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Status of the Major Oyster Diseases in Virginia 1993 A Summary of the Annual Monitoring Program

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STATUS OF THE MAJOR OYSTER DISEASES IN VIRGINIA—1993.

A SUMMARY OF THE ANNUAL MONITORING PROGRAM.

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EXECUTIVE SUMMARY

Weather. 1993 was characterized by a very wet and cold spring and a very hot and very dry summer and fall. Riverflow was considerably above normal during March and April, but below average for 6 consecutive months during summer and fall. Because of this streamflow pattern, salinity was near 0 ppt in the upper James River for an extended period during March and early April, but increased rapidly during the summer and reached sustained levels that were higher than any previous summer since 1988. Water temperature was generally above average by 1 to 2°C except during March, April and much of May when it was 1 to 2°C below average.

***Haplosporidium nelsoni* (MSX).** This parasite was abundant in the monitoring trays at VIMS (60% prevalence) suggesting that it was probably abundant throughout the high salinity areas of the lower Bay, although there are few native oysters in these regions to be affected. The parasite was observed in oysters from many locations on the seaside of the Eastern Shore and from the lower Rappahannock River and the lower Great Wicomico River, but prevalences and intensities were generally low in these areas. Prevalence of *H. nelsoni* at Wreck Shoal in the James River averaged between 10 and 40% during winter and early spring of 1993, but the low salinities resulting from the unusually high riverflow in March and April eliminated the parasite and it was absent at Wreck Shoal from May through August. However, *H. nelsoni* reinvaded the upper James River in September as a result of the favorable salinities throughout the summer and was present at low levels at both Wreck Shoal and Horsehead Rock during late fall. This pattern of expulsion in spring and reinvasion in fall is typical of the annual cycle of *H. nelsoni* in the James River when weather patterns include normal spring runoff. In the major tributaries, oyster mortality from *H. nelsoni* is reduced under these circumstances because the parasite is present mainly during winter when cold water temperature slows development of the parasite.

***Perkinsus marinus* (Dermo).** This parasite continues to be present on all oyster beds in Virginia. Prevalence and intensity varied considerably depending on location, but generally *P. marinus* was abundant in most areas except the upper reaches of the major tributaries. An extensive survey of the seaside of the Eastern Shore revealed high prevalence and intensity of *P. marinus* at most locations. The low salinity during March and April in the James River had no effect on subsequent prevalence of *P. marinus* the following summer; high summer salinity allowed the parasite to develop and prevalence was 100% at Wreck Shoal during fall. The parasite was also abundant at Horsehead Rock and Deepwater Shoal where prevalences were higher during 1993 than the previous summer. There was some evidence, however, that intensity of infections in the James River was lower during 1993 than during 1992 and this decline may be a result of the low salinity observed during March and April.

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 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 about 12-15ppt. *Haplosporidium nelsoni* is eliminated from oysters after about 10 days below 10ppt; 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 1993 are presented in this report.

SAMPLING METHODS

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 either Deep Water Shoal in the upper portion of the James River seed area, or Ross' Rock in the upper Rappahannock River, and placed in 2-foot by 4-foot legged trays in the York River at Gloucester Point and in Burton's Bay at Wachapreague, Virginia on the seaside of the Eastern Shore. Oysters from the upper James River and upper Rappahannock River are known to be highly susceptible to *H. nelsoni* and thus they serve as excellent indicators of annual abundance of this parasite when placed in an endemic areas 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* abundance since 1987, oysters in the monitoring trays have become infected with this pathogen in recent years. 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 James and Rappahannock Rivers are now infected with *P. marinus* when they are collected. Nonetheless, these oysters can still be used to monitor *H. nelsoni*, which 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 recent years *P. marinus* has been present at low prevalence (<10%). At least 400 oysters are placed in each of two trays at each location on 1 May each year. Trays are cleaned every week and counts are 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 data base 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 approximately 1 June and 1 October from many sites in Mobjack Bay, the Rappahannock River, the Great Wicomico River, Pocomoke Sound, and from the seaside of the Eastern Shore. Because of the intense fishing pressure in the James River, samples are collected monthly at Wreck Shoal, Horsehead Rock and Deep Water Shoal and periodically at 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 is obtained from a continuous monitor at the VIMS pier in the lower York River. 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—1993

Temperature and streamflow/salinity.

Water temperature during 1993 was generally above average except during March, April and May, when it was usually 1 to 2°C below average (Figure 1). Water temperature was especially warm, almost 3°C above normal, during late January and late July; temperature was generally 1 to 2°C above normal during early January, July, September and December (Figure 1).

James River streamflow during 1993 was well above average during March and April, but below average for six consecutive months from May through October (Figure 1). Streamflow in the James River reflected monthly mean streamflow for the entire Chesapeake Bay system as shown in Figure 2. The above average streamflow during spring resulted in salinity between 0 and 1 ppt at Wreck Shoal and Horsehead Rock during late March and early April (Figures 5 and 6); at Deepwater Shoal salinity was near 0 ppt from April through mid May (Figure 7). However, salinity increased rapidly during the unusually dry summer and was favorable for development of *P. marinus* at all three James River stations from July through November. Salinity in the upper James River reached higher sustained levels during summer of 1993 than any summer since 1988 (Figures 5–7).

Native Oyster Samples.

Haplosporidium nelsoni **(MSX).** This parasite was generally rare in oysters sampled from public beds, although there are few oysters left to sample in areas where salinity conditions are optimal for MSX. Low prevalence of MSX occurred during fall in the lower Rappahannock and Great Wicomico Rivers, but no infections were found in the Piankatank River (Table 1). Low prevalence of MSX was also reported at some sites on both the bayside and seaside of the Eastern Shore. Prevalence of MSX was higher in the James River than at other sites. At Wreck Shoal, prevalence ranged from 8 to 40% during winter, but the low salinity during spring caused its expulsion and it was absent from Wreck Shoal from May through August. The favorable salinity during summer allowed its return in September and prevalence increased to 32% in December (Table 1). MSX also infected oysters at Horsehead Rock during late fall (Table 1, Figure 6).

Perkinsus marinus This parasite was found on all beds sampled in the fall (the period of maximum abundance) except Ross Rock in the upper Rappahannock River (Table 1) although negative results do not necessarily indicate that *P. marinus* has been eradicated at Ross Rock. The parasite was present at Ross Rock in April 1993 and has been present at that site for the last few years although intensity of infections is always very low.

Prevalence and intensity of *P. marinus* varied with location, but generally the parasite was abundant in most locations during fall (Table 1). An extensive survey of the seaside of the Eastern Shore was conducted in October and revealed a wide distribution of *P. marinus*. The parasite was found at all 15 locations sampled; prevalence ranged from 68 to 100%. Infections were all of low intensity in some areas (Table 1), but other areas had a high proportion of moderate and heavy infections. In the James River, the abundance of *P. marinus* followed the typical annual cycle with a decline in prevalence and intensity of infections in late winter and early spring and an increase in both parameters as water temperature and salinity increased in the summer and fall (Table 1, Figure 3). The intensity of infections in the James River was low at stations above Wreck Shoal, with only a few moderate or heavy infections observed; almost all infections were of light intensity. At Wreck Shoal, where salinity is more favorable for *P. marinus* development, there were a much higher number of moderate and heavy infections (Table 1) and undoubtedly some disease--induced oyster mortality at this location.

Tray Samples.

May (Spring) Imports. Counts of live and dead oysters and prevalence and intensity of *H. nelsoni* and *P. marinus* in the trays established 21 April 1993 at Gloucester Point are listed in Table 2. The oysters had a very low prevalence of *P. marinus* when they were placed in the trays; prevalence of this pathogen increased through the summer and was 100% on 13 September. Infection intensity of *P. marinus* remained low through July, but then increased rapidly and over half the infections were moderate or heavy on 13 September. *Haplosporidium nelsoni* (MSX) was not detected in the tray oysters until 30 July when prevalence was 60% and intensity of infections was also high. Prevalence of *H. nelsoni* had declined only slightly by 13 September and intensity remained high.

Cumulative mortality of oysters in both trays was about 80% by 13 September. It is impossible to apportion oyster mortality between the two parasites except to state that both parasites contributed to the mortality on the basis of their high prevalence and intensity.

DISCUSSION

***Haplosporidium nelsoni* (MSX).** It is difficult to accurately document the abundance of *H. nelsoni* in the lower Chesapeake Bay because few native oysters remain in the high salinity areas favorable for *H. nelsoni* survival. Nonetheless, some indication of abundance can be obtained from oysters in the monitoring trays at VIMS and those at Wreck Shoal in the James River. During 1993, prevalence of *H. nelsoni* was high in oysters in the monitoring trays and the intensity of a high proportion of the infections was moderate or heavy. Thus, even though there are few native oysters remaining in *H. nelsoni*–endemic areas, uninfected, susceptible oysters transplanted into these areas still acquire high levels of infection. This parasite was also commonly encountered on the seaside of the Eastern Shore and was present in the lower Rappahannock River and lower Great Wicomico River, but prevalence and intensity were generally low in all these areas.

Haplosporidium nelsoni is known to be very sensitive to salinity and it usually disappears from oysters after only about 10 days at a salinity of 10 ppt or less. This relationship was clearly demonstrated at Wreck Shoal in the James River during spring and summer of 1993. From January through April, the prevalence of *H. nelsoni* at Wreck Shoal varied between 10 and 40% (Figures 3 and 5). The high riverflow during March and April (Figure 1) caused the salinity at Wreck Shoal to decline to 1 ppt or less (Figure 5) and no *H. nelsoni* was observed from May through August. However, riverflow during summer and fall was below average for 6 consecutive months; salinity increased rapidly during that period and at Wreck Shoal was favorable for *H. nelsoni* by August. The parasite reinvaded the upper James River and was observed in oysters from September through December at Wreck Shoal and from November through December at Horsehead Rock (Figure 3). This pattern of expulsion of *H. nelsoni* during spring and summer because of high riverflow and reinvasion during fall is the typical pattern that has occurred historically. Oyster mortality is limited under these circumstances because *H. nelsoni* is present primarily during winter when cold water temperature slows development of the parasite, although some heavy infections ans some mortality does occur.

It is interesting to compare the annual cycle of *H. nelsoni* at Wreck Shoal during 1993 and during 1989. During 1993, the parasite was expulsed because of low salinity during spring, but reinvaded the area during early fall after salinity had increased above 15 ppt. During 1989, there was a similar expulsion during spring (Figure 5), but salinity remained below 15 ppt throughout the year and *H. nelsoni* did not reinvade the area for 14 months. These results are further evidence that *H. nelsoni* is rapidly eliminated at salinity below 10 ppt, but also suggest that the parasite can reinvade an area fairly quickly when salinity increases above approximately 15 ppt.

***Perkinsus marinus* (Dermo).** This parasite spread to all oyster beds in Virginia in 1988 as a result of movement of infected oysters and of the extreme drought that provided favorable conditions for development of *P. marinus* in all areas. Results of the 1993 monitoring program reported here indicate that the parasite continues to be present on all oyster beds in Virginia. The high riverflow and resultant low salinity in the spring had little effect on the subsequent summer prevalence of *P. marinus* in the James River; prevalence still increased to 100% by September. However, no *P. marinus* was observed in oysters collected from Wreck Shoal during May 1993 (Figure 5) and this apparent absence may have been the result of the combination of low salinity and low temperature during that period. May 1993 was the first month of 0% prevalence at Wreck Shoal since 1987. The peak prevalence of *P. marinus* during 1993 was slightly higher than 1992 levels at both Horsehead Rock and Deep Water Shoal (Figures 6 and 7), but prevalences were still lower during 1993 at these sites than the maximum recorded prevalences observed during fall of 1991. In addition, intensity of *P. marinus* infections was generally lower during 1993 than 1992 at Wreck Shoal and Horsehead Rock (see monitoring report for 1992). These results suggest that the low salinity in the spring may have had some effect on the intensity of subsequent infections even though the overall prevalence did not appear to be influenced.

ACKNOWLEDGMENTS

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Table 1. Prevalence and intensity of *Haplosporidium nelsoni* (MSX) and *Perkinsus marinus* (Dermo) in oysters from Virginia harvesting areas in 1993. See accompanying figures for station locations.

Location	Date	MSX Infect./exam.	% Infect.	H–M–L*	*Perkinsus* Infect./exam.	% Infect.	H–M–L*
James River							
Deep Water Shoal	14 Jan	NS**			2/20	10	0–0–2
	22 Feb	NS			4/25	16	0–0–4
	26 Mar	NS			0/25	0	
	19 Apr	NS			0/25	0	
	17 May	NS			0/25	0	
	16 Jun	NS			1/25	4	0–0–1
	14 Jul	NS			0/25	0	
	18 Aug	NS			1/25	4	0–0–1
	15 Sep	NS			4/25	16	0–1–3
	13 Oct	NS			10/25	40	1–0–9
	16 Nov	NS			15/25	60	0–0–15
	06 Dec	NS			6/25	24	0–0–6
Horsehead Rock	14 Jan	0/20	0		14/20	70	0–0–14
	22 Feb	0/25	0		2/25	8	0–0–2
	26 Mar	0/25	0		1/25	4	0–0–1
	19 Apr	0/25	0		1/25	4	0–0–1
	17 May	0/25	0		1/25	4	0–0–1
	16 Jun	0/25	0		0/25	0	
	14 Jul	0/25	0		0/25	0	
	18 Aug	0/25	0		2/25	8	0–0–2
	15 Sep	0/25	0		9/25	36	0–0–9
	13 Oct	0/25	0		24/25	96	0–1–23
	16 Nov	2/25	4	1–0–1	15/25	60	0–0–15
	06 Dec	3/25	12	0–0–3	10/25	40	0–0–10
Point of Shoals	14 Jan	NS			12/20	60	0–0–12
	22 Feb	NS			8/25	32	0–1–7
	26 Mar	NS			2/25	8	0–0–2
	19 Apr	NS			0/25	0	
	17 May	NS			1/24	4	0–0–1
	16 Jun	NS			1/25	4	0–0–1
	14 Jul	NS			0/25	0	
	18 Aug	NS			3/25	12	0–0–3
	15 Sep	NS			12/25	48	0–0–12
	13 Oct	NS			20/25	80	0–3–17
	16 Nov	NS			21/25	84	0–1–20
	06 Dec	NS			9/25	36	0–0–9
Wreck Shoal	14 Jan	2/25	8	0–0–2	23/25	92	2–3–18
	22Feb	9/25	36	3–1–5	20/25	80	2–1–17
	26 Mar	4/25	16	0–0–4	11/25	40	0–0–11
	19 Apr	10/25	40	0–0–10	4/25	16	0–0–4
	17 May	0/25	0		0/25	0	
	16 Jun	0/25	0		9/25	36	0–0–9
	14 Jul	0/25	0		17/25	68	0–1–16
	18 Aug	0/24	0		21/24	88	0–2–19
	15 Sep	5/24	20	0–0–5	25/25	100	1–7–17
	13 Oct	6/25	24	1–0–5	25/25	100	3–5–17
	16 Nov	6/25	24	1–2–3	22/25	88	1–3–18
	06 Dec	8/25	32	3–0–5	23/25	92	4–3–16

*H=number of heavy infections, M=moderate infections, L=light infections. **NS=not sampled for MSX.

Table 1 (Continued)

Location	Date	MSX Infect./exam.	% Infect.	H–M–L*	*Perkinsus* Infect./exam.	% Infect.	H–M–L*
Mobjack Bay							
Tow Stake	24 Sep	0/14	0		14/15	93	0-2-12
Piankatank River							
Ginney Point	24 Sep	NS			22/25	88	2-3-17
Burton Bar	24 Sep	0/25	0		24/25	96	0-4-20
Palace Bar	20 Oct	0/25	0		10/25	40	1-3-6
	20 Oct	0/25	0		4/25	16	0-0-4
	20 Oct	0/25	0		25/25	100	1-3-21
Rappahannock River							
Ross Rock	21 Apr	NS			1/25	4	0-0-1
	19 May	NS			0/25	0	
	28 Sep	NS			0/25	0	
Long Point-Sharps	20 May	NS			0/25	0	
Smokey Point	20 May	0/25	0		11/25	44	0-0-11
Morattico Bar	20 May	NS			8/24	33	0-0-8
	28 Sep	NS			15/19	79	5-2-8
Bowlers Rock	19 May	NS			3/25	12	0-0-3
	28 Sep	NS			15/25	60	0-2-13
Parrots Rock	20 Sep	0/25	0		24/25	96	3-1-20
Broad Creek	20 Sep	1/24	4	0-0-1	22/25	88	0-1-21
Middle Ground	20 Sep	NS			12/19	63	1-0-11
Drumming Ground	20 Sep	NS			7/25	28	1-0-6
Great Wicomico River							
Fleet Point	14 Sep	1/25	4	1-0-0	19/25	76	0-1-18
Whaleys Flats	14 Sep	NS			16/25	64	0-0-16
Haynies Bar	14 Sep	NS			5/25	20	0-0-5
Yeocomico River							
Mundy Point #1	7 Jul	NS			2/25	8	0-0-2
Mundy Point #2	7 Jul	NS			0/25	0	
Mundy point #1	8 Sep	NS			25/25	100	6-5-14
Cornish Cove	7 Jul	NS			12/25	48	0-1-11
Cornish Cove	24 Aug	NS			20/25	80	1-2-17
Lynch Point	7 Jul	NS			5/25	20	0-0-5
Lynch Point	8 Sep	NS			23/25	92	0-4-19
Ford Point	8 Sep	NS			23/25	92	3-1-19
Eastern Shore							
Machipongo Creek	23 Aug	1/25	4	0-0-1	14/25	56	0-0-14
Craddock Creek	23 Aug	0/25	0		7/25	28	0-1-6
Drawing Channel	19 Oct	0/25			23/25	92	3-3-17
Hummock Light	19 Oct	0/20			20/20	100	1-4-15
Bradford Bay	19 Oct	0/25			24/25	96	3-0-21
Black Narrows	19 Oct	0/25			23/25	92	0-1-22
Walker Point	19 Oct	0/25			21/25	84	0-0-21
Powells Bay	13 Oct	1/25	4	0-1-0	18/25	72	0-0-18
Egging Marsh	15 Oct	1/25	4	1-0-0	24/25	96	6-4-14
Hog Island Bay-South	20 Oct	1/25	4	0-0-1	25/25	100	2-5-18
Willis Wharf	20 Oct	0/24			17/25	68	0-2-15

*H=number of heavy infections, M=moderate infections, L=light infections. **NS=not sampled for MSX.

Table 1 (Continued)

Location	Date	MSX Infect./exam.	% Infect.	H–M–L*	*Perkinsus* Infect./exam.	% Infect.	H–M–L*
Eastern Shore							
Loon Channel	19 Oct	0/25	0		24/25	96	1-2-21
Point of Rock Channel	20 Oct	2/25	8	0-0-2	25/25	100	2-4-19
Brackenberry Bay	20 Oct	2/25	8	1-0-1	24/25	96	2-4-18
Sandy Island Bay	13 Oct	0/24	0		18/25	72	1-1-16
Barton Stake Bay	13 Oct	0/25	0		24/25	96	8-4-12
Little Gap Channel	13 Oct	0/25	0		24/25	96	6-4-14
Tom's Cove	12 Nov	0/25	0		3/25	12	0-1-2

*H=number of heavy infections, M=moderate infections, L=light infections. **NS=not sampled for MSX.

Table 2. Mortality and disease prevalence in upper Rappahannock River oysters placed in replicate trays at Gloucester Point, VA in April, 1993. PRK = *Perkinsus marinus*, MSX = *Haplosporidium nelsoni*.

Date–1993	Counts live/dead	Monthly mortality–%	Cumulative mortality-%	Infected/examined–%	Intensity H–M–L*
21 Apr	400/0			PRK 1/25 - 4%	0-0-1
	400/0			MSX 0/25 - 0%	
8 Jun	384/7	1.53%	1.79%		
	393/7	1.50%	1.75%		
8 Jul	381/3	0.78%	2.56%	PRK 12/25 - 48%	0-1-11
	361/7	1.90%	3.62%	MSX 0/25 - 0%	
30 Jul	376/5	1.79%	3.84%	PRK 19/25 - 76%	0-0-19
	325/11	4.46%	6.77%	MSX 15/25 - 60%	5-1-9
13 Sep	57/231	68.75%	81.12%	PRK 25/25 - 100%	8-6-11
	58/267	70.42%	83.36%	MSX 13/25 - 52%	5-1-7

*H = number of heavy infections, M = moderate infections, L = light infections.

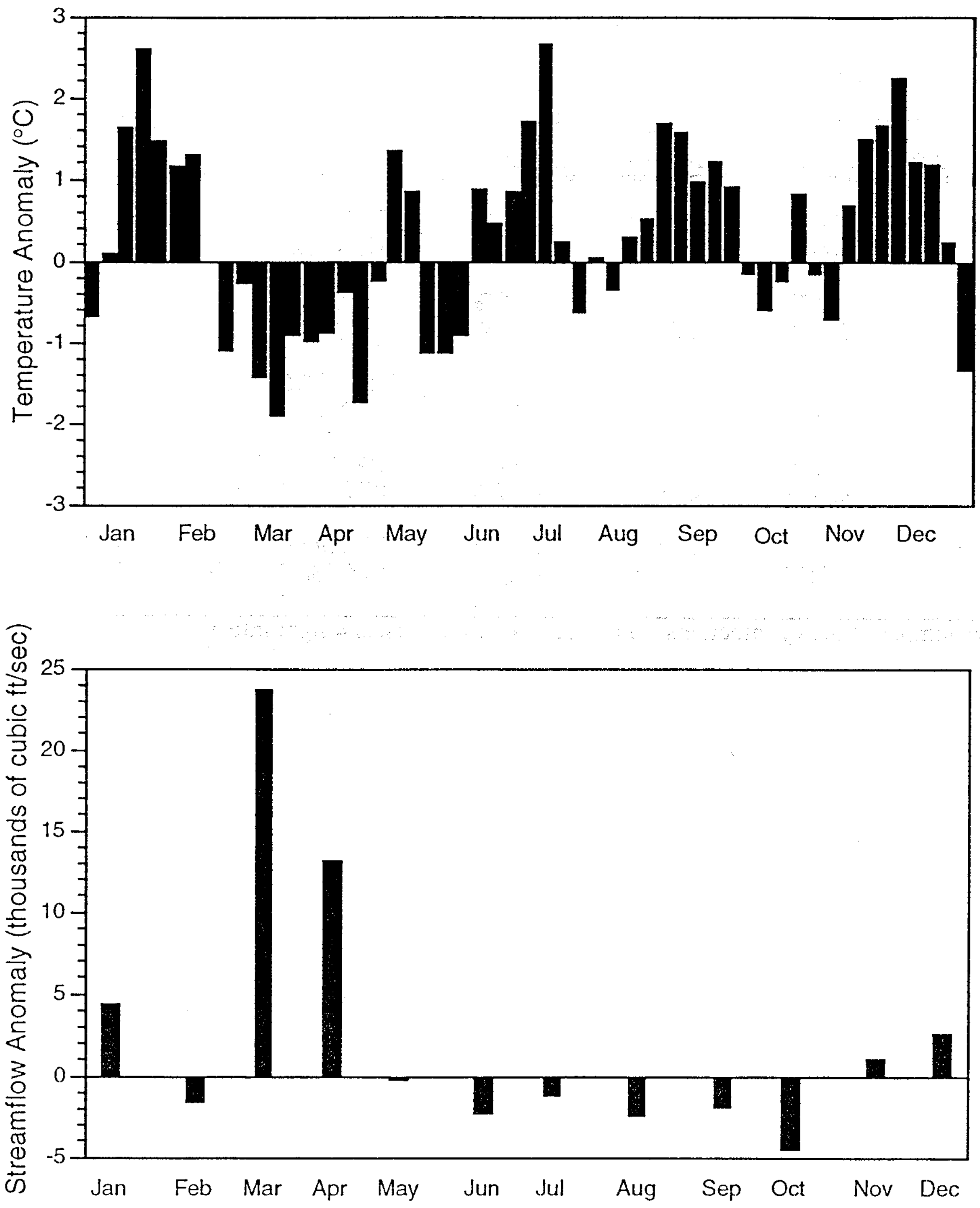


Figure 1. Weekly water temperature anomaly at the VIMS pier, Gloucester Point, VA based on average temperature from 1947-1992 (top) and monthly James River streamflow anomaly based on average discharge from 1951-1992 (bottom) for the calendar year 1993.

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
in Cooperation with
STATES OF MARYLAND, PENNSYLVANIA, AND VIRGINIA
ESTIMATED STREAMFLOW ENTERING CHESAPEAKE BAY

A monthly summary of cumulative streamflow into the Chesapeake Bay designed to aid those concerned with studying and managing the Bay's resources. For additional information, contact the District Chief, U.S. Geological Survey, 208 Carroll Building, 8600 LaSalle Road, Towson, Maryland 21286, Phone 410–828–1535.

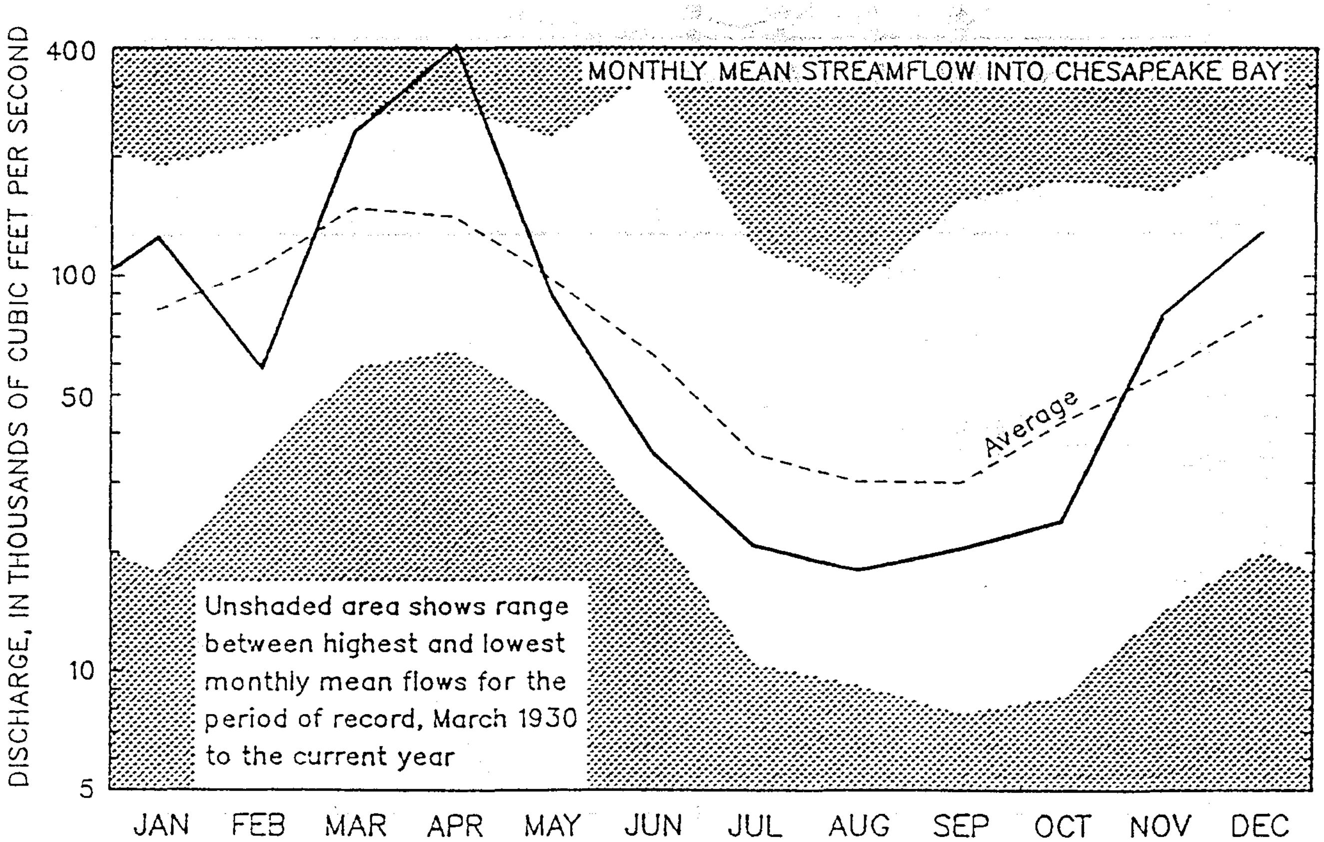


Figure 2. Monthly mean streamflow into Chesapeake bay during 1993 (solid line) compared with average monthly streamflow for the period 1951-1992 (dashed line).

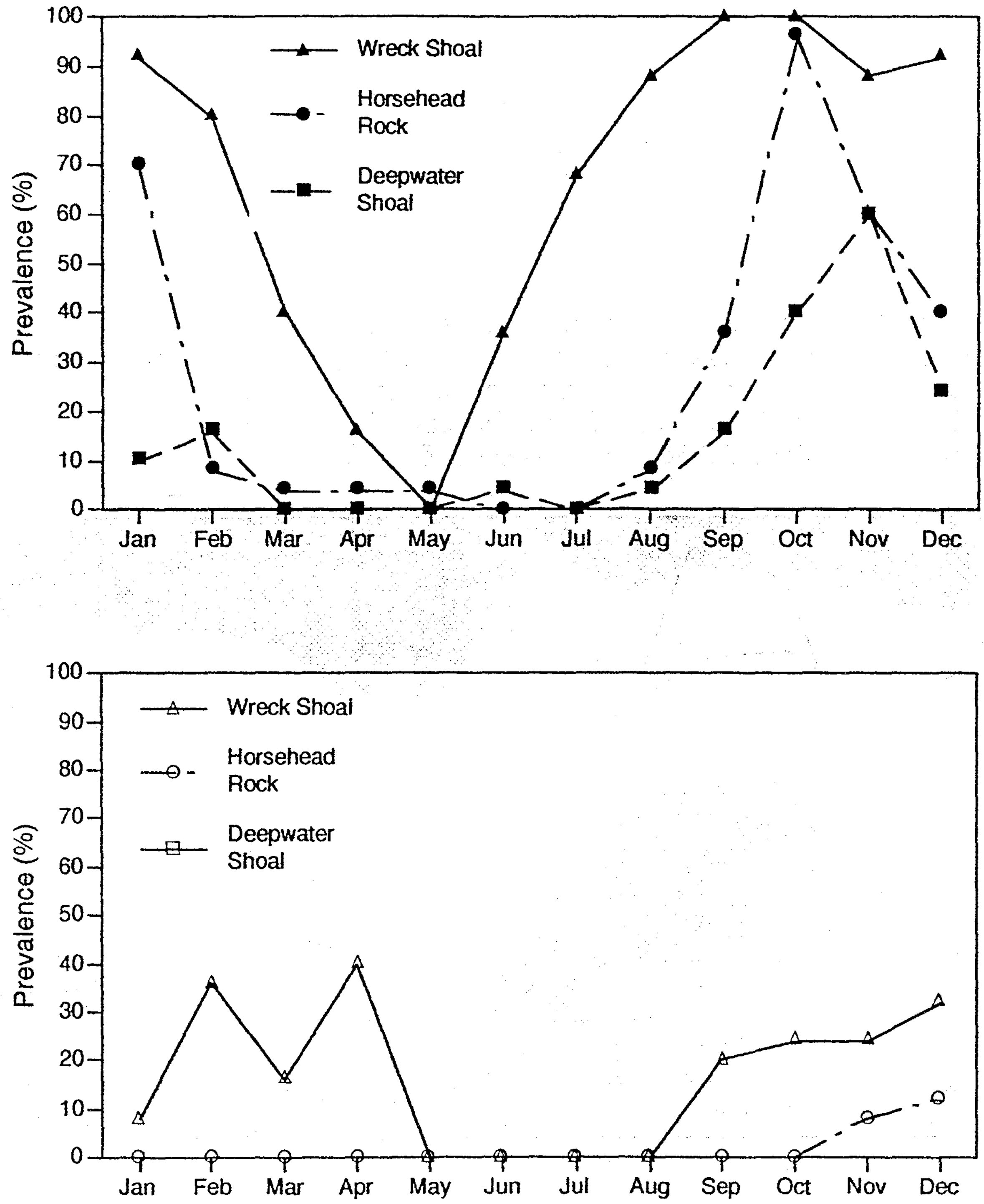
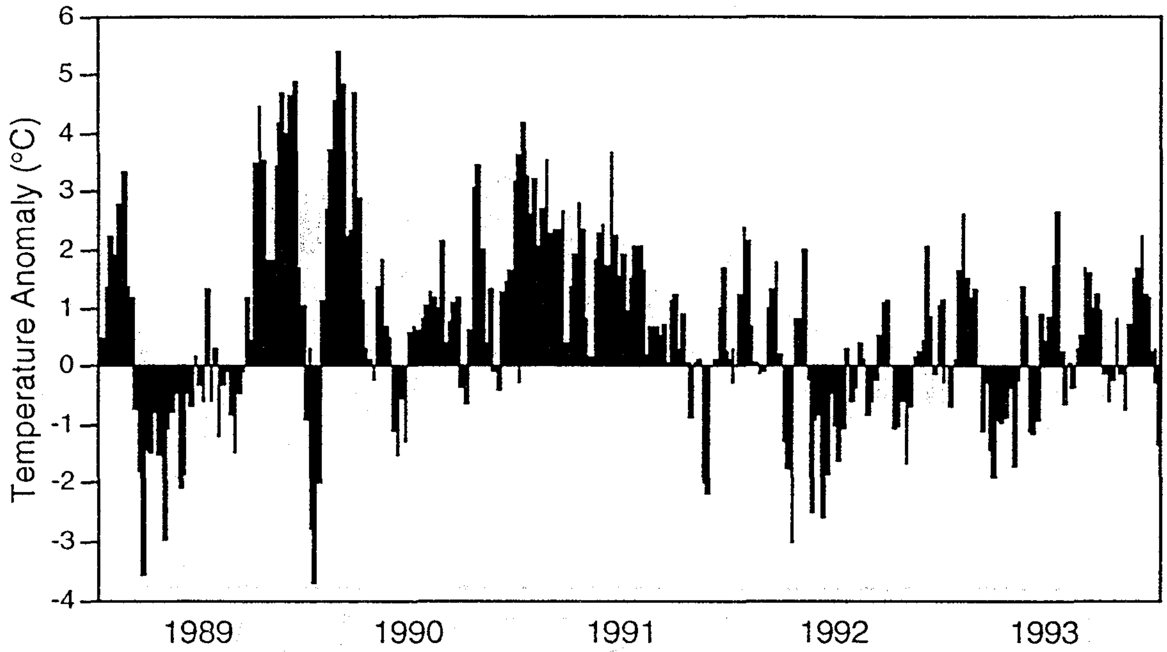


Figure 3. Prevalence of *P. marinus* (top) and *H. nelsoni* (MSX) (bottom) in James River oysters from Wreck Shoal, Horsehead Rock and Deepwater Shoal in 1993.



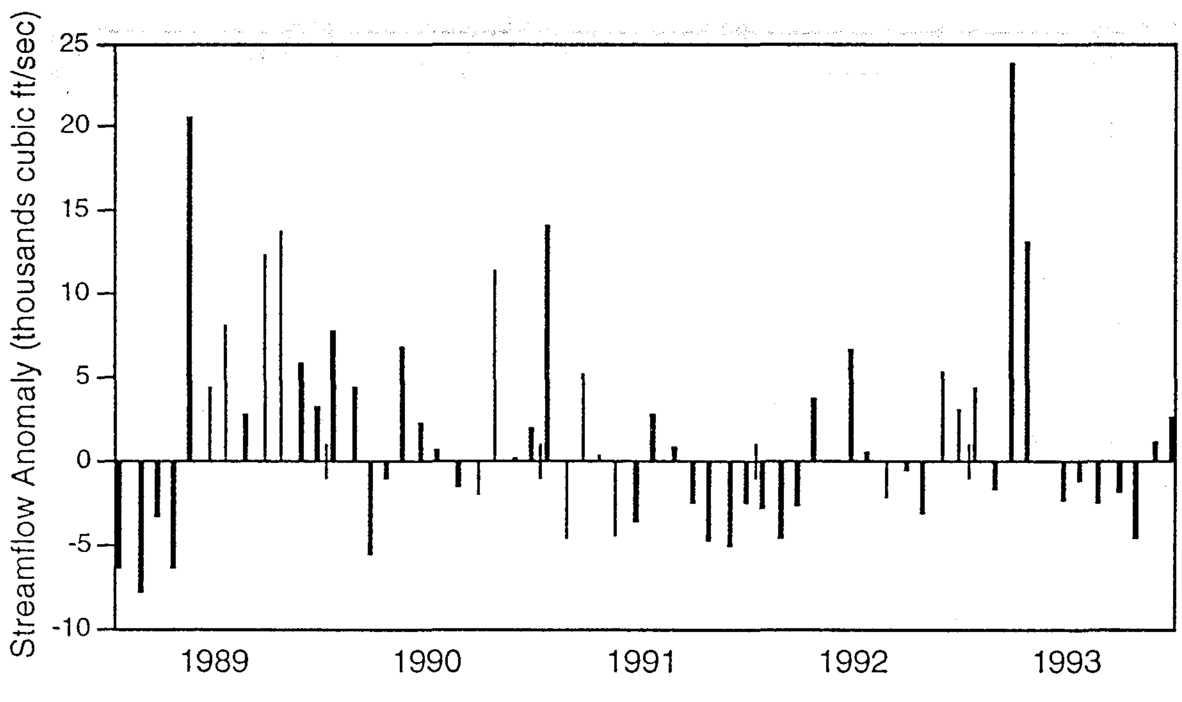


Figure 4. Mean weekly VIMS pier water temperature anomaly from long-term (1947-1992) average (top). Mean monthly James River streamflow anomaly from long-term (1951-1992) average (bottom).

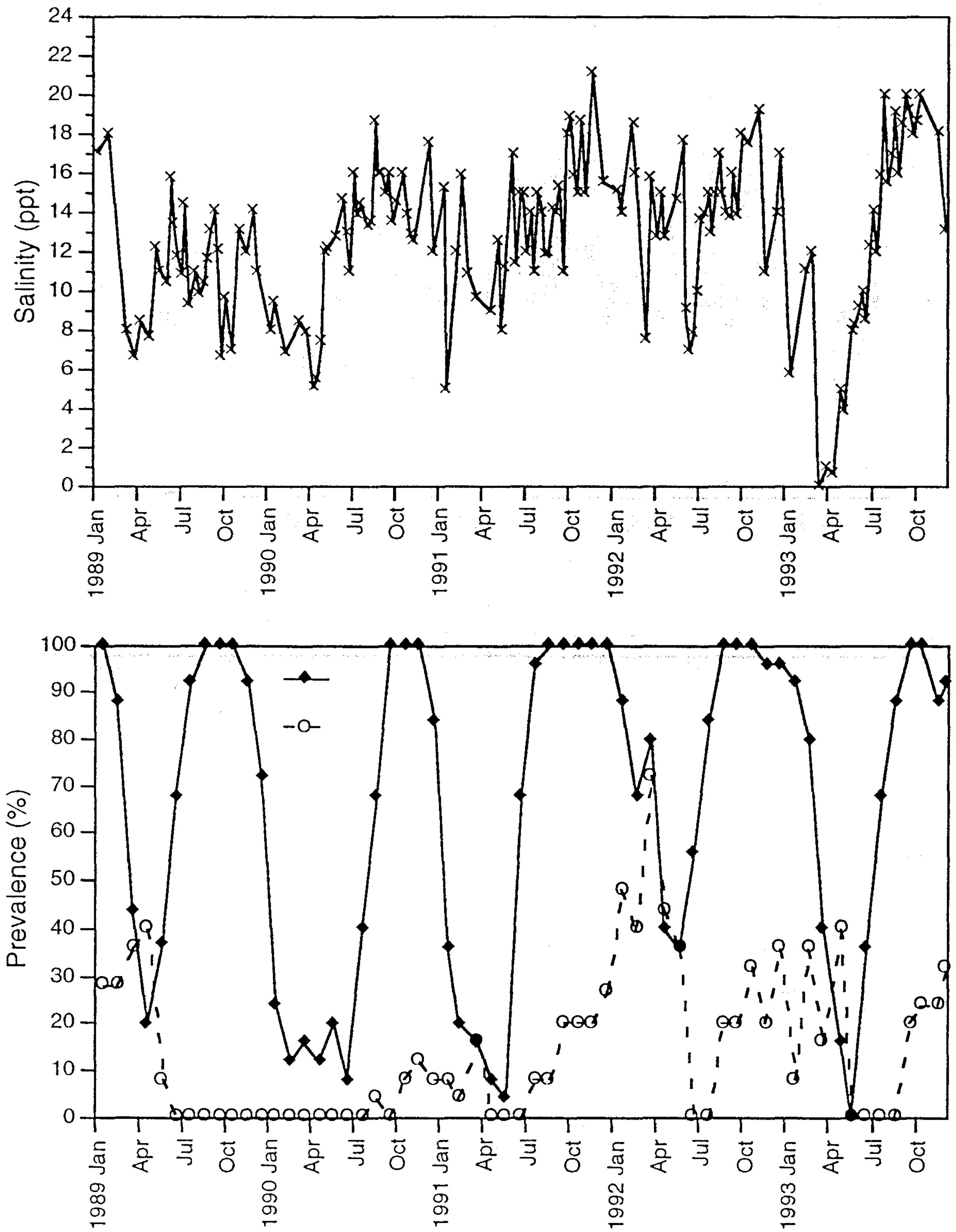


Figure 5. Salinity (top) and prevalence of *P. marinus* (PRK) and *H. nelsoni* (MSX) (bottom) at Wreck Shoal, James River, VA.

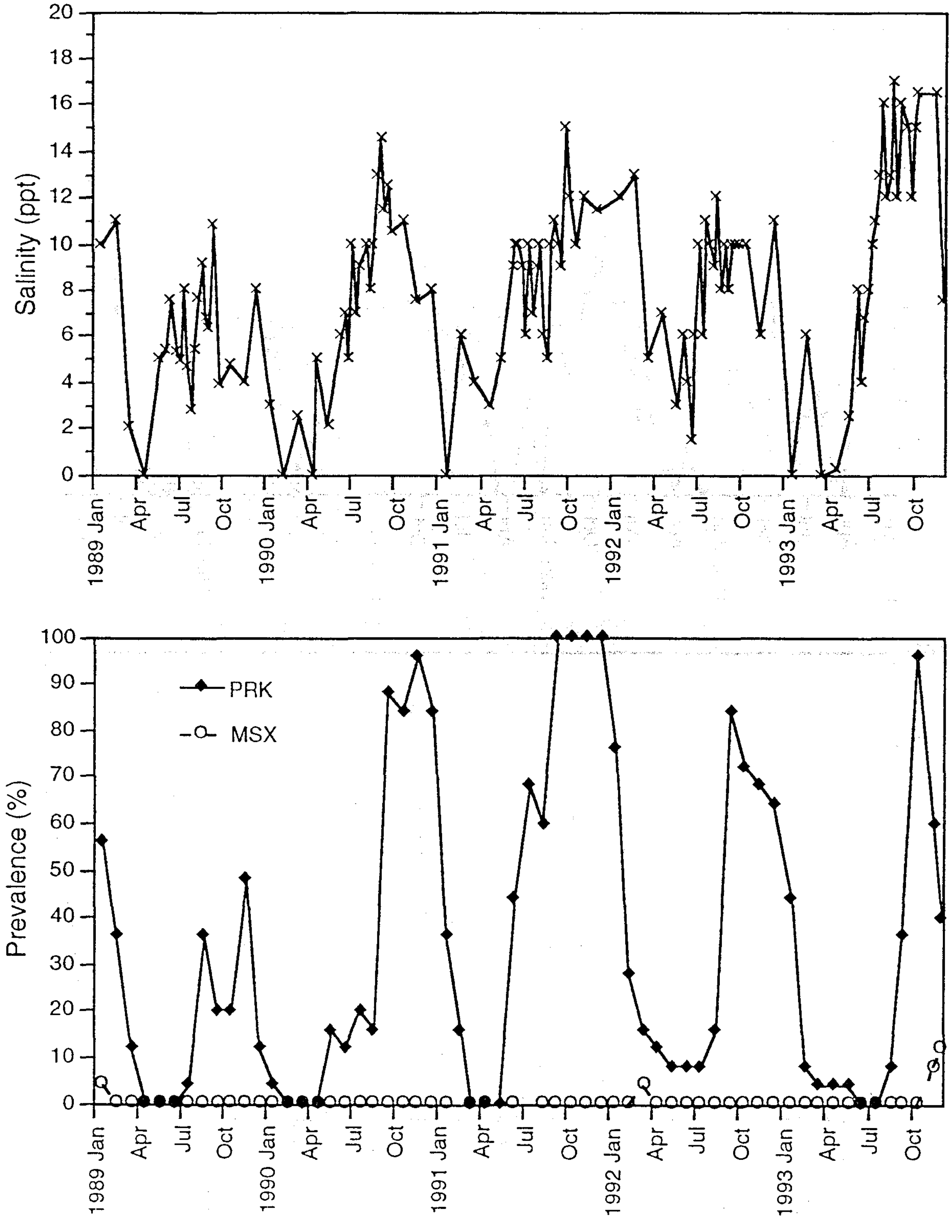


Figure 6. Salinity (top) and prevalence of *P. marinus* (PRK) and *H. nelsoni* (MSX) (bottom) at Horsehead Rock, James River, VA.

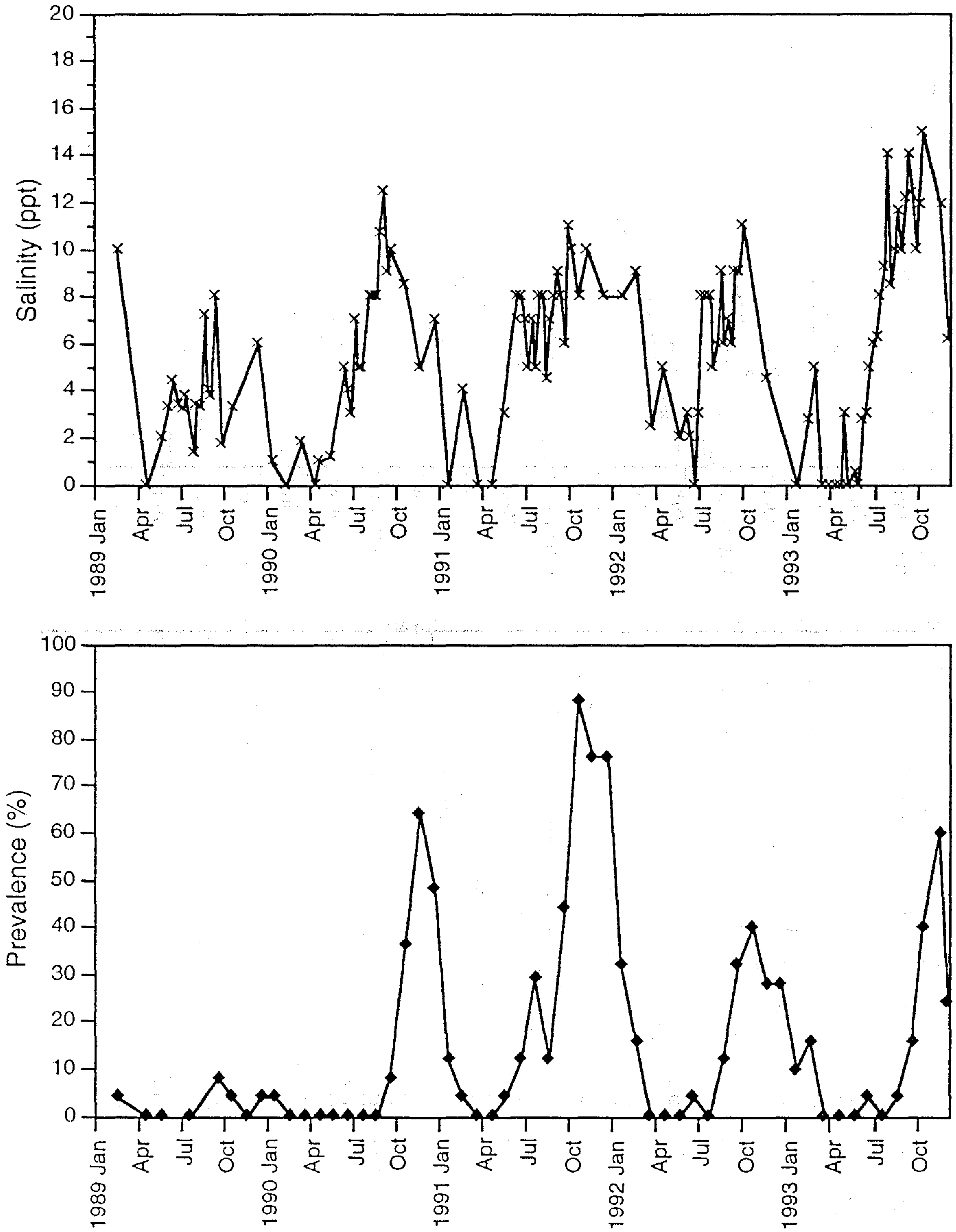
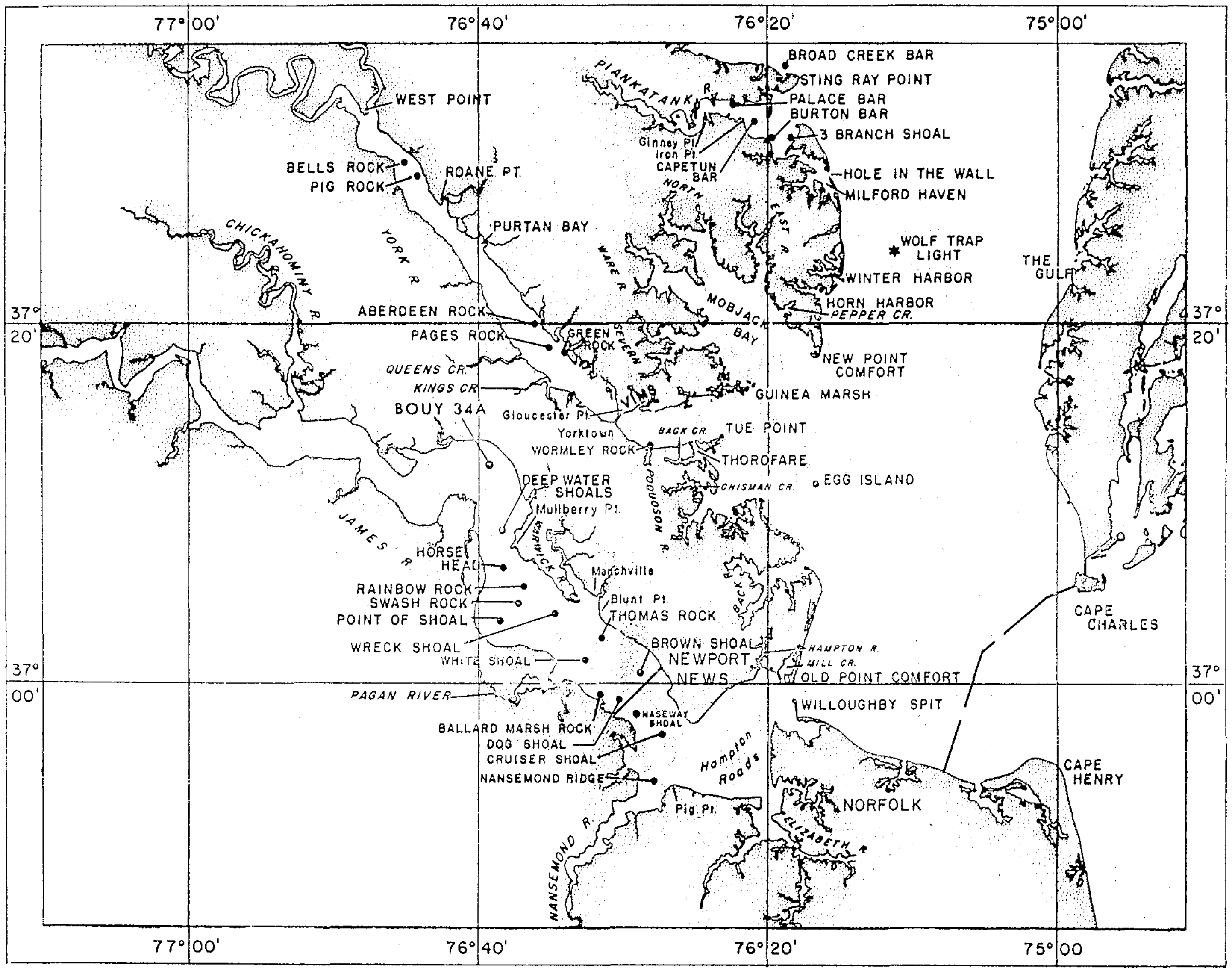
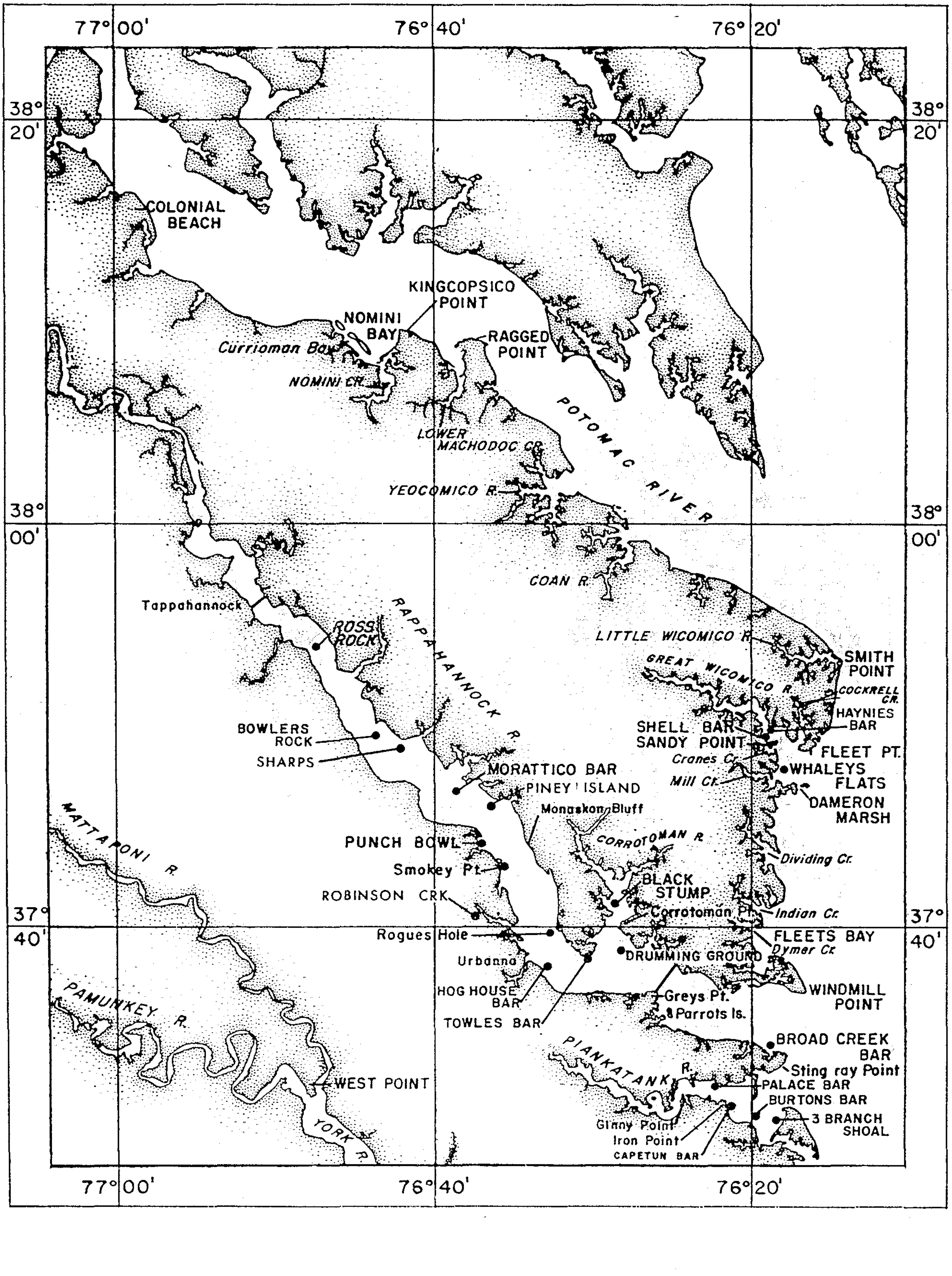


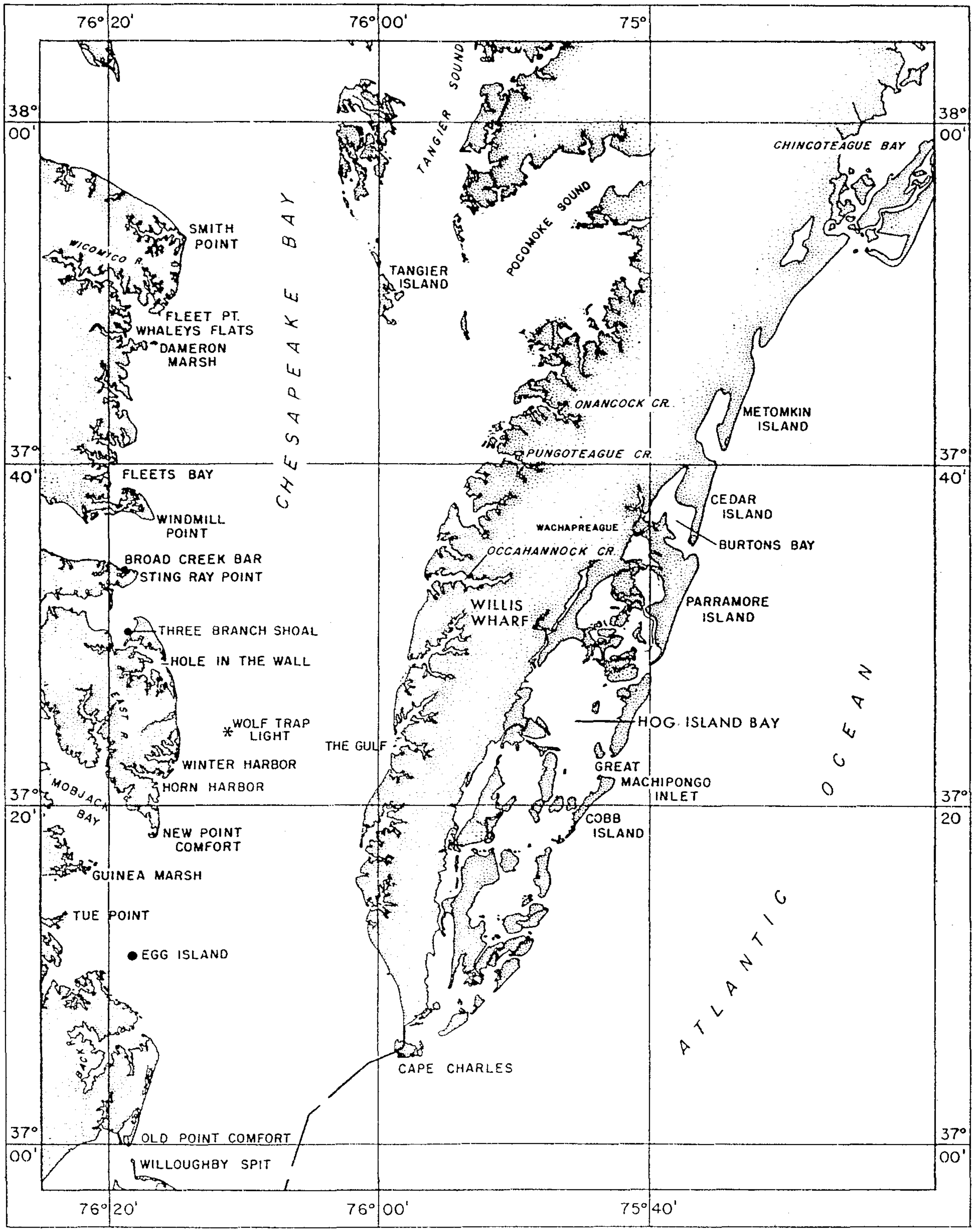
Figure 7. Salinity (top) and prevalence of *P. marinus* (bottom) at Deep Water Shoal, James River, VA



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.