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EXECUTIVE SUMMARY

Weather. Generally, 1992 was a year with considerable short–term variability in both water temperature and streamflow and no long–term trends. January through March were generally dry and warm and culminated seven consecutive abnormally dry months. However, the remainder of the year was relatively normal except perhaps May and June, which were unusually cold, and November, which was unusually warm and wet.

MSX. The seven consecutive dry months from September, 1991 through March, 1992 allowed the abundance of MSX to increase dramatically during 1992. Prevalence of MSX at Wreck Shoal in the James River reached 72% in March, 1992 and it was 60% in the monitoring trays at VIMS in June, 1992. Intensity of infection was also high and this parasite was responsible for some oyster mortality in Virginia for the first time since early 1989. Prevalence of MSX declined at Wreck Shoal after March, but remained at about 20 to 30% most of the remainder of the year. MSX was also present at other locations with appropriate salinity including Mobjack Bay, the lower Rappahannock River and the Great Wicomico River. Overall mortality from MSX was limited because few native oysters remain in most areas with salinity favorable for MSX.

Perkinsus. This parasite continued to be present in all oyster beds in Virginia and exhibited typically high prevalence and intensity in most areas. In the James River, *P. marinus* overwintered at higher prevalences than ever before; however, the maximum fall prevalence actually declined slightly at two low salinity areas, Horsehead Rock and Deepwater Shoal, compared to record high levels the previous two years. The decline may be related to the return to relatively normal temperature and salinity conditions after two previous years of very warm and relatively dry conditions. However, there was no similar decline at oyster beds in moderate or high salinity areas and both the prevalence and intensity of *P. marinus* remained high in these areas. Nevertheless, the decline in prevalence in the upper James River is the first encouraging sign that a return to more normal environmental conditions may cause *P. marinus* to abate.

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 MSX begins in early May each year with peak mortality 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.

Historically, *Perkinsus* 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 *Perkinsus* was not as serious a pathogen as MSX because *Perkinsus* 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 MSX as an oyster pathogen in the Bay. The population dynamics of *Perkinsus* 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. MSX is eliminated from oysters after about 10 days below 10ppt; however, *Perkinsus* 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.

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 MSX and thus they serve as excellent indicators of annual MSX abundance when placed in an endemic areas such as the lower York River just prior to the normal infection period for MSX that begins in May and continues through July. Historically, *Perkinsus* 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 *Perkinsus* abundance since 1987, oysters in the monitoring trays have become infected with *Perkinsus* in recent years. The presence of both MSX and *Perkinsus* 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 *Perkinsus* when they are collected. Nonetheless, these oysters can still be used to monitor MSX, which does not occur in the upper reaches of the rivers.

Prior to establishing trays, a sample of 25 oysters is analyzed for MSX and *Perkinsus* to determine the level of existing infections at the dredge site. No MSX infections have ever been encountered at these sites during April, but in recent years *Perkinsus* has been present. 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 MSX abundance and it is possible to compare years and to relate disease abundance and distribution to various environmental parameters.

Oysters are also usually dredged from the upper James River during August and placed in trays in the lower York River. Mortality and disease prevalence are followed in these trays throughout winter and spring to determine the severity of MSX infections that may be acquired during fall. Fall infections, which do not always occur, cause mortality during late spring and early summer, as opposed to spring infections which cause mortality during late summer.

Native Oyster Samples. In order to determine the annual distribution and severity of both MSX and *Perkinsus*, 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 MSX is determined by histological analysis of paraffin–embedded tissue sectioned at 6 μm and stained with hematoxylin and eosin; prevalence of *Perkinsus* is determined by thioglycollate culture of mantle, gill and rectal tissue.

Monthly mortality in tray samples is 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 complex formula that accounts for live oysters removed for disease diagnosis.

RESULTS–1992

Temperature and streamflow/salinity.

After an abnormally warm year during 1991, water temperature during 1992 was generally cooler, but variable (Figure 1). Water temperature during winter was generally 1°C to 2°C above average, but during spring and early summer temperature was generally below average, especially during May and June. Water temperature during late summer and fall was generally about average, but variable with no consistent trends.

During 1991, James River streamflow was well below average from September through December and this trend continued during January, February and March of 1992 (Figure 1). However, James River streamflow was variable during the remainder of the year, with some months well above average and some months below average (Figure 1). Monthly mean streamflow for the entire Chesapeake Bay system is shown in Figure 2. It was generally below average during winter of 1992, but was near normal for the remainder of the year except for November and December, which were above average. Streamflow is inversely correlated with salinity indicating that salinity declined to more typical levels during 1992. Thus, after an extremely warm and dry year during 1991, conditions during 1992 were relatively normal after the first few months.

Native Oyster Samples.

MSX. This parasite was very rare in the lower Chesapeake Bay during 1989 and 1990, but increased in abundance during the warm, dry conditions of 1991. This increasing trend continued during early 1992 and MSX was abundant at Wreck Shoal in the James River with prevalence reaching 72% in March (Figure 3, Table 1). Moderate and heavy infections were encountered during most months (Table 1) suggesting that MSX was causing some oyster mortality at Wreck Shoal. No MSX was present at Wreck Shoal during June or July, probably because of the high streamflow (Figure 1), and resultant low salinity (Figure 5), during June. However, the prevalence of MSX increased again in August and the parasite was present the remainder of the year (Figure 3). MSX was also present at other locations in the lower Bay, including Mobjack Bay, the Great Wicomico River and the lower Rappahannock River (Table 1).

Perkinsus. The warm, dry conditions during 1991 resulted in record high levels of *Perkinsus* on all oyster beds in Virginia (see 1991 monitoring report and Figures 5–7 herein). During 1992, *Perkinsus* was still present on all beds, but the peak prevalence in low salinity areas was reduced compared with 1991. For example, prevalence of *Perkinsus* was 100% for four months during fall of 1991 at Horsehead Rock in the upper James River (Figure 6), but peak prevalence at that location during 1992 was only 84% for one month (Figures 3, 6). At Deep Water Shoal, the uppermost oyster bed in the James River, *Perkinsus* prevalence was above 70% for three months during 1991 (Figure 7), but peaked at 40% during 1992 (Figures 3, 7). Intensity of infection at these locations was also lower during 1992 than 1991.

The prevalence and intensity of *Perkinsus* infections always declines during winter to a minimum during spring. During 1991 the minimum prevalence was higher than normal at both Wreck Shoal and at Horsehead Rock in the James River (Figures 5 and 6). Typically, prevalence is zero at Horsehead Rock and below 10% at Wreck Shoal for a few months during spring. During 1992 infections were found every month at Horsehead Rock and prevalence never declined below 36% at Wreck Shoal (Figures 3, 5, 6).

Prevalence and intensity of *Perkinsus* at other locations in Virginia, including the seaside of the Eastern Shore, was generally high (Table 1). The lower reaches of the Rappahannock, Great Wicomico and Piankatank Rivers had especially high levels of *Perkinsus*.

Tray Samples.

May (Spring) Imports. Counts of live and dead oysters and prevalence and intensity of MSX and *P. marinus* in the tray established 1 May 1992 at Gloucester Point are listed in Table 2. Both MSX and *P. marinus* were abundant in tray oysters by late July. The intensity of MSX infections was high and this parasite certainly contributed substantially to the mortality observed in this tray. This is the first year since 1989 that MSX has been detected in spring import trays. Total mortality in the tray was 90.0%.

The monitoring trays are used primarily to document the annual fluctuations in abundance of MSX as a result of changing environmental conditions. Historically, *P. marinus* never invaded the trays during the eight month exposure period and any mortality in the trays could be attributed to MSX. Since 1988, *P. marinus* has invaded the trays each year, complicating mortality estimates. In addition, the presence of *P. marinus* on all oyster beds in Virginia now precludes using uninfected oysters in the trays. Cryptic over wintering stages are usually not detectable in late April when oysters are collected for the trays, but they appear later and it is impossible to know the percentage of newly acquired versus overwintering infections in the trays during the exposure period. Thus, the monitoring trays are not necessarily good indicators of *P. marinus* activity for any given year. However, *Perkinsus* does not interfere with MSX infectivity, so the trays are still a good indicator for annual MSX distribution and abundance.

Counts of live and dead oysters and prevalence of MSX and *P. marinus* in duplicate trays established 1 May 1992 in Burton's Bay at Wachapreague on the seaside of the Eastern Shore are listed in Table 3. Mortality in the tray was low until about 1 September at which time a sample from one tray revealed 100% prevalence of *P. marinus*. There was no MSX present in the sample. Mortality increased during October, as a result of the *P. marinus* infections, but then declined through late fall as water temperature decreased. Total mortality in the two trays averaged about 35%.

August (Fall) Imports. Susceptible oysters placed in the York River in late summer are used to monitor the success of MSX infections acquired during fall. Counts of live and dead oysters and prevalence and intensity of MSX and *P. marinus* in trays established 1 September 1992 at Gloucester Point are shown in Table 4. MSX was detected in oysters in this tray on 1 April and prevalence and intensity increased through mid June when the tray was removed. Cumulative mortality in the tray was 28.2% and was attributable entirely to MSX. On the basis of data from this tray, fall MSX infections were successful during 1992 and this parasite probably caused substantial mortality in some areas during early summer. However, few native oysters remain in areas that would have had similar environmental conditions as those of the tray, so the impact on native oyster populations was probably small. The tray data do support the field data from Wreck Shoal that illustrated high MSX prevalence during spring.

DISCUSSION

MSX. The distribution of MSX is known to be controlled by salinity and results obtained during the last few years from the James River reinforce this conclusion. A comparison of Figures 4 and 5 illustrates the influence of riverflow and resultant low salinity on the presence of MSX at Wreck Shoal in the James River. This parasite was relatively prevalent during 1988 and early 1989, which was a consistently dry period (Figure 4). However, MSX was rapidly eliminated from oysters at Wreck Shoal after the record–high runoff during May, 1989 and remained absent for 14 months because of consistently above average runoff and reduced salinity. Salinity was well below 10 ppt just prior to the elimination of MSX and exposure to this value for 10 days is known to be lethal to MSX on the basis of laboratory studies. Runoff was relatively average during mid and late 1990 and MSX reinvaded oysters at Wreck Shoal during late 1990 and 1991. During early 1992 the prevalence of MSX at Wreck Shoal increased dramatically after seven consecutive months of below average runoff and there was a high prevalence of MSX in monitoring trays at VIMS as well. The absence of MSX during July and August, 1992 may have been the result of low salinity during June, 1992 (Figure 5), but the parasite quickly became re-established. In any case, during 1992 the prevalence of MSX was higher than at any period during the previous four years.

The pattern of MSX abundance at Wreck Shoal in the James River is probably typical of what would be expected at areas with similar salinity in rivers with large watersheds like the Rappahannock River. In subestuaries with smaller watersheds and lower runoff, the abundance of MSX may not fluctuate quite so dramatically; however, the long–term streamflow pattern for the Chesapeake Bay as a whole is similar to the pattern observed in the James River so overall long–term trends in MSX abundance should be similar throughout the Bay. Unfortunately, few native oysters remain in most areas with appropriate salinity for MSX survival, so it is difficult to document the prevalence of this parasite except in the upper James River.

Perkinsus. This parasite spread to all oyster beds in Virginia in 1988 as a result of the extreme drought and it continues to be present in all areas. It is clear that *P. marinus* is not susceptible to short–term fluctuations in salinity as is MSX. For example, the high runoff during May, 1989 that eliminated MSX had no effect on the subsequent summer prevalence of *P. marinus* (Figure 5). The maximum prevalence of *P. marinus* at Wreck Shoal has been 100% every fall since 1988 and the prevalence at Horsehead Rock and at Deepwater Shoal increased every year from 1989 through 1991 (Figures 6, 7). During 1992, *P. marinus* overwintered at higher prevalences than ever before at both Wreck Shoal and Horsehead Rock; however, maximum fall prevalence actually declined during 1992 at both Horsehead Rock and Deepwater Shoal (Figures 6, 7) compared with previous years of steady increase. Reasons for the decline are not obvious, but may be related to the return to relatively normal temperature and streamflow after two years of very warm and relatively dry conditions. Horsehead Rock and Deepwater Shoal are typically areas of low salinity that had no history of *P. marinus* prior to 1988 and it is not surprising that they are the first to show some possible expulsion of *Perkinsus*. Unfortunately, prevalence and intensity of *P. marinus* remained high at Wreck Shoal (Figure 5) and at other moderate to high salinity areas in Virginia.

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Table 1. Prevalence and intensity of MSX and *Perkinsus* in oysters from Virginia harvesting areas in 1992. 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	21 Jan	nd			8/25	32	0-0-8
	18 Feb	nd			4/25	16	0-0-4
	17 Mar	nd			0/25	0	
	14 Apr	nd			0/25	0	
	14 May	nd			0/25	0	
	17 Jun	nd			1/25	4	0-0-1
	15 Jul	nd			0/25	0	
	12 Aug	nd			3/25	12	0-0-3
	17 Sep	nd			8/25	32	0-0-8
	13 Oct	nd			10/25	40	0-1-9
	18 Nov	nd			7/25	28	0-1-6
	08 Dec	nd			7/25	28	1-0-6
Horsehead Rock	21 Jan	0/25	0		19/25	76	0-0-19
	18 Feb	0/25	0		7/25	28	0-0-7
	17 Mar	1/24	4	0-0-1	4/25	16	0-0-4
	14 Apr	0/25	0		3/25	12	0-0-3
	14 May	0/25	0		2/25	8	0-0-2
	17 Jun	0/25	0		2/25	8	0-0-2
	15 Jul	0/25	0		2/25	8	0-0-2
	12 Aug	0/25	0		4/25	16	0-0-4
	17 Sep	0/25	0		21/25	84	1-1-19
	13 Oct	0/25	0		18/25	72	1-1-16
	18 Nov	0/25	0		17/25	68	1-0-16
	08 Dec	0/25	0		16/25	64	1-0-15
Point of Shoals	21 Jan	nd			20/25	80	0-0-20
	18 Feb	nd			15/25	60	0-1-14
	17 Mar	0/20	0		4/25	16	0-0-4
	14 Apr	nd			4/25	16	0-0-4
	14 May	nd			4/25	16	0-0-4
	17 Jun	nd			1/25	4	0-0-1
	15 Jul	nd			8/25	32	0-0-8
	12 Aug	nd			13/25	52	0-1-12
	17 Sep	nd			23/24	96	3-2-18
	13 Oct	nd			24/25	96	2-3-19
	18 Nov	nd			17/25	68	1-1-15
	08 Dec	nd			12/25	48	1-0-11
Wreck Shoal	21 Jan	12/25	48	0-0-12	22/25	88	1-1-20
	18 Feb	10/25	40	2-0-8	17/25	68	0-1-16
	17 Mar	18/25	72	1-2-15	20/25	80	0-1-19
	14 Apr	11/25	44	2-2-7	10/25	40	0-2-8
	14 May	9/25	36	2-0-7	9/25	36	0-0-9
	17 Jun	0/25	0		14/25	56	0-0-14
	15 Jul	0/25	0		21/25	84	0-3-18

Table 1. (Continued)

Location	Date	MSX Infect./exam.	% Infect.	H-M-L*	*Perkinsus* Infect./exam.	% Infect.	H-M-L*
James River (Cont.)							
Wreck Shoal	12 Aug	5/25	20	1-1-3	25/25	100	5-6-14
	17 Sep	5/25	20	0-1-4	25/25	100	7-10-8
	13 Oct	8/25	32	2-0-6	25/25	100	3-4-18
	18 Nov	5/25	20	0-0-5	24/25	96	3-4-17
	08 Dec	9/25	36	2-0-7	24/25	96	1-2-21
Swash	05 May	nd			5/25	20	0-0-5
Warwick River	28 Aug	nd			25/25	100	5-6-14
Mobjack Bay							
Tow Stake	28 Sep	3/22	14	0-0-3	22/22	100	6-3-13
East River	25 Nov	nd			19/25	76	0-0-19
	25 Nov	nd			14/25	56	0-0-14
Piankatank R.							
Ginny Point	01 Oct	0/25	0		25/25	100	2-2-21
Burton Point	01 Oct	nd			25/25	100	4-4-17
Palace Bar	25 Nov	nd			1/20	5	0-0-1
Freeport	25 Nov	nd			5/22	23	0-0-5
Rappahannock R.							
Little Carter Rock	23 Nov	nd			1/25	4	0-0-1
Ross Rock	29 Aug	0/25			0/25	0	
	06 Oct	nd			6/25	24	0-0-6
	23 Nov	nd			2/25	8	0-0-2
Long Pt-Sharps	12 May	1/25	4	0-0-1	11/25	44	0-0-11
Smokey Pt.	11 May	nd			12/25	48	0-0-12
	06 Oct	nd			14/14	100	4-3-7
Morattico Bar	11 May	nd			11/25	44	0-0-11
	06 Oct	nd			18/18	100	7-6-5
Bowlers Rock	11 May	nd			11/25	44	0-0-11
	06 Oct	nd			24/25	96	2-1-21
	23 Nov	nd			7/20	35	0-1-6
Parrot's Rock	07 Oct	3/12	25	1-0-2	21/21	100	3-1-17
Broad Creek	07 Oct	3/21	14	0-0-3	23/25	92	0-0-23
Hog House Bar	07 Oct	nd			25/25	100	6-4-15
Great Wicomico R.							
Shell Bar	24 Mar	nd			18/24	75	1-0-17
Sandy Point	24 Mar	nd			13/25	52	0-0-13
Cranes Creek	24 Mar	nd			19/25	76	0-0-19
Fleeton Point	02 Oct	8/24	33	3-2-3	23/24	96	1-3-19
Whaley's Flats	24 Mar	2/25	8	0-2-0	18/25	72	0-0-18
	02 Oct	nd			13/15	87	0-2-11
Haynie's Creek	24 Mar	nd			14/25	56	1-1-12
	05 Oct	nd			20/23	87	4-2-14

Table 1. (continued)

Location	Date	MSX Infect./exam.	% Infect.	H-M-L*	*Perkinsus* Infect./exam.	% Infect.	H-M-L*
Yeocomico River							
Hampton Hall Cr.	17 Jun	nd			12/25	48	0-0-12
Mill Cr.	17 Jun	nd			23/25	92	2-5-16
Barn Point	17 Jun	nd			25/25	100	0-2-23
Corotoman River	07 Oct	nd			19/20	95	2-0-17
Eastern Shore							
Seaside							
Hog Island Bay							
Tug Ames	27 Apr	nd			0/25	0	
Fowling Point	27 May	nd			22/25	88	1-0-21
Bradfords Bay					21/25	84	1-3-17
Bayside							
The Gulf					21/25	84	3-1-17
Poquoson	09 Sep	nd			24/24	100	5-7-12
	23 Oct	nd			25/25	100	1-1-23

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

nd = no diagnosis for this parasite in this sample.

Table 2. Mortality and disease prevalence in upper Rappahannock River oysters placed in tray at Gloucester Point, VA on 1 May, 1992. PRK = *Perkinsus marinus*, MSX = *H. nelsoni*.

Date–1992	Counts live/dead	Monthly mortality–%	Cumulative mortality-%	Infected/examined–%	Intensity H–M–L*
1 May	1000/0	0.0%	0.0%	MSX: 0/25–0% PRK: 0/25–0%	
27 Jul	559/416	14.71%	42.7%	MSX: 20/25–80% PRK: 22/25–88%	6-3-11 1-2-19
24 Aug	266/268	55.76%	71.4%	MSX: 15/25–60% PRK: 25/25–100%	4-3-8 3-1-21
7 Oct	76/140	44.19%	90.0%		

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

Table 3. Mortality and disease prevalence in upper Rappahannock River oysters placed in replicate trays at Wachapreague, VA on 4 May, 1992. PRK = *Perkinsus marinus*, MSX = *H. nelsoni*.

Date–1992	Counts live/dead	Monthly mortality–%	Cumulative mortality-%	Infected/examined–%	Intensity H–M–L*
4 May	537/0	0.0%	0.0%		
	538/0	0.0%	0.0%		
3 Jun	531/6	1.12%	1.12%		
	532/6	1.13%	1.13%		
6 Jul	524/7	1.20%	2.42%		
	528/4	0.68%	1.87%		
10 Aug	510/14	2.36%	5.03%		
	509/19	3.18%	5.40%		
4 Sep	464/46	11.27%	13.59%		
	487/22	5.40%	9.49%	MSX: 0/25–0.0%	
				PRK: 25/25–100.0%	4-6-15
1-Oct	379/85	21.14%	29.42%		
	383/79	19.73%	24.97%		
9-Nov	337/42	8.52%	37.24%		
	341/42	8.44%	33.20%		
4-Dec	331/6	2.14%	38.36%		
	331/10	3.52%	35.15%		

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

Table 4. Mortality and disease prevalence in upper Rappahannock River oysters placed in a tray at Gloucester Point, VA on 17 September, 1991. PRK = *Perkinsus marinus*, MSX = *H. nelsoni*.

Date 1991-1992	Counts live/dead	Monthly mortality–%	Cumulative mortality-%	Infected/examined–%	Intensity H–M–L*
17 Sept	300/0	0.0%	0.0%		
9 Oct	299/1	0.45%	0.33%		
7 Nov	297/2	0.72%	1.00%		
8 Dec	295/2	0.65%	1.67%		
1 Apr	nc			MSX: 5/25–20.0%	0-4-1
12 May	nc			MSX: 9/25–36.0% PRK: 0/25–0.0%	6-2-1
15 Jun	179/66	24.49%	28.16%	MSX: 15/25–60.0% PRK: 2/25–8.0%	4-3-8 0-0-2

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

nc=no count was made at this time

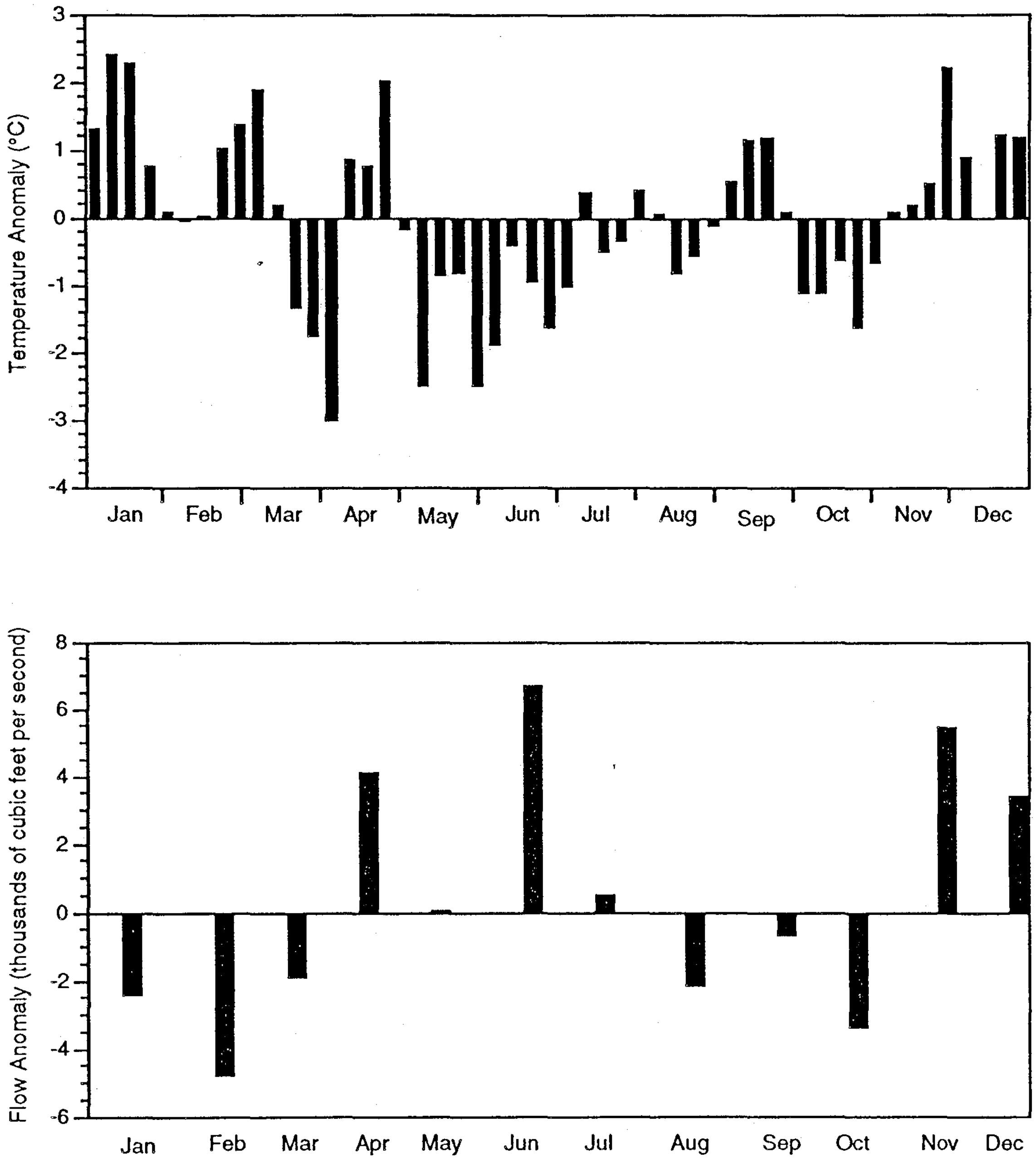


Figure 1. Weekly water temperature anomaly at the VIMS pier, Gloucester Point, VA based on average temperature from 1947-1991 (top) and monthly James River streamflow anomaly based on average discharge from 1951-1990 (bottom) for the calendar year 1992.

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.

December 31, 1992.

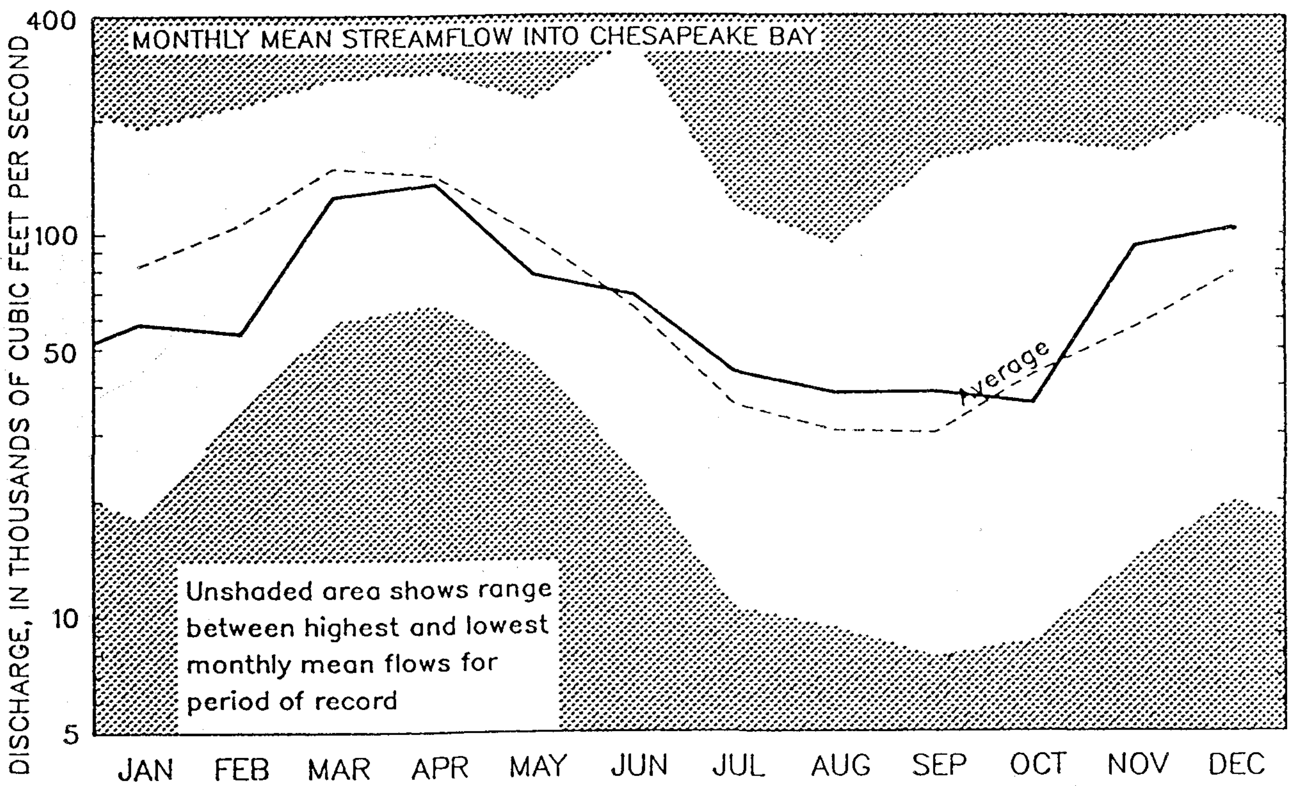


Figure 2. Monthly mean streamflow into Chesapeake Bay during 1992 (solid line) compared with average monthly mean streamflow for the period 1951–1991 (dashed line).

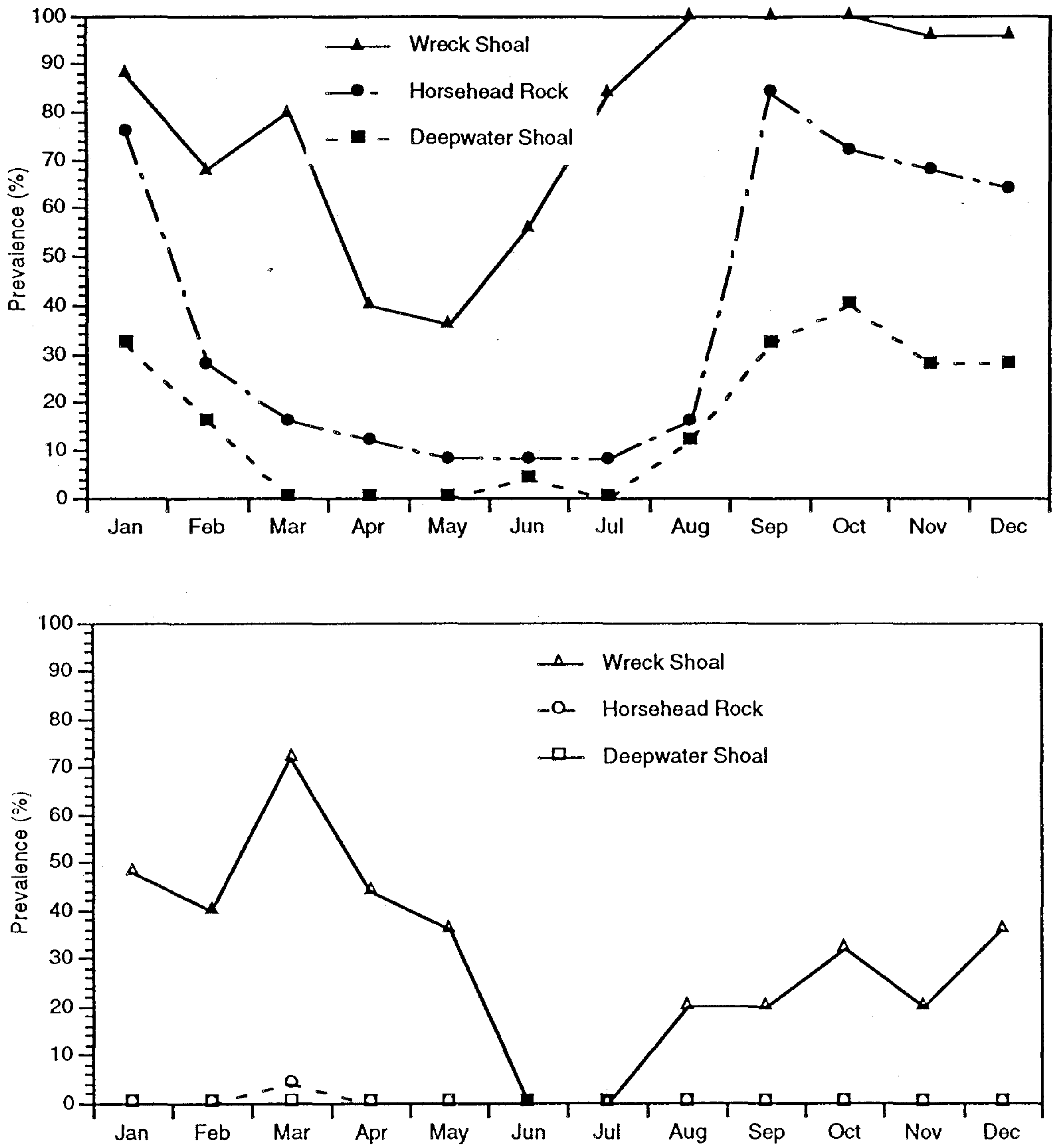


Figure 3. Prevalence of *P. marinus* (top) and *H. nelsoni* (MSX) (bottom) in James River oysters from Wreck Shoal, Horsehead Rock and Deepwater Shoal in 1992.

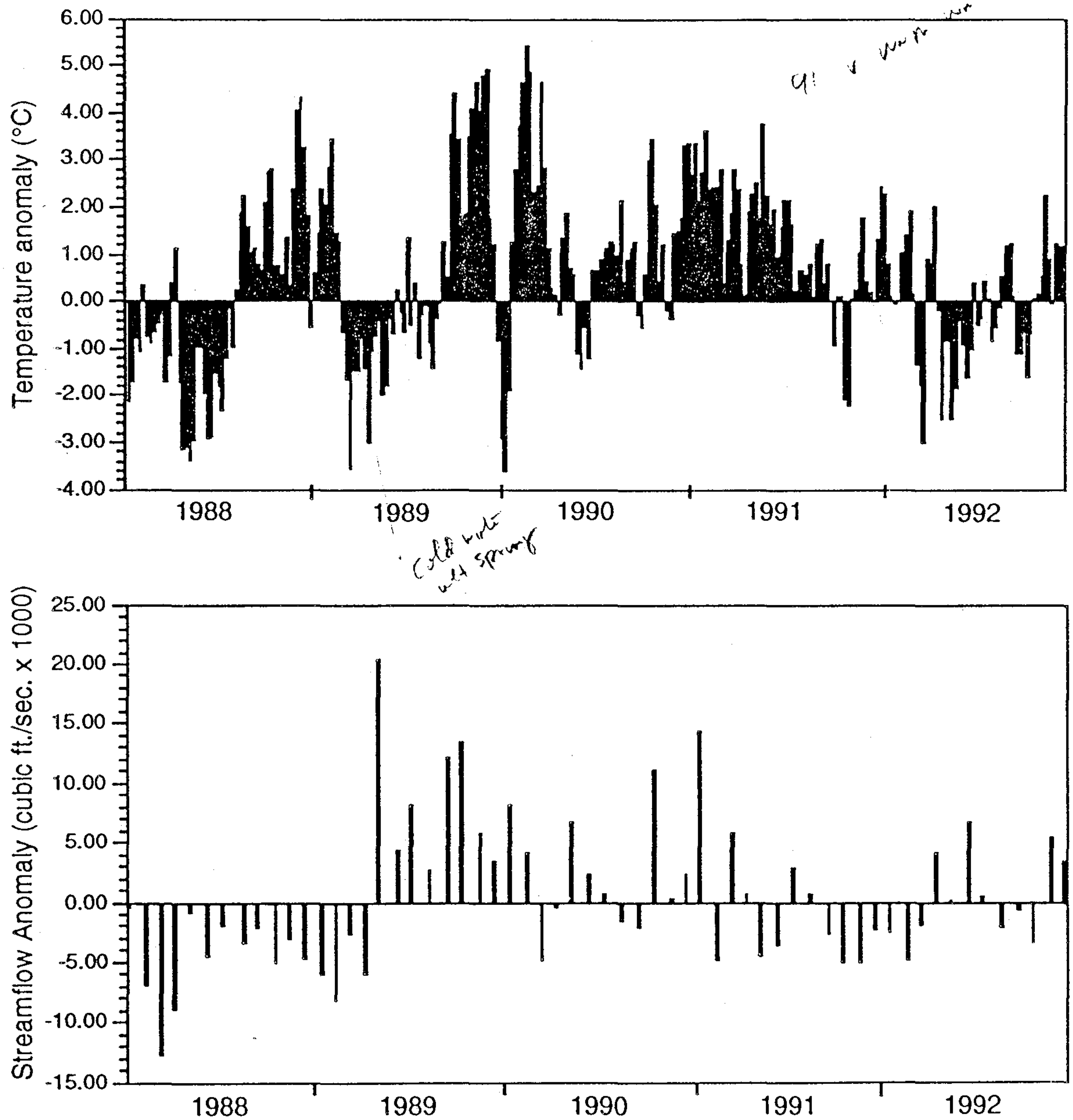


Figure 4. Mean weekly VIMS pier water temperature anomaly from long-term (1947-1992) average (top). Mean monthly James River streamflow anomaly from long-term (1951-1990) average (bottom).

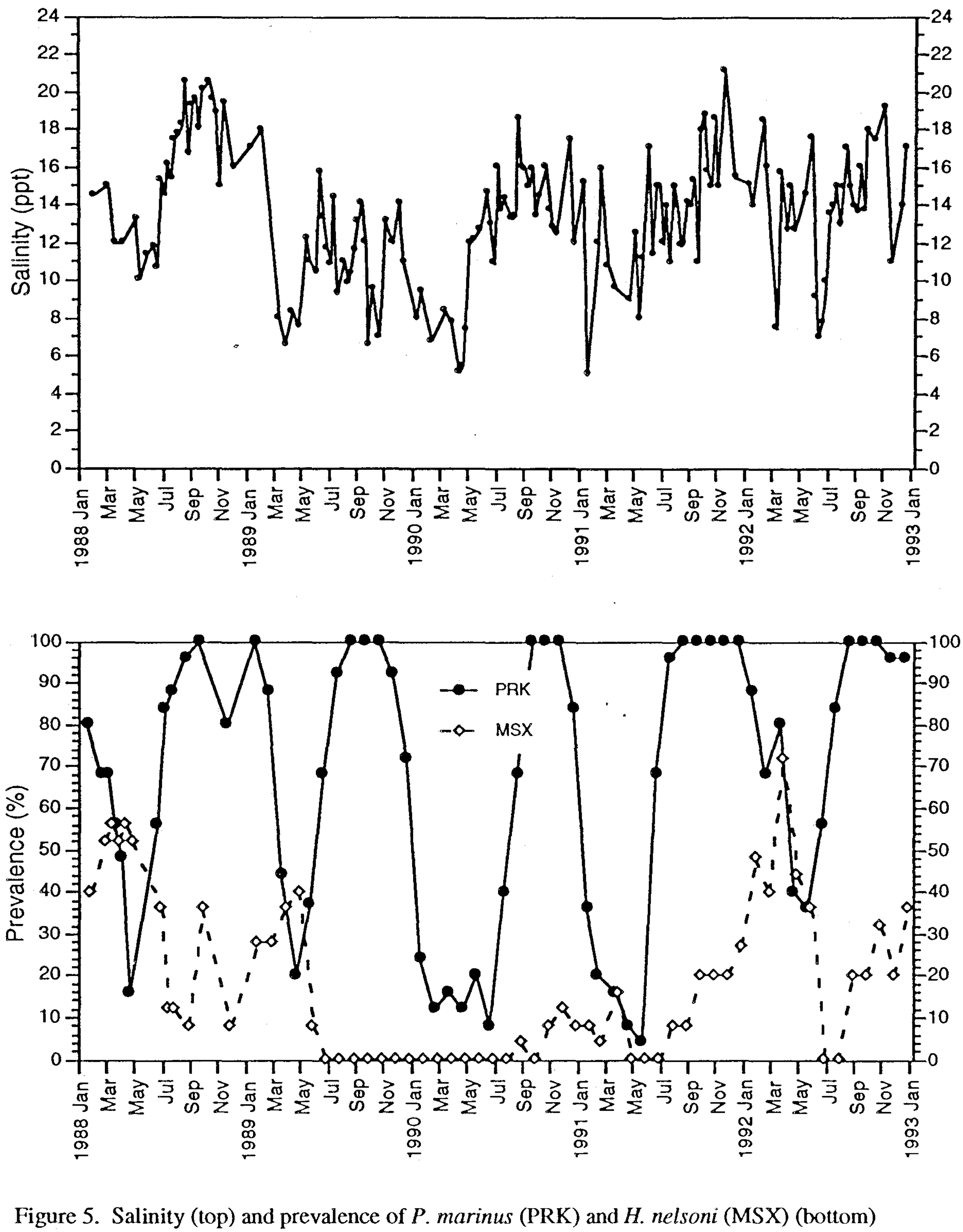


Figure 5. Salinity (top) and prevalence of *P. marinus* (PRK) and *H. nelsoni* (MSX) (bottom) at Wreck Shoal, James River, VA

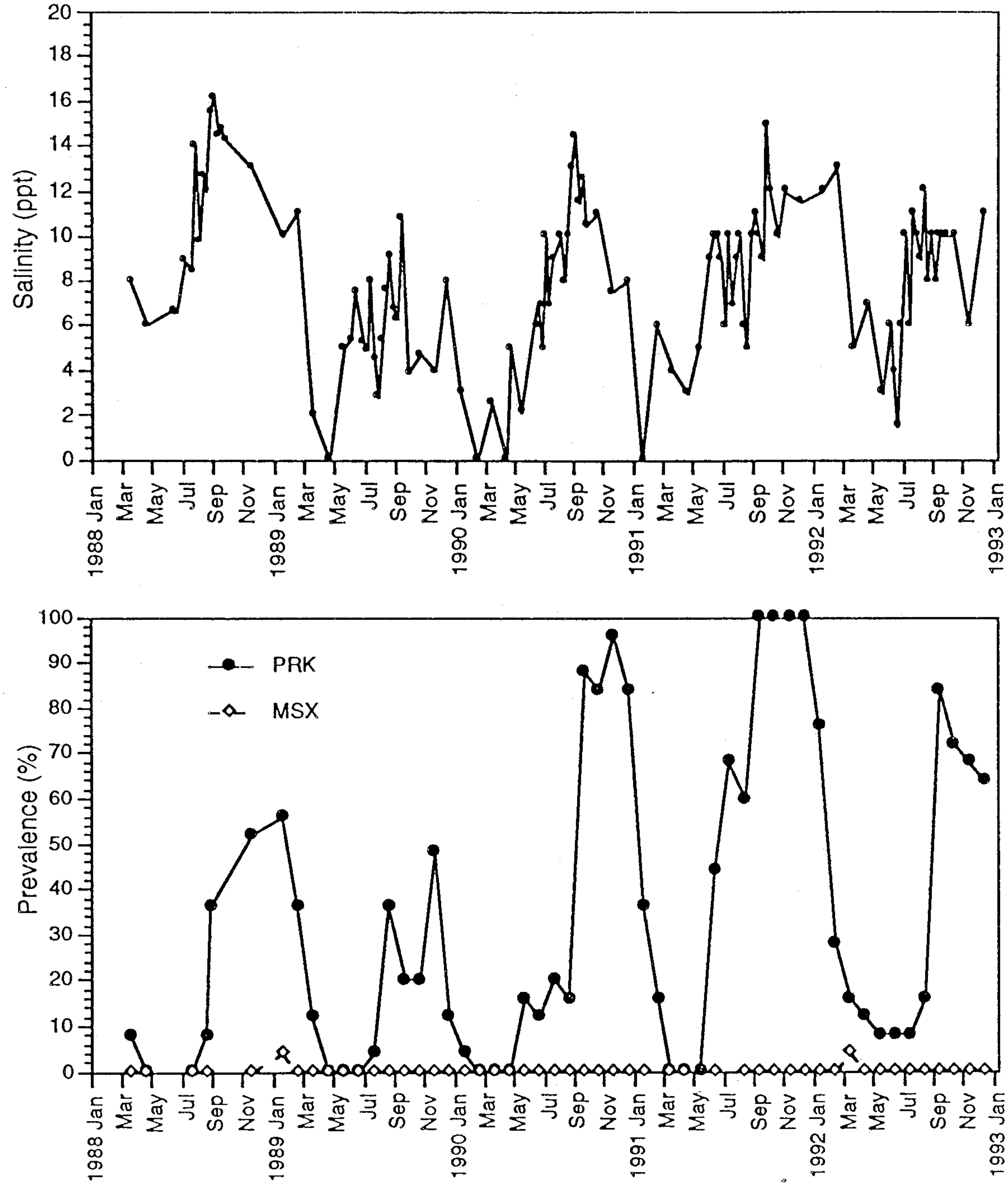


Figure 6. Salinity (top) and prevalence of *P. marinus* (PRK) and *H. nelsoni* (MSX) (bottom) at Horsehead Rock, James River, VA.

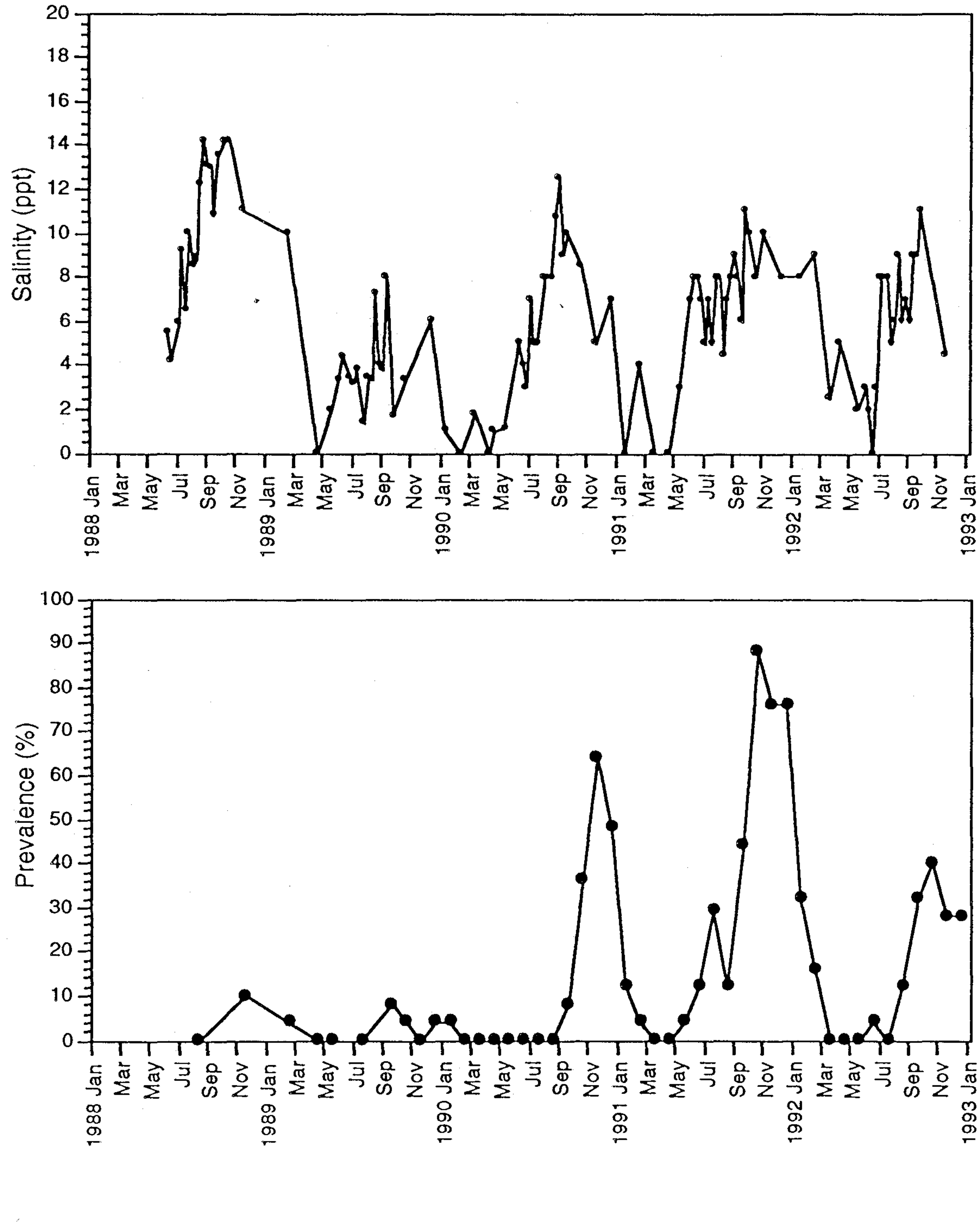
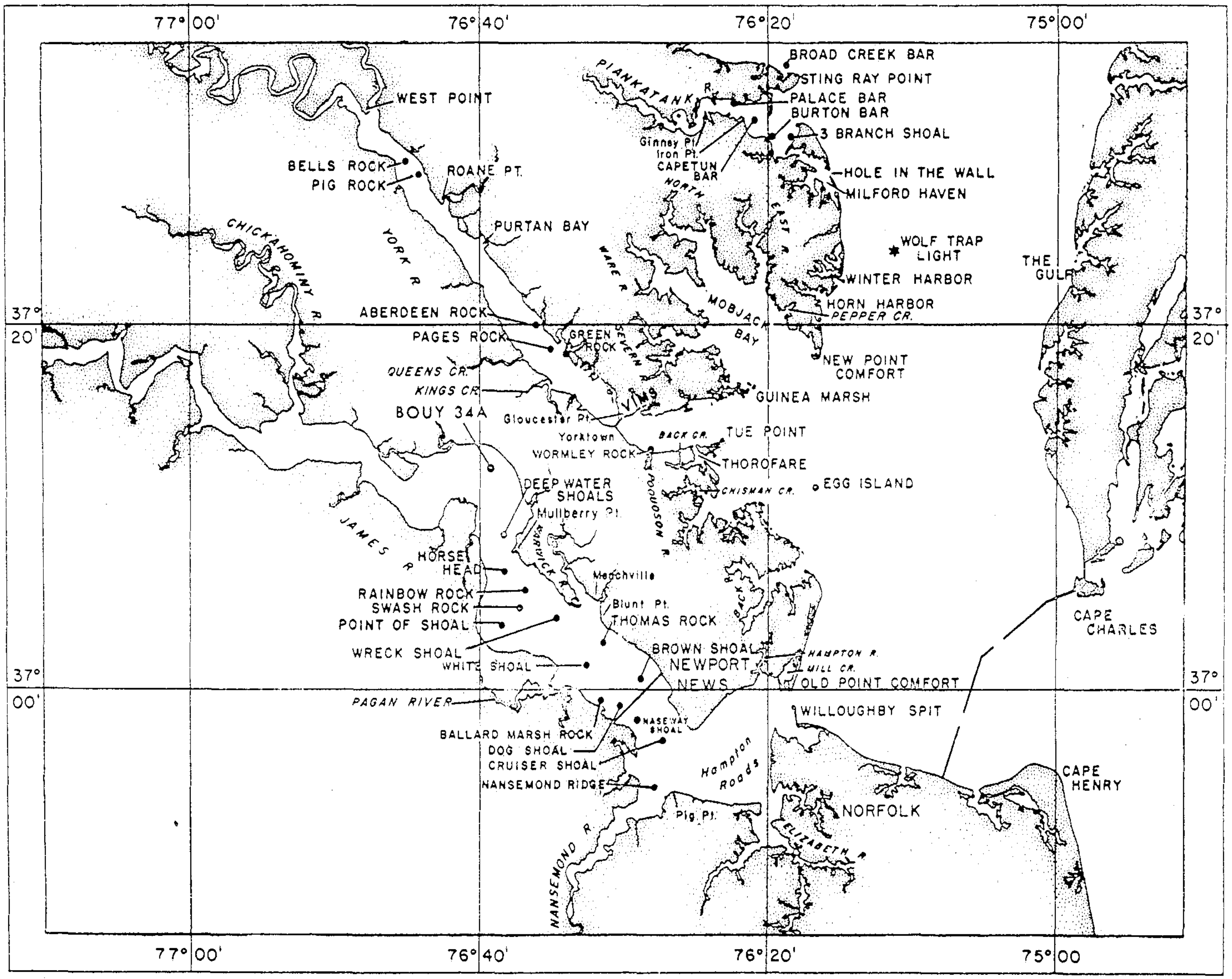
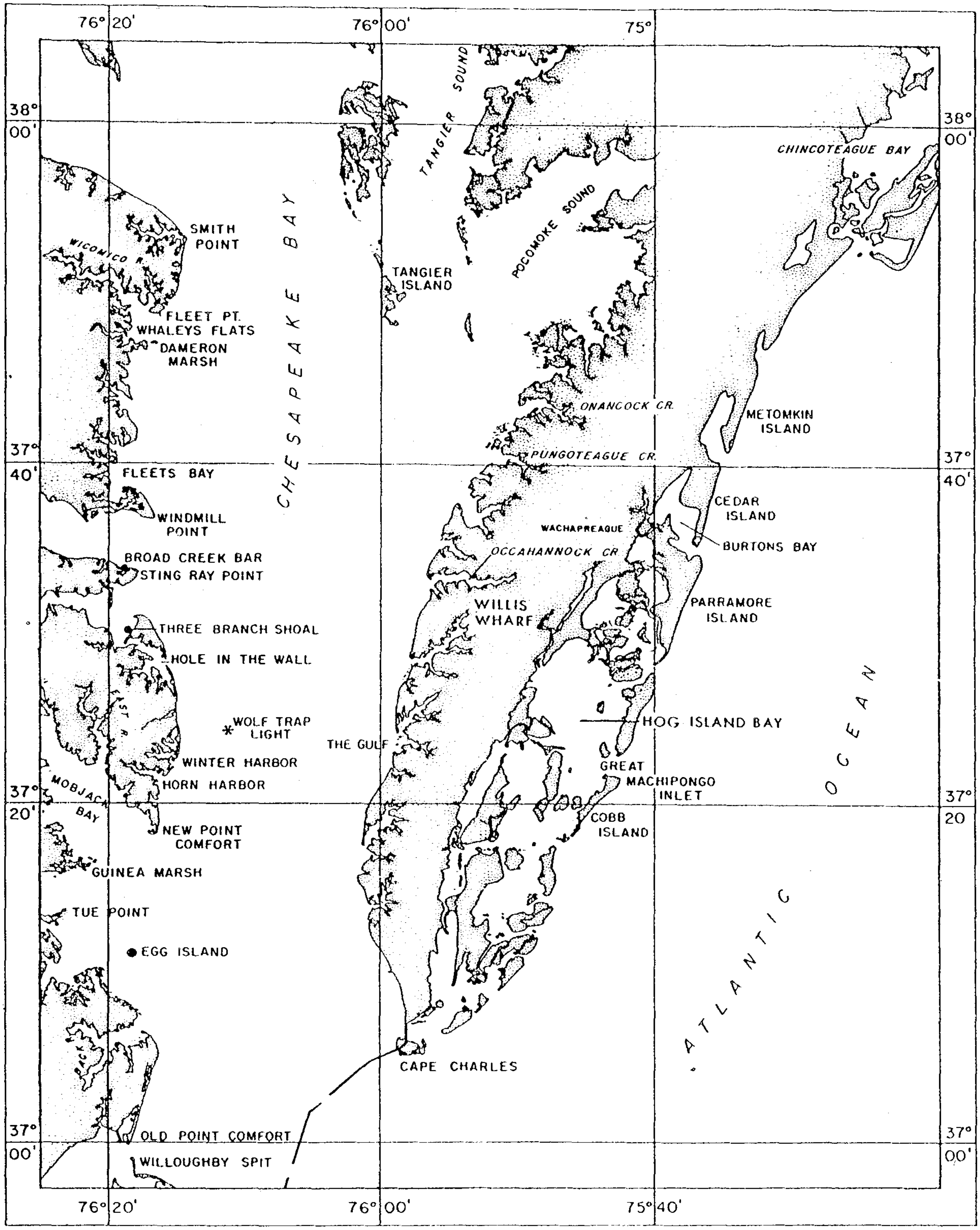


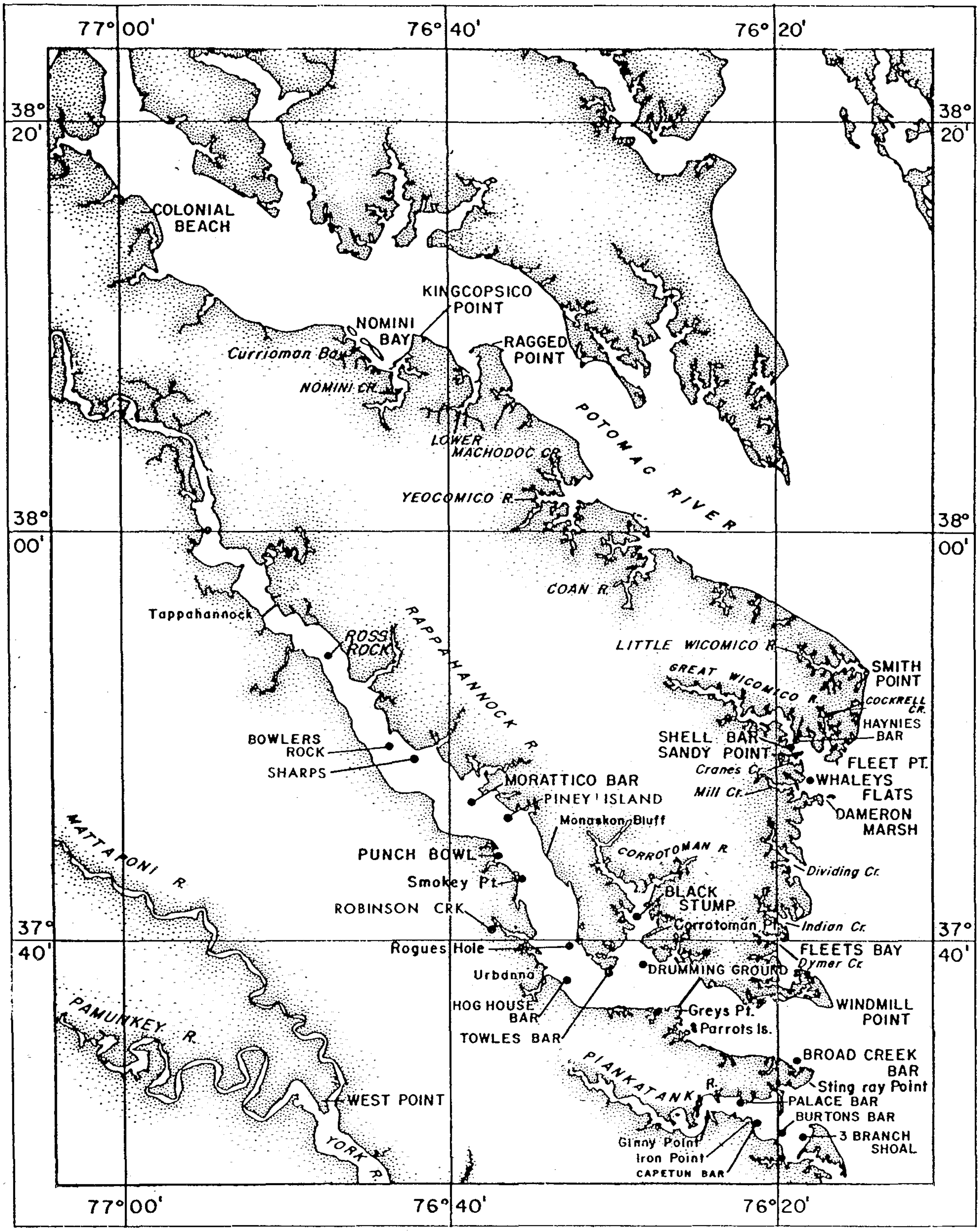
Figure 7. Salinity (top) and *P. marinus* prevalence (bottom) at Deepwater Shoal, James River, VA.



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 on Eastern Shore of Virginia.



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