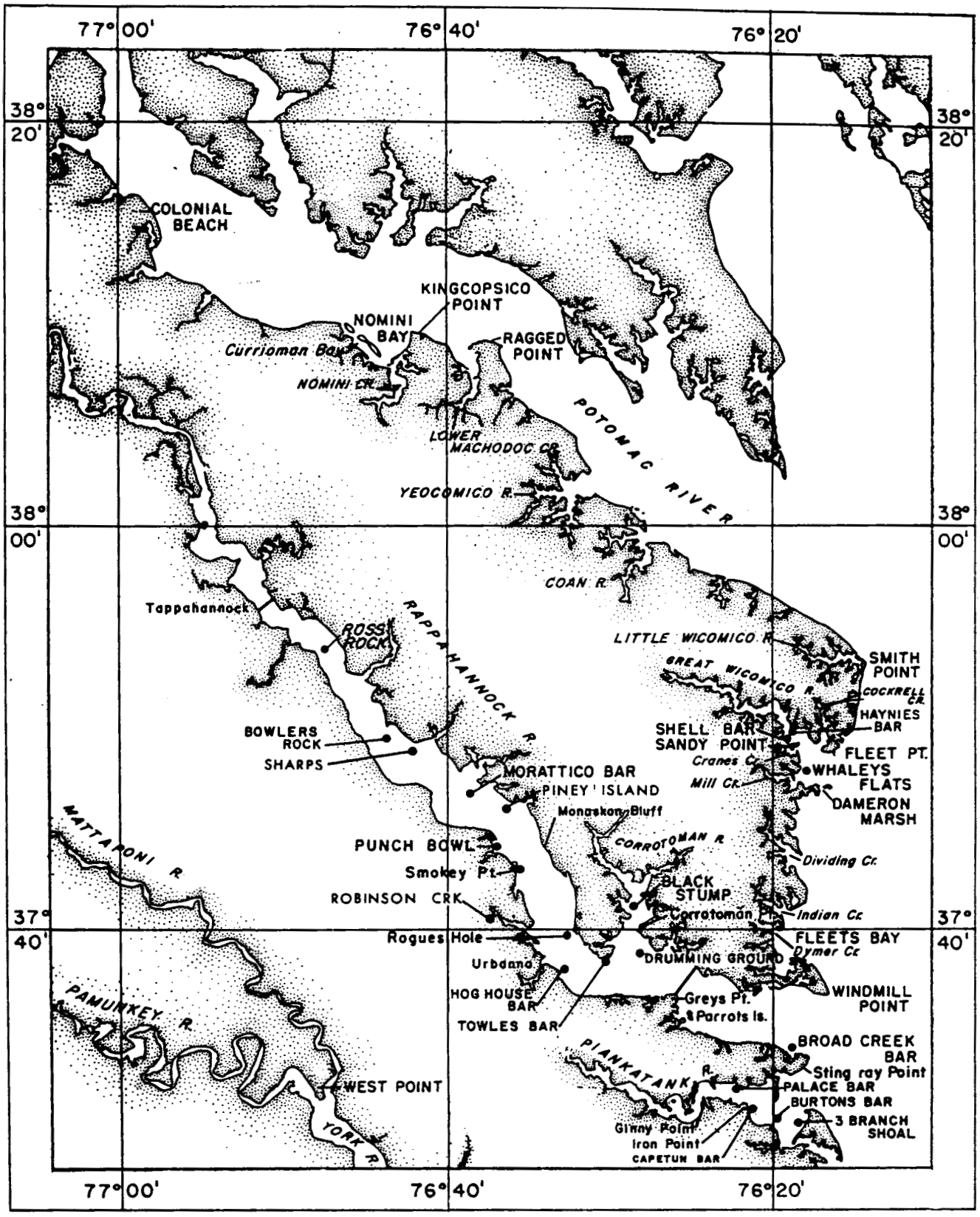
Haplosporidium nelsoni prevalences in the lower Chesapeake Bay were similar to those observed in 2000, both years having lower abundances of the parasite than in 1999. The distribution of the parasite was fairly widespread reaching up the Rappahannock River to Morattico Bar and up the James River to Horsehead Rock. Generally prevalences were low; however, prevalences ranging from 28-40% were observed at Horsehead Rock, Point of Shoals, Swash, Thomas Rock and Nansemond Ridge in the James River; at Hog House Rock in the Rappahannock River, at Fleet Point in the Great Wicomico River, and at Burton Point in the Piankatank River. It is particularly unusual for such high prevalences to be found in the upper James River; normally spring freshets eradicate the parasite. Streamflow conditions in the James River in 2001 were below average and apparently did not cause salinity to decline low enough or for long enough duration to effectively eradicate the parasite from the upper tributary. High summer and fall salinities promoted the reinvasion or spread and intensification of the disease into upper tributary areas. Although the majority of samples infected with *H. nelsoni* had primarily light infection intensities, heavy intensity infections were noted in oysters from some areas and these areas likely experienced MSX associated oyster mortalities. A dry and relatively warm winter and spring in 2002 will enable these infections to persist and it is likely that early summer oyster mortalities will result.

Acknowledgments

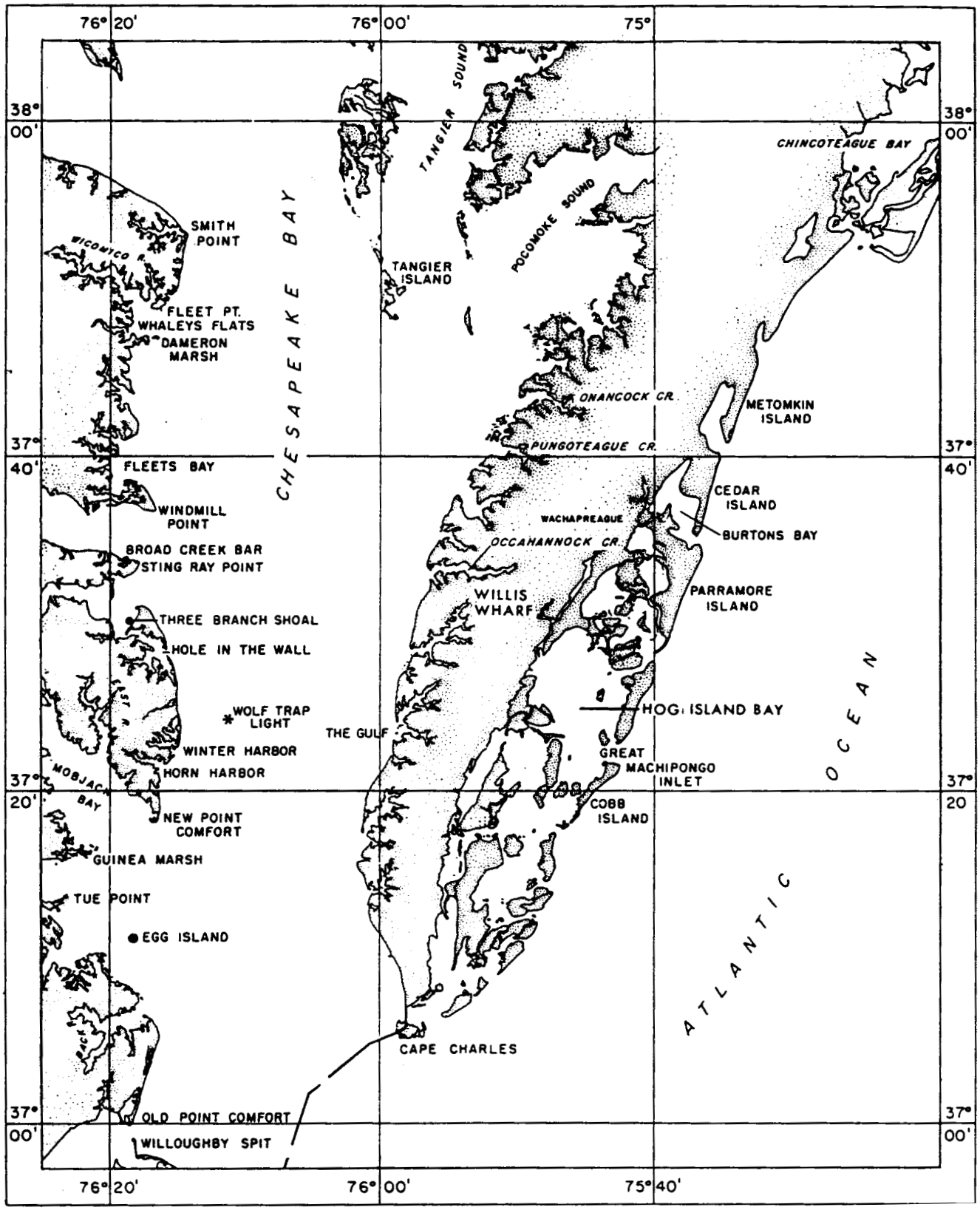
The oyster disease-monitoring program could not be conducted without the help of many VIMS staff members. Paul Oliver (Vessel Operations), Rita Crocket and Jennifer Cardinal were responsible for field collection of oysters from the James and Rappahannock Rivers. Missy Southworth (VIMS) and VMRC staff members collected fall survey oyster samples. Rita Crocket and Jennifer Cardinal were responsible for sample processing and diagnosis. Kathleen Apakupakul, Sara Mirabilio, and Vince Lovko provided occasional assistance with sample collection and processing. Gary Anderson provided hydrographic data from the VIMS monitoring station. We thank Dr. Jim Wesson for reviewing this report.



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



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



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