2-1992

Status of the Major Oyster Diseases in Virginia 1991 A Summary of the Annual Monitoring Program

Eugene M. Burreson
Virginia Institute of Marine Science

Recommended Citation

Burreson, E. M. (1992) Status of the Major Oyster Diseases in Virginia 1991 A Summary of the Annual Monitoring Program. Marine Resource Report 92-1. Virginia Institute of Marine Science, College of William and Mary. https://doi.org/10.21220/V58F0B

STATUS OF THE MAJOR OYSTER DISEASES IN VIRGINIA—1991.

A SUMMARY OF THE ANNUAL MONITORING PROGRAM.

EUGENE M. BURRESON, PH.D.

Virginia Institute of Marine Science,
The College of William and Mary
Gloucester Point, Virginia 23062

Marine Resource Report 92-1

February 1992

EXECUTIVE SUMMARY

Abnormally warm and dry conditions prevailed during 1991 and provided optimal conditions for both MSX and *Perkinsus marinus* (see Figures 1 and 2 on pages 12 and 13). Water temperature was below the long term average for only three weeks during the year. January and February averaged almost 3°C above normal and the first seven months of the year averaged about 2°C above normal . Streamflow was well below average for nine consecutive months beginning in April; the fall season was especially dry.

The increased salinity resulting from low streamflow allowed MSX to reinvade oysters at Wreck Shoal in the upper James River, where it was absent for most of 1989 and 1990. Prevalence only reached 27% by December, but it was steadily increasing; MSX was not found in oyster beds above Wreck Shoal. Abundance of MSX also increased in the lower Rappahannock River and in the Great Wicomico River during 1991. Prevalence and intensity values in all areas were relatively low compared to 1987 and 1988 and little mortality could be attributed to this parasite for the third year in a row. The resurgence of MSX during 1991 reinforces the concept that this parasite responds rapidly to changing salinity.

The seasonal cycle of *P. marinus* was typical during 1991, with a gradual decline in prevalence in winter and an increase during summer. However, the summer increase began about two months earlier in 1991 than in 1990, probably as a result of the unusually warm winter during 1991. The prevalence and intensity of *P. marinus* infections in the upper James River have been increasing since 1987. During 1991 record high levels of *P. marinus* were recorded at both Horsehead Rock and Deep Water Shoal in the upper James River. On the basis of infection intensity, measurable oyster mortality probably occurred at both locations. *Perkinsus* was also abundant during fall at most other locations sampled, including all rivers and on the seaside of the Eastern Shore.

Two years of above average rainfall during 1989 and 1990 had little effect on the abundance of *Perkinsus* and dry, warm conditions during 1991 only exacerbated the trend of increasing abundance. To protect the remaining oyster resource in the face of continuing disease pressure, it seems prudent to reduce other sources of oyster mortality to the maximum extent possible.

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 prevented 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 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 has recently increased in abundance and has spread throughout all public oyster beds. Until the late 1980s *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 recent 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 seems to be 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 Horsehead Rock or 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 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. 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 and this has made interpretation of the cause of mortality difficult. In addition, 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 late summer MSX infections.

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.

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.

RESULTS–1991

Temperature and streamflow/salinity.

The winter of 1991 was the warmest on record and the year as a whole was the second warmest on record. Water temperature from January through July averaged about 2°C above normal (Figure 1), but was almost 3°C above normal during January and February. There were only three weeks during the year when temperature averaged below normal and these occurred during fall.

Stream flow into Chesapeake Bay during 1991 was below the long term average during all months except January and March (Figure 2). Streamflow is inversely correlated with salinity so decreased streamflow results in increased salinity. The months of June, September, October and November were especially dry.

Thus, 1991 was an unusually warm and also a dry year. The distribution and abundance of both MSX and *Perkinsus* appear to be regulated, at least in part, by the combined effects of temperature and salinity. Temperature and salinity above normal result in an increase in abundance of both parasites, while conditions below normal result in a decrease in abundance. Thus, conditions present during 1991 should have been favorable for both parasites.

Native Oyster Samples.

MSX. During 1989 and 1990, this parasite was extremely rare, but during 1991 it demonstrated a fairly typical abundance pattern, although prevalence remained relatively low. In the James River (Table 1) MSX was present at Wreck Shoal during January, February and

March, but was absent during spring. The parasite reappeared in Wreck Shoal samples in July and the prevalence and intensity gradually increased through December, although maximum prevalence only reached 27%. MSX was not found above Wreck Shoal in the James River, but was present during fall in the lower James at Nansemond Ridge, in Mobjack Bay, in the Great Wicomico River and in the lower Rappahannock River (Table 1). Prevalence of MSX was generally low, but heavy infections did occur in most areas suggesting some limited oyster mortality from this parasite.

Perkinsus. This parasite was still present in all oyster growing areas in Virginia during 1991 and prevalence and intensity of infections were high in most areas during fall (Table 1). Both prevalence and intensity continued to increase in the upper James River at Horsehead Rock and at Deep Water Shoal. *Perkinsus* has been steadily increasing in abundance at these two locations since 1988. Maximum prevalence at Deep Water Shoal was 88% in 1991, up from 64% in 1990; most infections were light, but there were heavy infections present from September through December and some mortality probably occurred. The prevalence of *P. marinus* at Horsehead Rock reached 100% for the first time on record in September and remained at that level through December. Most infections were light, but heavy infections were not uncommon during October and November and some mortality undoubtedly occurred during those months.

The prevalence of *P. marinus* always declines during winter and spring (see Table 1, James River stations) and then increases during mid to late summer. Even though winter 1991 was unusually warm, the winter decline in prevalence still occurred. However, the subsequent summer increase occurred almost two months earlier in 1991 than in 1990 and maximum prevalence values were higher.

High prevalence and intensity of *P. marinus* were also observed during fall at most other oyster growing areas (Table 1), including some areas on the Eastern Shore.

Tray Samples.

May (Spring) Imports. Counts of live and dead oysters and prevalence and intensity of MSX and *P. marinus* in the duplicate trays established 1 May 1991 at Gloucester Point are listed in Table 2. Average total mortality for the two trays was 51.9% and all of it can be attributed to *P. marinus* because only one case of MSX was found during the exposure period. The total mortality in the trays during 1991 was much less than during 1990 (76.5%). Because of the increasing prevalence of natural *P. marinus* infections in the upper James River, we used upper Rappahannock River oysters in the monitoring trays during 1990 and their lower prevalence of natural infections resulted in lower mortality.

The monitoring trays are used primarily to document the annual waxing and waning 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, 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 we collect oysters, 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 *Perkinsus* in duplicate trays established 1 May 1991 in Burton's Bay at Wachapreague on the seaside of the Eastern Shore are listed in Table 3. Unfortunately, one of the trays was tipped over in June and the oysters smothered in the mud; data is not shown for that tray. Mortality could not be accurately estimated in the other tray because it was lost during October and many oysters were missing from the tray when it was subsequently found. These problems precluded any meaningful comparisons with other areas or years. No MSX was present in the sample removed from the tray in September, but the prevalence of *Perkinsus* was 100% and mortality had been high during the preceding month.

August (Fall) Imports. Susceptible oysters placed in the York River in August are used to monitor the success of MSX infections acquired during late summer. Counts of live and dead oysters and MSX abundance in these oysters are shown in Table 4. Only two cases of MSX were found in the oysters suggesting that late summer infections did not occur during 1990. This result supports field data that shows a low abundance of MSX during summer of 1991. The high mortality in the tray during late summer of 1991 can be attributed to high levels of *P. marinus*, although prevalence and intensity data for this parasite are not shown in Table 4.

DISCUSSION

The unusually warm and dry year provided conditions favorable for both major oyster parasites during 1991 and both MSX and *P. marinus* increased in abundance from 1990 levels. MSX is known to be controlled primarily by salinity and the low streamflow and resultant increased salinity during 1991 allowed the parasite to gradually increase at Wreck Shoal in the upper James River. Prevalence reached 27% by December, 1991 and, while still low compared to 1988 values of 56% at the same location, it demonstrates that MSX is increasing again after two low abundance years. The general increase in MSX abundance was also reflected in the lower Rappahannock River and in the Great Wicomico River.

The relationship between *Perkinsus* abundance and temperature and salinity is not as well understood as the relationship between MSX and salinity. Both environmental factors appear to be important, but possibly at different seasons. During fall and winter, temperature may be most important. Unusually cold winters appear to speed the typical winter decline and also delay the summer prevalence increase. However, during summer, salinity may be more important, but it may take values below 6ppt to limit oyster mortality. In any case, the combination of a warm winter and low streamflow during 1991 provided optimal conditions for *P. marinus* and record high prevalences and intensities were recorded in oysters at both Deep Water Shoal and Horsehead Rock in the upper James River. The parasite was also abundant, as usual, in oysters at Wreck Shoal and at Point of Shoals and measurable mortality undoubtedly occurred at all four locations based on the percentage of heavy infections.

Even though 1989 and 1990 were relatively wet (though warm) years, the abundance of *P. marinus* and the level of disease-induced oyster mortality in the James River continues to increase. The warm, dry conditions of 1991 have only exacerbated this upward trend. Thus, to protect the remaining oyster stock, it seems imperative to reduce other sources of mortality to the maximum extent possible.

ACKNOWLEDGEMENTS

The oyster disease monitoring program could not be conducted without the help of many VIMS scientists and staff. Nita Walker was responsible for sample processing and diagnoses for both MSX and *Perkinsus*. Judy Meyers and Beth McGovern assisted with sample processing and with cleaning and sampling monitoring trays at Gloucester Point; Mike Castagna and his staff maintained the trays at Wachapreague. Judy Meyers and Kenny Walker collected the monthly James River samples; Dr. Bruce Barber and his field staff assisted with sample collection from other areas. Mike Oesterling of the Marine Advisory Service staff coordinated much of the sample collection from private oyster growers and communicated results of analyses.

Table 1. Prevalence and intensity of MSX and *Perkinsus* in oysters from Virginia harvesting areas in 1991. 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	15 Jan	nd			3/25	12	0-0-3
	19 Feb	nd			1/25	4	0-0-1
	20 Mar	nd			0/24	0	
	17 Apr	nd			0/25	0	
	13 May	nd			1/25	4	0-0-1
	12 Jun	nd			3/25	12	0-0-3
	10 Jul	nd			7/24	29	0-2-5
	14 Aug	nd			3/25	12	0-0-3
	18 Sep	nd			11/25	44	3-1-7
	16 Oct	nd			22/25	88	0-2-20
	13 Nov	nd			19/25	76	1-0-18
	9 Dec	nd			19/25	76	1-2-16
Horsehead Rock	15 Jan	0/25	0		9/25	36	0-1-8
	19 Feb	nd			4/25	16	0-0-4
	20 Mar	0/25	0		0/25	0	
	17 Apr	0/25	0		0/25	0	
	14 May	nd			0/25	0	
	12 Jun	nd			11/25	44	0-0-11
	10 Jul	0/25	0		17/25	68	1-1-15
	14 Aug	nd			15/25	60	0-1-14
	18 Sep	0/25	0		25/25	100	4-2-19
	16 Oct	0/25	0		25/25	100	7-1-17
	13 Nov	0/25	0		25/25	100	5-2-18
	9 Dec	0/25	0		25/25	100	1-1-23
Point of Shoals	14 May	0/25	0		0/25	0	
	24 Jul	nd			20/25	80	2-2-16
	14 Aug	0/25	0		17/25	68	2-2-13
	10 Sep	nd			25/25	100	6-7-12
	18 Sep	0/25	0		24/25	96	2-2-20
	13 Nov	nd			25/25	100	6-2-17
Wreck Shoal	15 Jan	2/25	8	0-0-2	9/25	36	1-1-7
	19 Feb	1/25	4	0-0-1	5/25	20	0-0-5
	20 Mar	4/25	16	0-0-4	4/25	16	0-0-4
	17 Apr	0/25	0		2/25	8	0-0-2
	14 May	0/25	0		1/25	4	0-0-1
	12 Jun	0/25	0		17/25	68	0-2-15
	10 Jul	2/25	8	1-0-1	24/25	96	2-1-21
	14 Aug	2/25	8	0-0-2	25/25	100	2-5-18
	18 Sep	5/25	20	1-1-3	25/25	100	6-3-16
	16 Oct	5/25	20	1-0-4	25/25	100	3-6-16
	13 Nov	5/25	20	2-0-3	25/25	100	4-2-18
	9 Dec	7/25	27	4-0-3	25/25	100	3-5-17

Table 1. (Continued)

Location	Date	MSX Infect./exam.	% Infect.	H-M-L*	*Perkinsus* Infect./exam.	% Infect.	H-M-L*
James River (Cont.)							
Nansemond Ridge	4 Sep	12/25	48	1-4-7	23/25	92	4-4-15
York River							
Aberdeen Rock	23 Sep	nd			9/20	45	1-1-7
Bell Rock	23 Sep	nd			1/25	4	0-0-1
Mobjack Bay							
East River	28 Jun				22/24	92	0-4-18
Tow Stake	24 Sep	3/25	12	0-0-3	25/25	100	1-6-15
Pultz Bar	24 Sep	4/25	16	3-0-1	25/25	100	1-4-20
Piankatank River							
Ginny Point	26 Sep	nd			25/25	100	8-3-14
Burton Point	26 Sep	nd			22/24	92	5-5-12
Palace Bar	26 Sep	nd			25/25	100	3-10-12
Rappahannock R.							
Ross Rock	23 Apr	0/25	0		0/25	0	
	16 May	nd			0/25	0	
	26 Aug	nd			0/50	0	
	16 Sep	nd			0/25	0	
Long Pt-Sharps	16 May	nd			0/25	0	
Smokey Pt.	16 May	nd			9/25	36	0-0-9
	30 Sep	nd			25/25	100	2-4-19
Morattico Bar	16 May	nd			5/24	21	0-0-5
	1 Oct	nd			24/24	100	6-3-15
Bowlers Rock	16 May	nd			2/25	8	0-0-2
	30 Sep	nd			22/25	88	0-3-19
Parrot's Rock	1 Oct	nd			25/25	100	6-3-16
Broad Creek	1 Oct	3/25	12	1-1-1	25/25	100	2-4-19
Hog House Bar	1 Oct	7/25	28	3-0-4	25/25	100	2-7-16
Middle Ground	1 Oct	2/25	8	1-0-1	24/25	96	1-3-20
Drumming Ground	1 Oct	nd			11/25	44	0-0-14
Great Wicomico R							
Fleeton Point	5 Oct	2/25	8	0-0-2	22/25	88	0-4-18
Whaley's Flats	5 Oct	nd			21/25	84	0-3-18
Haynie's Creek	5 Oct	0/25	0		20/25	80	0-0-20
Potomac River							
Rosier Creek, #1	24 Jun	nd			2/25	8	0-0-2
Rosier Creek, #2	24 Jun	nd			1/25	4	0-0-1
Colonial Beach	5 Sep	nd			18/25	72	2-2-14
Church Point	5 Sep	nd			25/25	100	4-7-14
Yeocomico River							
Hampton Hall Br.2	26 Jun	0/25	0		3/25	12	0-0-3
Hampton Hall Br.1	26 Jun	0/25	0		1/25	4	0-0-1

Table 1. (Continued)

Location	Date	MSX Infect./exam.	% Infect.	H-M-L*	*Perkinsus* Infect./exam.	% Infect.	H-M-L*
Yeocomico River							
Barn Point	26 Jun	nd			9/25	36	1-1-7
Eastern Shore							
Hog Is. Bay	04 Jan	0/25	0		nd		
Hump Drain 1	03 Apr	0/25	0		1/25	4	0-0-1
Hump Drain 2	03 Apr	3/25–SSO**	12		9/23	39	0-0-9
	09 Jul	0/25	0		25/25	100	1-3-21
Machipongo R. seed	03 Apr	5/25–SSO**	20		3/25	12	0-0-3
	09 Jul	0/25	0		25/25	100	6-6-13
Rogues Is.	18 Apr	nd			4/25	16	0-0-4
Hog Is. Bay	9 Jul	0/25	0		25/25	100	2-5-18
Tug Haynes	18 Apr	0/25	0		0/25	0	
	10 Jul				1/25	4	0-0-1
Metompkin Bay	03 May	1/25–SSO**	4		0/25	0	
Hog Is. Bay	09 Jul	0/25	0		8/100	32	0-2-6
Nassawaddox Cr.	20 Nov	nd			22/22	100	3-5-14

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

**SSO = seaside organism, *Haplosporidium costale*.

nd = no diagnosis for this parasite in this sample.

Table 2. Mortality and disease prevalence in upper Rappahannock River seed oysters placed in replicate trays at Gloucester Point, VA in May, 1991. PRK = *Perkinsus marinus*, MSX = *H. nelsoni*.

Date–1991	Counts live/dead	Monthly mortality–%†	Infected/examined–%	Intensity H–M–L*
24 April	500/0	0.0%	MSX: 0/25–0%	
			PRK: 0/25–0%	
	500/0	0.0%		
6 June	499/1	0.2%		
	489/11	1.5%		
3 July	495/4	0.9%		
	481/8	1.8%	MSX: 0/25–0%	
			PRK: 3/25–12%	0-0-3
2 August	483/12	2.4%	MSX: 0/25–0%	
			PRK: 12/25–48%	2-1-9
	442/14	3.1%		
6 September	412/46	8.6%	MSX: 1/24–4%	0-0-1
			PRK: 18/24–75%	0-1-17
	408/34	6.6%		
8 October	298/90	21.8%		
	274/134	30.8%	MSX: 0/25–0%	
			PRK: 25/25–100%	8-3-14
6 November	252/46	16.0%	MSX: 0/25–0%	
			PRK: 25/25–100%	6-9-10
	203/46	19.1%		
8 December	214/13	5.4%		
	185/18	8.3%		

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

†Total mortality from 1 May through 8 December for the first tray listed was 46.7%. Total mortality for the second tray during the same period was 57.0%. On the basis of timing of mortality and of disease prevalence and intensity, almost all of the mortality can be attributed to *Perkinsus*.

Table 3. Mortality and disease prevalence in Rappahannock River seed oysters placed in a tray in Burton's Bay near Wachapreague on the Eastern Shore of Virginia in May, 1991. PRK = *Perkinsus marinus*, MSX = *H. nelsoni*.

Date–1991	Counts live/dead	Monthly mortality–%	Infected/examined–%	Intensity H–M–L*
24 April	450/0	0.0%		
5 June	380/69	11.0%		
3 July	342/38	7.1%		
1 August	312/30	9.1%		
3 September	214/98	29.5%	MSX: 0/25–0% PRK: 25/25–100%	1-8-16
6 November	118/23**	—		
4 December	113/5	4.2%		

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

**The tray could not be located in October and many oysters were missing from the tray in November. Therefore mortality estimates between 3 September and 6 November could not be determined and no total mortality could be calculated for this tray.

Table 4. Mortality and MSX prevalence in James River seed oysters placed at Gloucester Point in late August, 1990 to monitor infections of MSX acquired in late summer.

Date	Counts live/dead	Monthly mortality–%**	MSX Infected/examined–%	Intensity H-M-L *
29 Aug 90	500/0	0.0%	0/25–0%	
26 Sep 90	478/22	4.7%		
24 Oct 90	429/49	10.6%	0/25–0%	
06 Dec 90	386/18	3.1%	0/25–0%	
09 Apr 91	347/14	0.9%	1/25–4%	0-0-1
07 May 91	311/11	3.7%	0/25–0%	
06 Jun 91	278/8	2.8%	0/25–0%	
03 Jul 91	196/57	25.0%	1/25–4%	0-0-1
02 Aug 91	98/73	42.6%**	0/25–0%	

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

**Although not shown, oysters in this tray were heavily infected with *Perkinsus marinus*, which was responsible for the observed mortality.

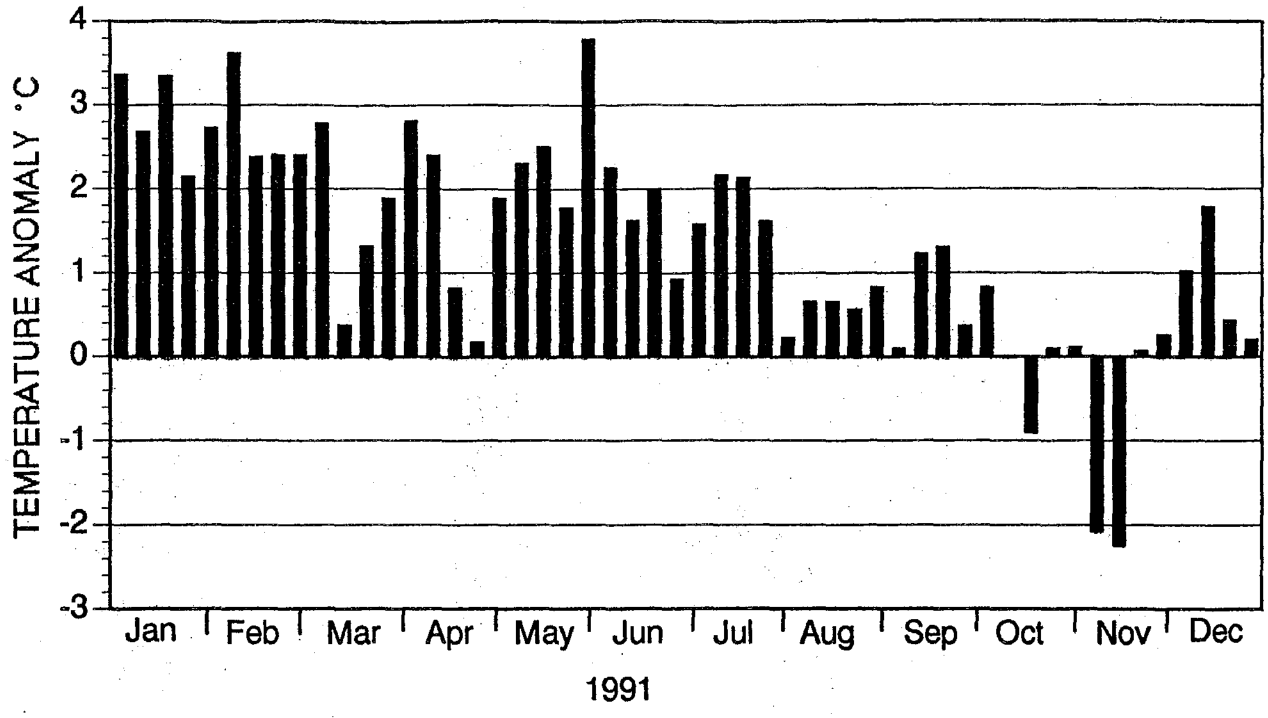


Figure 1. Weekly temperature anomaly at the VIMS pier, Gloucester Point, VA for calendar year 1991 compared with the average weekly temperature from 1947 through 1990.

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 21204, Phone 301–828–1535.

December 31, 1991.

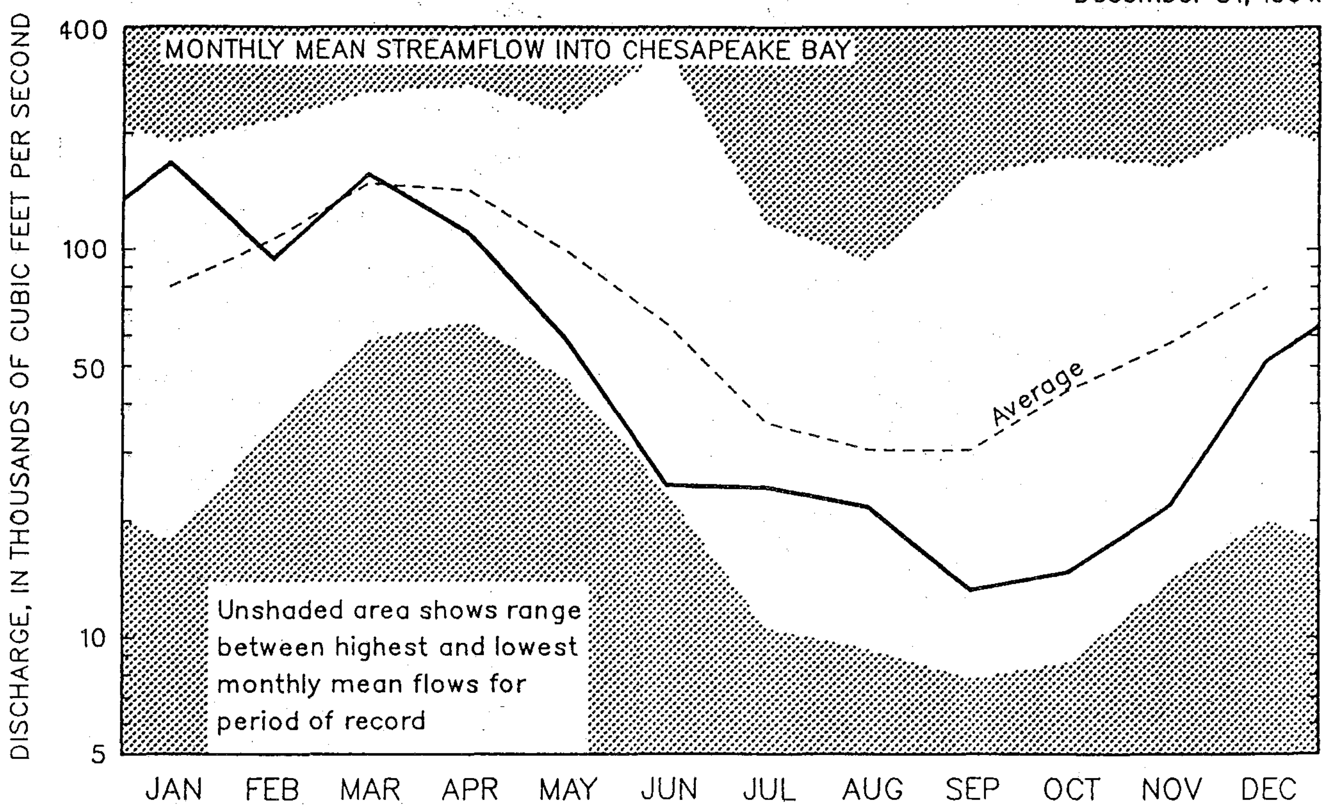
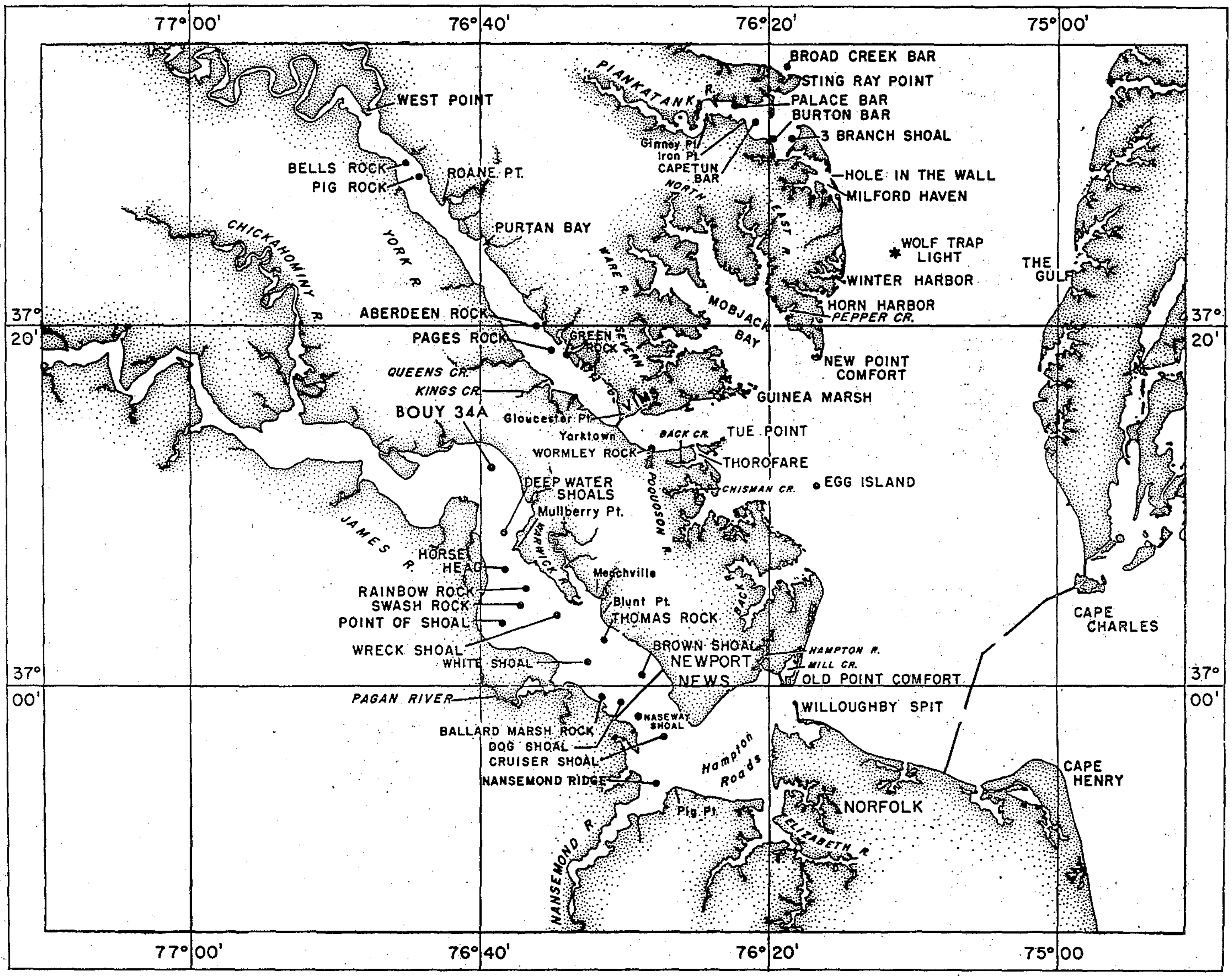
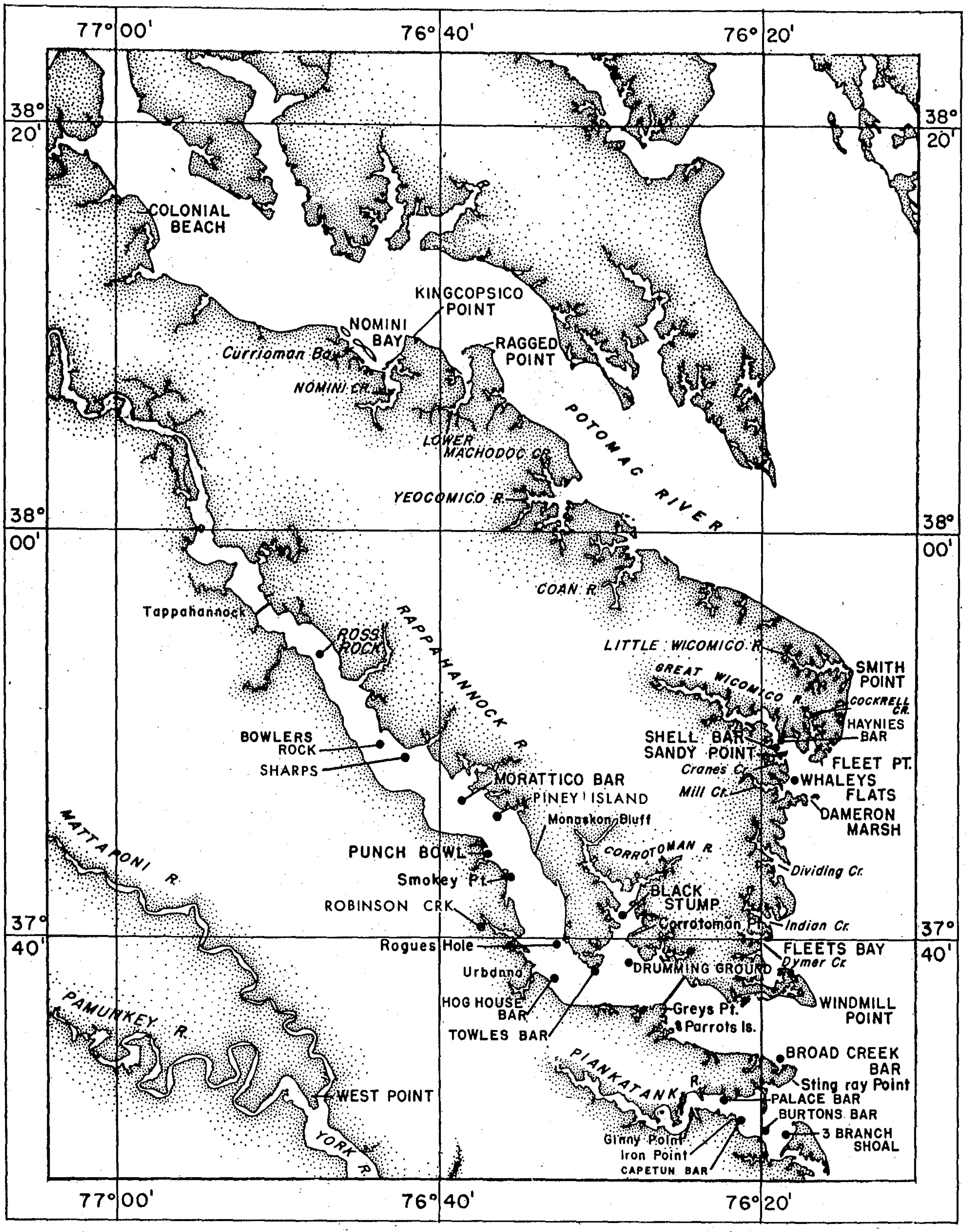


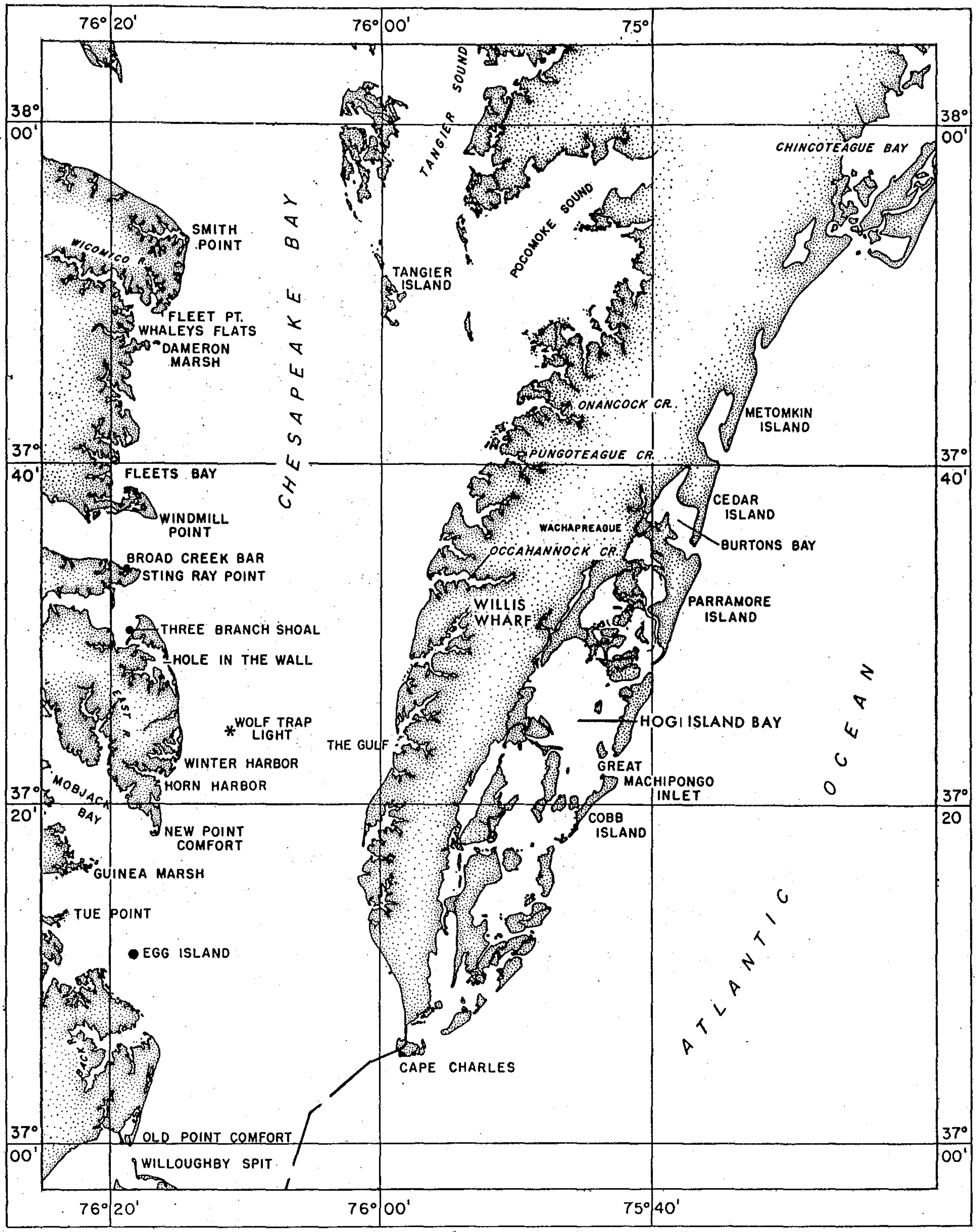
Figure 2. Monthly mean streamflow into Chesapeake Bay during 1991 (solid line) compared with average monthly mean streamflow for the thirty one year period from 1960 through 1990 (dashed line).



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.