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Heavy metals in oysters from Virginia since tropical storm Agnes

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Heavy Metals in Oysters from Virginia Since Tropical Storm Agnes

A Final Report

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By:

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Introduction:

Rainfall from tropical storm Agnes caused the salinity of the major estuaries entering the Chesapeake Bay to be drastically lowered. Bottom sediments normally subjected to 10 to 15 salinities were under fresh water. Heavy metals, pesticides and other pollutants adsorbed to these bottom sediments were undoubtedly mobilized. These once "stored" concentrations were augmented by the massive amounts of erosional products which created a high pollution potential in shellfish in the Chesapeake Bay. For this reason the Virginia Institute of Marine Science asked for and received financial assistance from the Food and Drug Administration to assess the changes in heavy metal concentrations in the eastern oyster, (Crassostrea virginica) as a result of Agnes.

Methods and Procedures:

Previous research (1. and 2.) has shown that a minimum of five organisms, analyzed individually, is necessary for the sample mean to approximate the population mean. Therefore five organisms were collected from each sampling location. Oyster samples have been taken from oyster beds in the James, York, Rappahannock, Corrotoman, Back, Poquoson, and Elizabeth rivers as well as Mobjack Bay (Figures 1,2,3). Sampling locations were chosen to correspond to those of a previous study completed in 1971 (2.). In some cases samples were particularly difficult to obtain due to a high oyster mortality in the upstream stations caused by the fresh water conditions accompanying Agnes. In the Hampton Roads segment of the James River, the samples were unavailable due to unexplained mortalities.

The analytical procedure involves opening the oyster through the hinge without puncturing the animal, draining, nitric acid wet digestion, and analysis on a Varian AA-5 atomic adsorption spectrophotometer by standard procedures.

Results:

The analytical results of samples from the James, York, Rappahannock, Poquoson, Back, Elizabeth and Corrotoman rivers and Mobjack Bay are shown in Table 1, Figures 4,5,6.

The discussions of the results from the individual systems are given below:

James River: Cadmium: The upper river appears to be "cleaner" with respect to cadmium since Agnes (Figs. 4,7). In 1971 the Deep Water Shoals and Burwell Bay areas were greater than 1.6 ppm but now are between 1.1 and 1.5 ppm and the lower part of Burwell Bay is less than 1 ppm. Between Burwell Bay to about five miles below the Warwick River was 1.1 to 1.5 ppm in 1971 but now is 0.6 to 1.0 to the James River Bridge.

The Nansemond River was 1.1 - 1.5 ppm but now is 0.6 - 1.0 ppm, however, the Nansemond Ridge area has increased from 0.6 - 1.0 to 1.1 - 1.5.

The lower portion of the Elizabeth River has decreased greatly i.e., 1.1 - 1.5 ppm to presently 0.6 - 1.0 ppm. The upper portion is unchanged.

The Willoughby Bay region has increased considerably with levels averaging 4.6 ppm now and ~ 2.5 in 1971.

Copper: The upper James River appears to have decreased with respect to copper in oysters since 1971 (Figs. 5,8). Except for a small area in the upper section of Burwell Bay, the levels have dropped from 101 - 150 ppm to 51 - 100 ppm. The area of 151 - 200 ppm found in the middle of Burwell Bay in 1971 is now absent. The concentrations from Burwell Bay to the James River Bridge are unchanged since the 1971 survey.

The Nansemond Ridge oyster beds show that this region has worsened since the previous survey with concentrations increasing from 26 - 50 ppm to 101 - 150 ppm.

The Nansemond River shows a slight increase in one section of the stream with levels now between 51 - 100 ppm as compared to 26 - 50 ppm in 1971.

The Elizabeth River samples indicate an increase of copper. In 1971 the levels were 26 - 50 ppm throughout most of the river but now the concentrations are all greater than 50 ppm.

Zinc: The upper James River has decreased with respect to its oyster-zinc levels since the previous sampling in 1971 (Figs. 6,9). The upstream part of Burwell Bay and Deep Water Shoals has dropped from 1201 - 1600 ppm to 801 - 1200 ppm.

The remainder of the river appears unchanged with the exception of Nansemond Ridge and Willoughby Bay. The samples from Nansemond Ridge showed an increase in zinc since Agnes with present levels 1201 - 1600 ppm. The Willoughby Bay samples indicate a decrease since Agnes of from 801 - 1200 ppm to 401 - 800 ppm.

The Elizabeth River remained the most contaminated area sampled. Although not obvious from the figures, one station yielded an animal with 19,936 ppm zinc. This is the highest level ever recorded by this laboratory and as far as we can ascertain, the highest ever recorded anywhere.

York River: Cadmium: The cadmium levels in oysters from the York River show no apparent change from the 1971 study (Figs. 4,7). The concentration range and distributions are approximately the same.

Copper: The copper levels in oysters from this river are higher in the middle and lower segments of the stream relative to the 1971 samples (Figs. 5,8). These levels have increased from 26 - 50 ppm in 1971 to the present range of 51 - 100 ppm.

Zinc: As was the case with copper, the zinc concentrations have increased from 401 - 800 ppm in 1971 to 801 - 1200 ppm in 1973 (Figs. 6,9). These increases are due either to natural variation or tropical storm Agnes.

Rappahannock River: Cadmium: The cadmium distribution appears to have changed since the 1971 study (Figs. 4,7). The concentration range is less for the post-Agnes samples and an apparent anomaly exists at the mouth of the estuary. This "high" cadmium level may be due to the influence of the storm waters that came down the Bay from the Potomac and Susquehanna rivers.

Copper: The copper data indicate that the concentration range is not different than that found in 1971 (Figs. 5,8), however, the distribution has changed in the upper estuary. From previous work, we expected the highest concentrations to appear in the low salinity waters. These data show that this is not the case since Agnes.

Zinc: The zinc distribution is very similar to that of copper. The concentration range has not changed since 1971, but the distribution has (Figs. 6,9).

Mobjack Bay, Poquoson River, Back River: Samples from these areas do not indicate any significant changes in either concentration ranges or distributions since the 1971 study. This is likely due to the immediate proximity of these areas to the Chesapeake Bay proper and therefore the lesser effects of the storm waters from Agnes.

Conclusions:

These data indicate that the levels of cadmium, copper and zinc in oysters from the James and Rappahannock rivers have decreased in the upper segments of these estuaries since tropical storm Agnes. The middle segments of the streams have remained nearly unchanged since the previous sampling and analysis in 1971.

The Rappahannock River oysters, which were subjected to fresh water not only from the Rappahannock drainage basin but also from the Potomac and Susquehanna drainages, shows higher than expected levels of cadmium and zinc at the mouth of the estuary. This may be due to metals either being transported to the system with the fresh waters from up-Bay or the mobilization of sediment-stored metals by the low salinities and accompanying low pH's.

The Elizabeth River oysters show a marked increase in zinc concentrations and the Willoughby Bay samples were higher in cadmium since 1971. These changes are apparently due to man-made sources rather than tropical storm Agnes since sediment analyses show these areas to be contaminated.

The various State agencies have been notified of these changes in hope of eliminating the indicated pollution sources.

The data from the York River is not nearly as extensive as the remaining systems studied. This is because this estuary was less affected by rains of Agnes and therefore fewer samples were taken. Some areas were sampled to compare with the 1971 study. The data indicate an increase in the copper and zinc concentrations while those of cadmium remained constant.

From this study it is suggested that with the exception of zinc in the Elizabeth River and cadmium in the Willoughby Bay area, no health hazards exist for the metals cadmium, copper and zinc in oysters from the areas sampled in this study.

Table 1

Heavy Metals in Oysters from the James and Elizabeth Rivers

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
1	7.42	90.1	1.38	1040
	4.60	92.3	1.47	986
	10.50	69.1	1.23	1010
	4.52	105.	1.80	1000
	7.88	133.	1.34	1450
Mean		97.9	1.44	1100
2	6.70	122.	0.94	716
	6.38	26.4	0.79	186
	2.55	146.	1.25	1530
	2.63	159.	1.33	1660
	3.92	167.	1.13	1360
Mean		124.	1.09	1090
3	17.70	64.6	0.68	770
	15.80	56.4	0.77	602
	10.78	72.4	1.18	998
	8.47	86.7	1.02	1020
	7.58	116.	1.51	1120
Mean		79.3	1.01	902
4	10.53	92.8	0.43	758
	6.60	143.	1.24	1670
	9.92	42.3	0.49	570
	7.82	131.	1.04	1220
	10.40	46.5	0.58	720
Mean		91.0	0.76	990
5	10.00	70.3	0.70	764
	12.92	104.	1.07	874
	12.75	73.6	0.55	590
	14.32	94.1	1.03	956
	20.90	69.3	0.80	1010
Mean		82.2	0.83	840
6	15.95	89.8	0.95	1370
	12.50	75.6	1.23	1130
	19.30	117.	1.12	1380
	12.10	104.	1.12	1070
	7.92	121.	1.44	1080
Mean		101.	1.17	1210

Table 1 (continued)

Heavy Metals in Oysters from the James and Elizabeth Rivers

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
7	7.33	15.1	0.56	213
	8.42	82.5	1.00	876
	2.65	126.	1.53	1310
	10.02	66.2	1.01	837
	5.32	124.	0.60	1280
Mean		82.8	0.94	903
8	9.21	90.3	0.86	1290
	7.75	50.4	0.80	872
	10.14	89.2	0.88	1150
	7.08	131.	0.95	1640
	3.71	103.	1.12	970
Mean		92.7	0.92	1180
9	8.79	78.1	0.55	970
	4.62	88.4	0.77	760
	14.73	87.5	0.44	1790
	12.09	64.3	0.96	1150
	9.79	105.	0.81	1240
Mean		84.7	0.71	1180
10	29.50	50.3	0.47	970
	14.50	116.	0.79	2320
	17.58	39.1	0.58	500
	9.70	51.1	0.64	945
	1.50	100.	0.80	1060
Mean		71.2	0.66	1160
11	7.25	124.	1.21	1450
	6.03	112.	1.53	1720
	4.98	80.1	1.05	970
	7.98	93.4	1.19	1160
	4.63	151.	1.76	1510
Mean		112.	1.35	1360
12	24.00	52.0	0.93	880
	16.20	53.3	0.81	1270
	46.52	18.8	0.55	250
	20.80	39.7	0.90	920
	18.40	26.9	0.37	360
Mean		38.2	0.71	730

Table 1 (continued)

Heavy Metals in Oysters from the James and Elizabeth Rivers

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
13	5.94	47.9	0.92	625
	21.22	61.2	0.50	870
	24.80	50.6	0.67	880
	8.19	64.5	0.99	1050
	6.38	39.5	0.83	640
Mean		52.7	0.78	810
14	19.21	17.3	1.12	370
	15.43	28.6	0.76	310
	26.38	53.5	0.79	1070
	18.38	65.6	1.07	960
	11.39	42.9	0.62	620
Mean		41.6	0.87	670
15	9.28	20.7	4.01	510
	9.55	23.4	4.99	520
	12.02	20.9	3.93	570
	6.25	20.5	6.06	640
	14.00	23.3	4.36	610
Mean		21.8	4.67	570
16	1.70	44.6	0.29	2150
	1.30	86.2	0.77	3520
	2.18	45.5	0.61	19900
	1.68	90.8	1.06	3050
	2.18	66.9	0.49	13000
Mean		67.0	0.64	8330
17	7.85	99.8	2.11	2650
	9.72	206.	1.59	6530
	3.38	243.	1.73	4880
	10.32	175.	1.55	4550
	13.10	114.	1.82	2990
Mean		168.	1.77	4240

Table 1 (continued)

Heavy Metals in Oysters from the York, Poquoson, and Back Rivers and Mobjack Bay

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
1	14.90	55.9	0.97	676
	14.80	105.	1.44	1310
	13.10	83.3	1.02	11.40
	17.10	15.1	0.89	157
	13.20	59.2	0.71	788
Mean		63.7	1.01	815
2	21.40	67.4	1.02	676
	20.60	34.0	0.79	517
	14.00	67.5	1.10	693
	30.70	48.2	1.06	489
	18.23	71.7	1.50	1060
Mean		58.0	1.09	687
3	25.95	47.9	1.16	925
	25.75	87.4	0.99	944
	18.62	86.0	1.45	1400
	16.90	78.4	1.31	990
	23.35	72.8	0.97	1060
Mean		75.0	1.18	1060
4	17.08	47.4	0.54	741
	11.50	55.0	0.70	1050
	11.35	65.0	0.51	839
	8.12	67.2	0.94	1160
Mean		58.7	0.67	948
5	18.50	47.9	0.78	813
	27.00	34.6	0.32	557
	17.60	60.1	0.75	875
	11.70	93.8	0.89	1400
	16.80	48.4	0.75	980
Mean		57.0	0.70	926
6	18.32	39.3	0.50	570
	10.18	36.5	0.45	638
	5.80	63.5	0.67	1330
	13.72	42.5	0.60	766
	19.90	48.4	0.82	776
Mean		46.0	0.61	815

Table 1 (continued)

Heavy Metals in Oysters from the York, Poquoson, and Back Rivers and Mobjack Bay

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
7	10.40	11.2	0.36	435
	5.58	9.5	0.35	285
	6.50	8.7	0.39	300
	8.57	10.2	0.31	337
	7.12	8.1	0.25	321
Mean		9.5	0.33	336
8	5.50	6.7	0.40	270
	5.85	7.9	0.48	369
	7.90	12.1	0.23	351
	6.12	8.8	0.32	324
	4.65	10.4	0.58	336
Mean		9.2	0.40	330
9	5.60	8.1	0.25	293
	8.00	6.5	0.15	232
	7.00	5.1	0.29	232
	7.65	7.6	0.19	267
	4.70	7.4	0.23	293
Mean		6.9	0.22	263
10	1.95	11.1	0.39	384
	1.75	8.9	0.58	335
	3.28	8.0	0.16	185
	2.28	9.6	0.68	344
	1.80	8.4	0.14	289
Mean		9.2	0.39	307
11	6.95	8.7	0.29	371
	8.30	7.4	0.21	313
	5.55	8.6	0.55	642
	5.00	6.7	0.16	187
	4.20	7.3	0.32	276
Mean		7.7	0.31	358
12	4.25	5.7	0.26	275
	7.10	6.1	0.33	244
	9.10	6.4	0.30	297
	2.90	7.5	0.36	219
	8.88	6.6	0.37	287
Mean		6.5	0.32	265

Table 1 (continued)

Heavy Metals in Oysters from the York, Poquoson, and Back Rivers and Mobjack Bay

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
13	5.40	8.7	0.41	368
	10.80	6.4	0.20	256
	5.00	6.8	0.33	271
	6.85	8.0	0.42	456
	5.18	7.9	0.27	297
Mean		7.6	0.33	330
14	15.00	10.3	0.15	329
	13.00	12.0	0.15	341
	11.85	9.2	0.18	326
	8.20	14.5	0.87	777
Mean		11.5	0.34	443
15	30.23	8.0	0.19	189
	13.40	17.6	0.74	352
	11.50	6.6	0.11	195
	9.15	22.4	1.75	489
Mean		13.6	0.56	306
16	12.00	10.9	0.31	440
	8.80	10.1	0.12	386
	11.42	8.4	0.32	314
	7.90	8.9	0.35	332
	5.95	10.4	0.21	319
Mean		9.8	0.26	358
17	50.01	10.5	0.33	332
	2.90	15.1	1.46	512
	1.92	17.3	1.48	368
	1.13	11.5	1.13	356
Mean		13.6	1.10	392
18	5.22	6.5	0.38	241
	3.35	14.2	0.48	385
	7.43	7.9	0.33	274
	5.70	11.1	0.24	257
Mean		9.9	0.36	289

Table 1 (continued)

Heavy Metals in Oysters from the York, Poquoson, and Back Rivers and Mobjack Bay

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
19	9.85	14.4	0.18	195
	5.10	5.6	0.05	264
	5.50	6.2	0.10	233
	12.68	5.0	0.10	258
	5.45	5.1	<0.01	277
Mean		7.1	0.09	245
20	6.40	3.9	0.08	193
	5.12	9.7	0.30	345
	7.33	5.4	0.15	233
	3.38	4.8	<0.01	176
	3.88	7.2	0.13	276
Mean		6.2	0.13	245
21	11.32	6.5	0.16	322
	13.45	5.6	0.03	218
	6.40	11.0	0.12	254
	6.75	6.8	0.08	270
	11.90	3.5	0.16	195
Mean		6.6	0.11	252
22	12.12	5.6	0.13	220
	16.70	7.8	0.20	260
	2.42	5.6	0.82	204
	6.80	11.9	0.28	375
	3.90	12.5	0.21	270
Mean		8.7	0.33	265
23	14.60	20.0	0.40	559
	12.34	9.1	0.13	314
	23.40	1.2	0.18	52
	28.01	15.3	0.43	585
	27.63	4.0	0.47	164
Mean		9.9	0.32	335
24	26.81	7.7	0.22	278
	18.12	8.2	0.22	299
	17.38	6.0	0.23	195
	20.32	12.6	0.19	398
	12.20	5.9	0.20	170
Mean		8.1	0.21	268

Table 1 (continued)

Heavy Metals in Oysters from the York, Poquoson, and Back Rivers and Mobjack Bay

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
25	9.25	10.7	0.28	288
	26.42	10.2	0.18	246
	14.55	7.1	0.15	192
	5.25	17.8	0.37	450
Mean		11.5	0.25	294
26	15.22	7.5	0.11	395
	6.38	4.5	0.25	162
	8.50	12.7	0.19	406
	4.85	5.0	<0.01	199
	3.67	18.6	0.14	397
Mean		9.7	0.14	312

Table 1 (continued)

Heavy Metals in Oysters from the Rappahannock River

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
1	15.08	5.5	0.43	294
	12.78	11.7	0.48	455
	14.60	11.1	0.48	335
	23.72	12.8	0.34	476
	10.18	18.7	0.52	483
Mean		11.9	0.45	408
2	10.03	12.3	0.51	274
	11.02	20.1	0.43	546
	12.15	16.3	0.56	479
	10.77	16.4	0.54	502
	12.12	16.0	0.66	485
Mean		16.2	0.54	457
3	16.44	16.0	0.51	402
	13.40	13.0	0.36	348
	9.92	6.7	0.54	283
	6.08	12.7	0.59	410
	11.15	14.7	0.30	354
Mean		12.6	0.46	359
4	27.38	4.3	0.29	175
	5.58	19.3	0.83	400
	34.72	10.6	0.31	414
	17.08	10.1	0.36	309
	21.85	15.0	0.42	531
Mean		11.8	0.44	366
5	15.72	13.9	0.73	353
	24.98	12.6	0.36	381
	24.42	14.2	0.36	391
	23.12	11.4	0.47	441
	16.80	10.6	0.45	317
Mean		12.3	0.47	377
6	12.08	17.1	0.45	394
	7.68	5.9	0.44	157
	8.12	10.3	0.56	268
	11.30	10.1	0.42	301
	9.88	17.4	0.60	439
Mean		12.2	0.49	312

Table 1 (continued)

Heavy Metals in Oysters from the Rappahannock River

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
7	4.28	13.9	0.52	255
	5.25	12.1	0.29	326
	6.05	12.6	0.48	235
	13.60	12.4	0.64	355
	10.10	13.4	0.32	288
Mean		12.9	0.45	292
8	21.3	30.8	0.46	549
	24.0	12.4	0.56	254
	20.8	30.5	0.53	593
	19.2	25.4	0.53	491
	21.1	27.7	0.46	490
	23.6	32.6	0.50	545
Mean		26.6	0.51	487
9	26.8	24.6	1.11	367
	23.9	28.5	1.04	418
	28.8	42.0	0.78	494
	25.0	35.6	0.82	467
	22.25	25.9	0.88	308
Mean		31.3	0.93	411
10	14.2	19.9	0.84	194
	12.6	24.8	0.35	275
	7.35	30.6	1.14	322
	12.6	11.1	0.36	136
	14.1	22.3	0.94	236
Mean		21.8	0.73	232
11	15.3	27.0	0.90	626
	24.3	16.0	0.57	326
	24.6	19.1	0.80	461
	25.8	17.3	0.94	537
	30.9	15.7	0.58	434
Mean		19.0	.76	477
12	10.3	14.2	0.74	280
	12.1	48.5	1.50	1270
	12.8	16.4	0.66	282
	22.3	9.7	0.38	232
	25.9	15.7	0.78	400
Mean		20.9	.81	493

Table 1 (continued)

Heavy Metals in Oysters from the Rappahannock River

Sample No.	Animal Wet Weight	ppm Cu	ppm Cd	ppm Zn
13	7.6	14.7	0.64	290
	18.0	23.2	0.80	573
	22.9	13.2	0.54	311
	24.4	15.9	0.52	419
	31.0	9.9	0.46	372
Mean		15.4	.59	393
14	6.6	22.9	0.75	484
	10.2	20.8	0.65	479
	15.5	22.9	0.72	625
	21.5	17.8	0.69	540
	21.7	17.0	0.63	384
Mean		20.3	.69	502

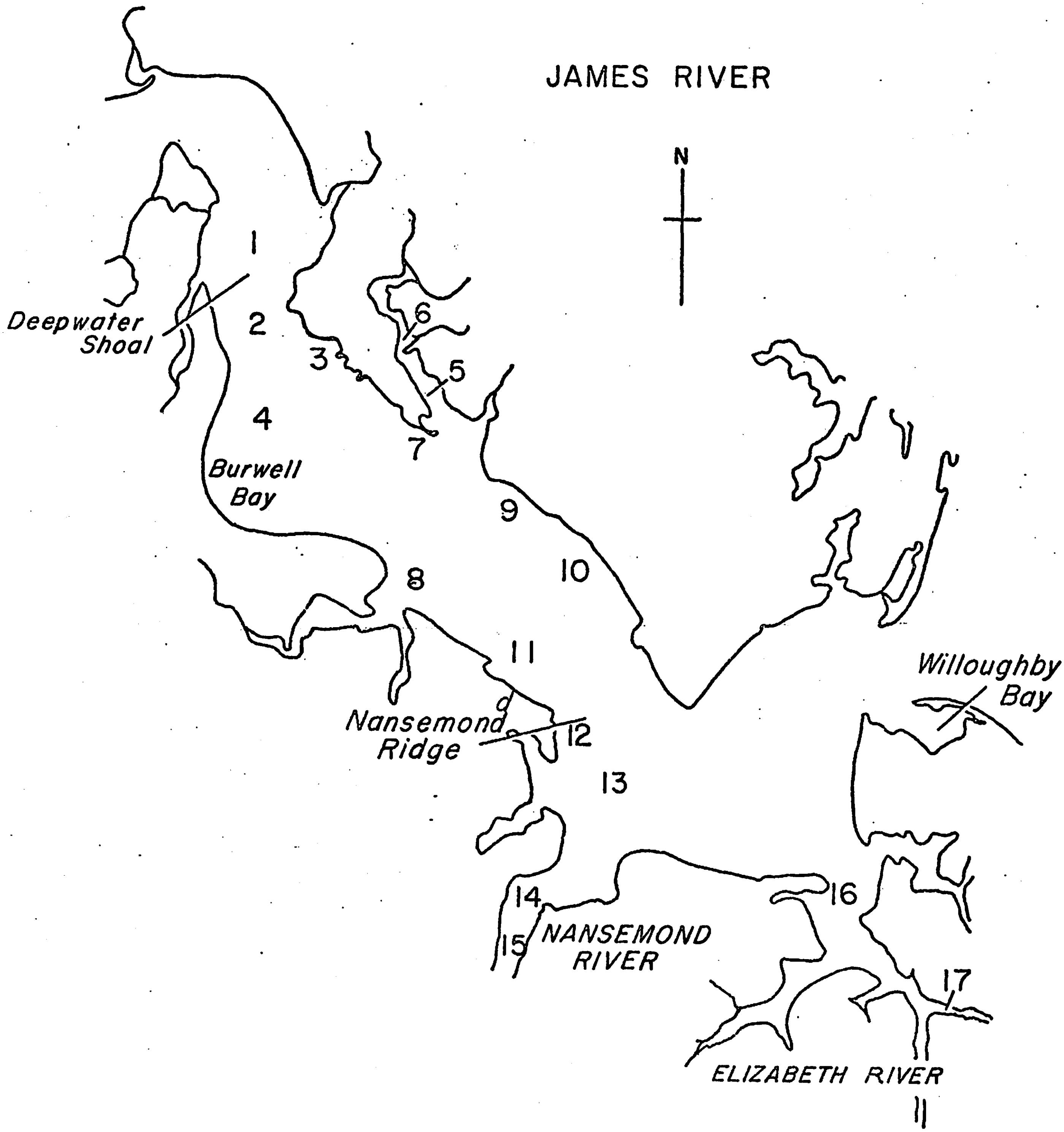

Figure 1

Sampling locations in the James, Elizabeth and Nansemond rivers.

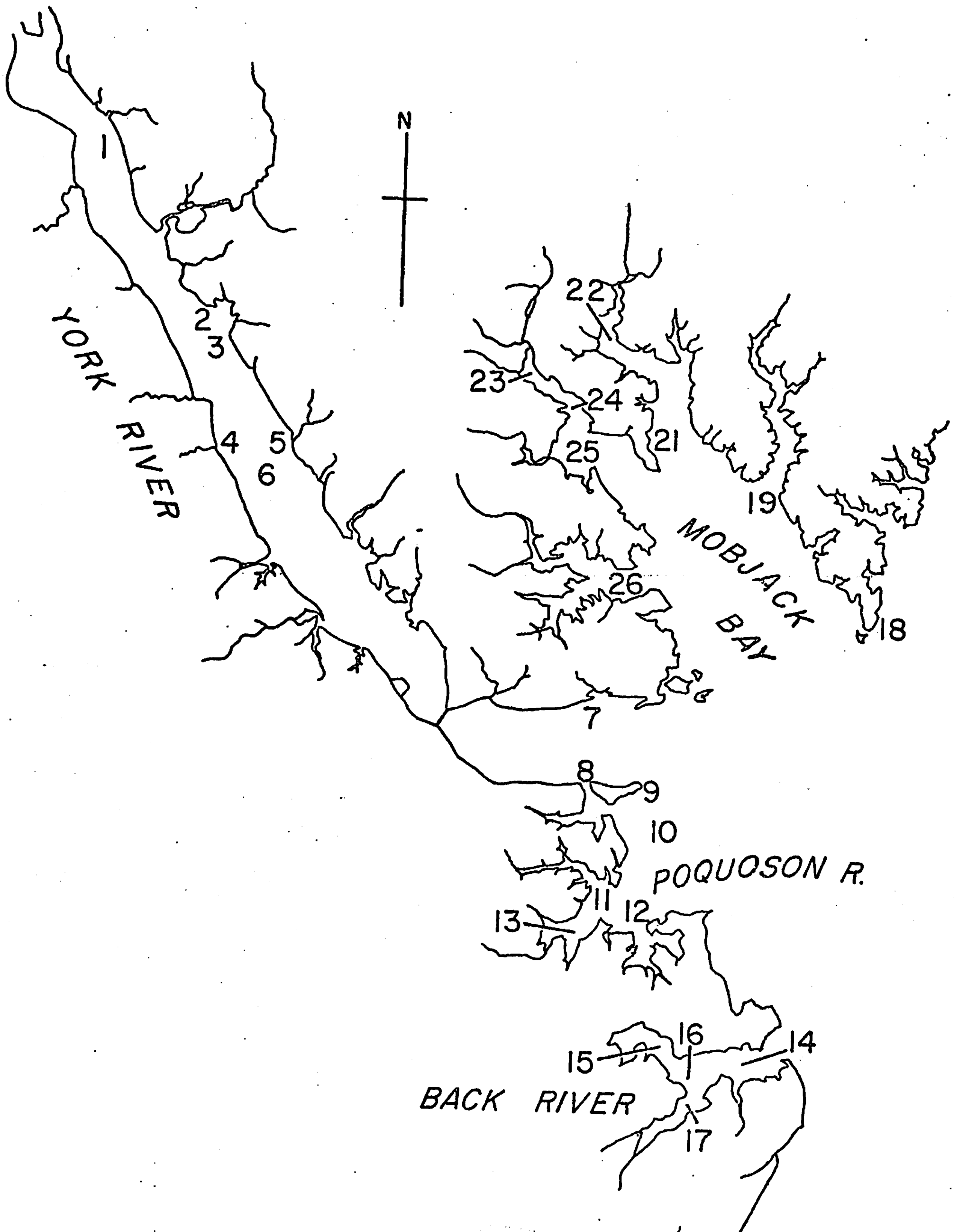

Figure 2

Sampling locations in the York, Back and Poquoson rivers and Mobjack Bay.

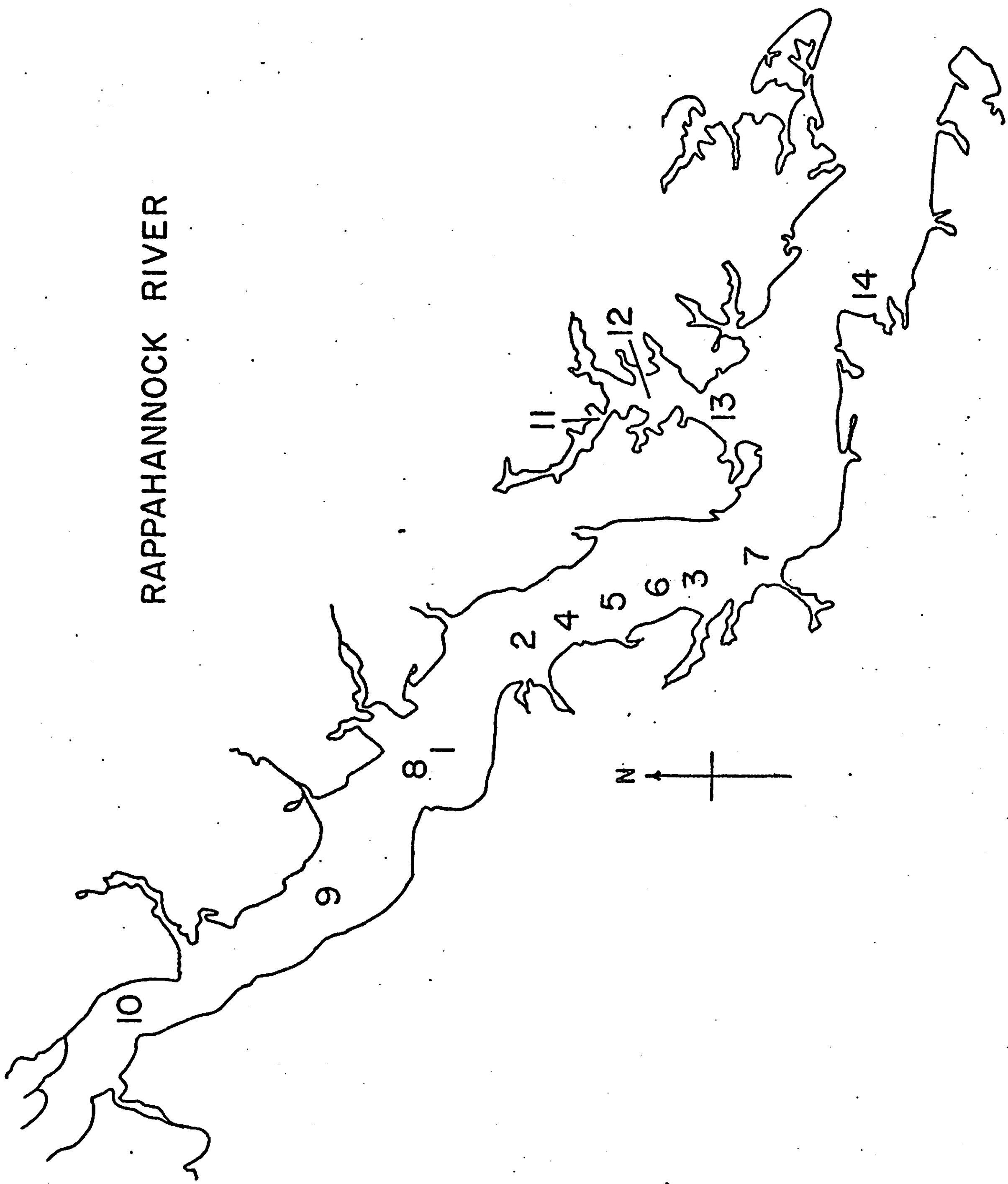

Figure 3

Sampling locations in the Rappahannock and Corrotoman rivers.

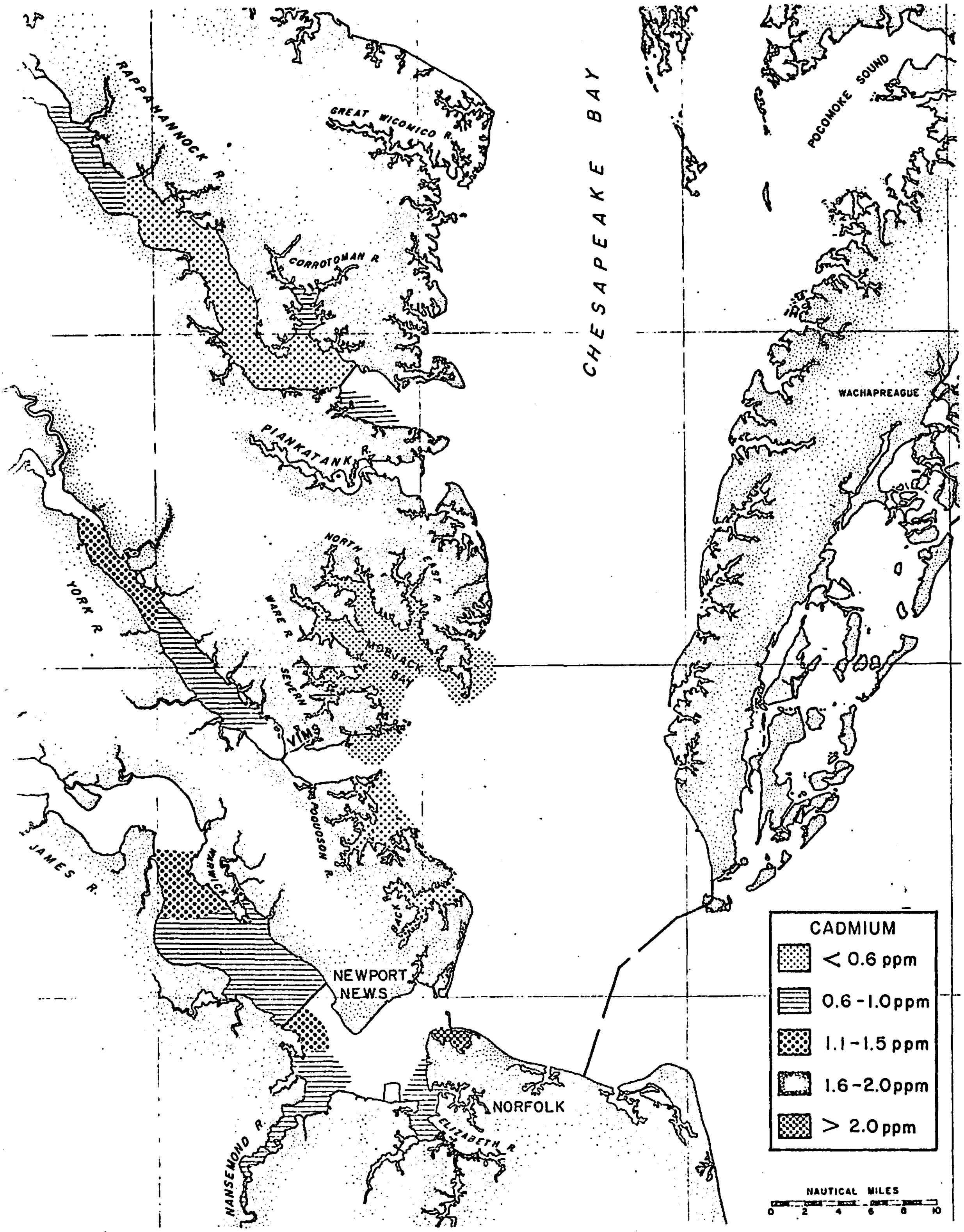

Figure 4

Distribution of cadmium in oysters sampled in January, 1973.

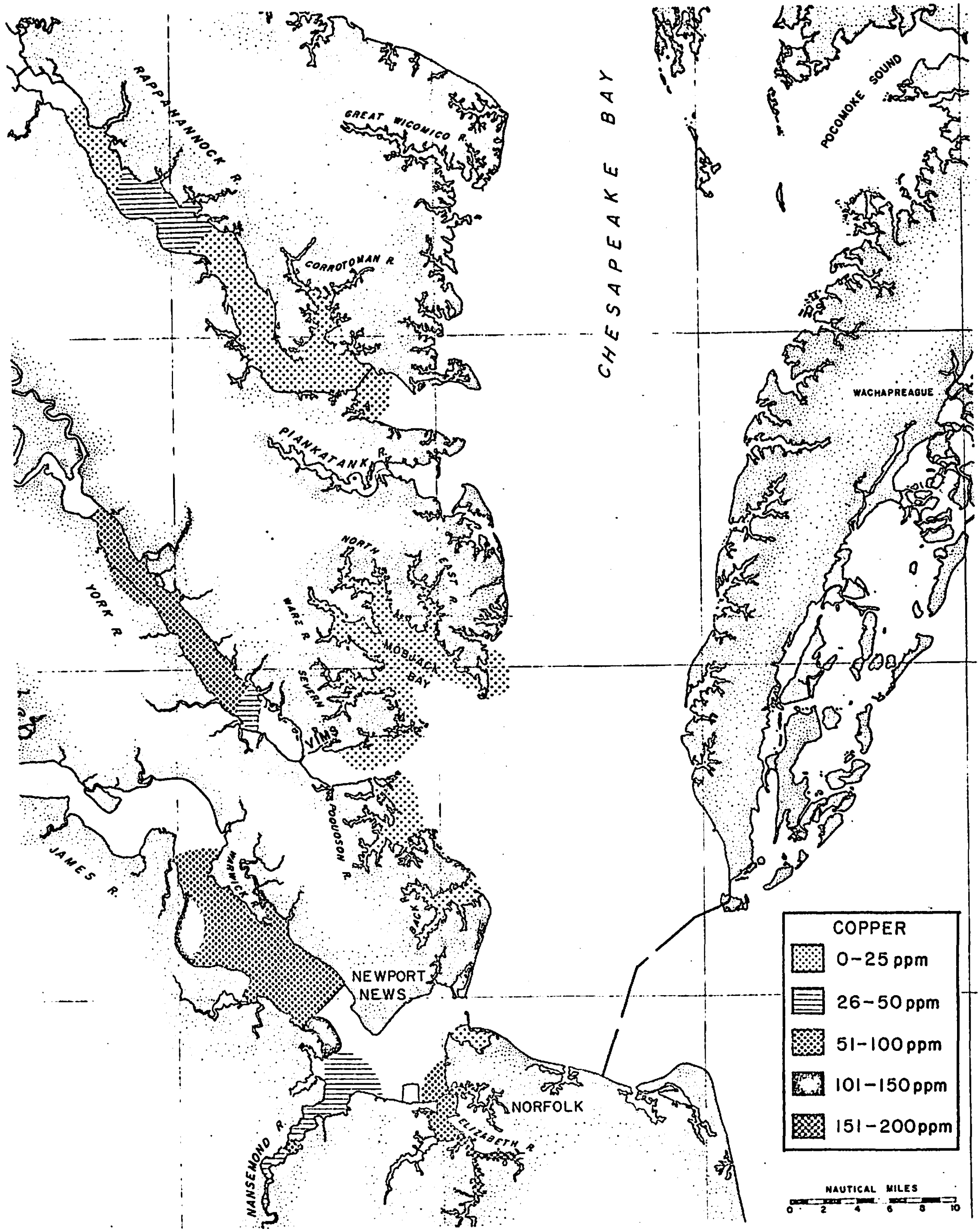

Figure 5

Distribution of copper in oysters sampled in January, 1973.

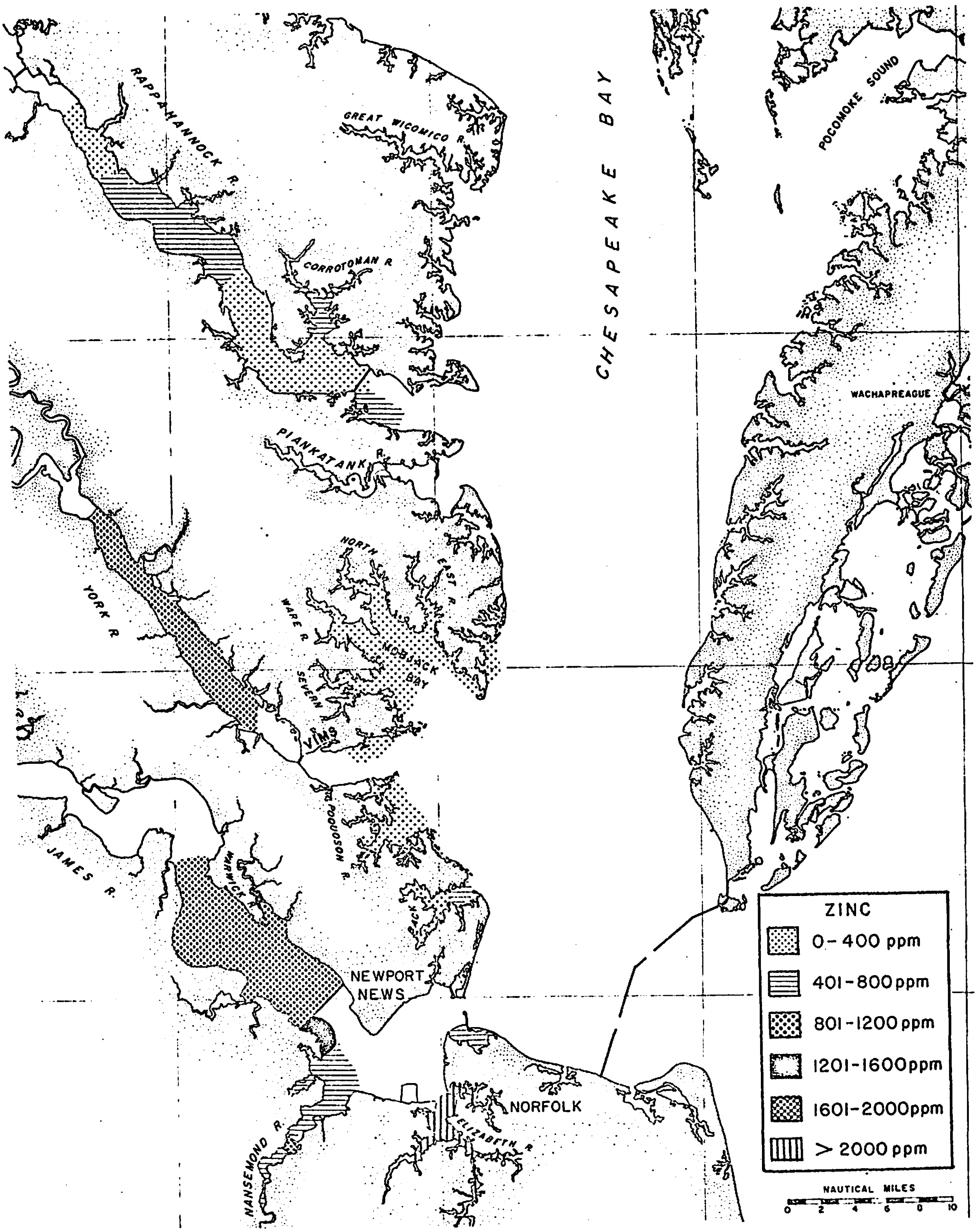

Figure 6

Distribution of zinc in oysters sampled in January, 1973.

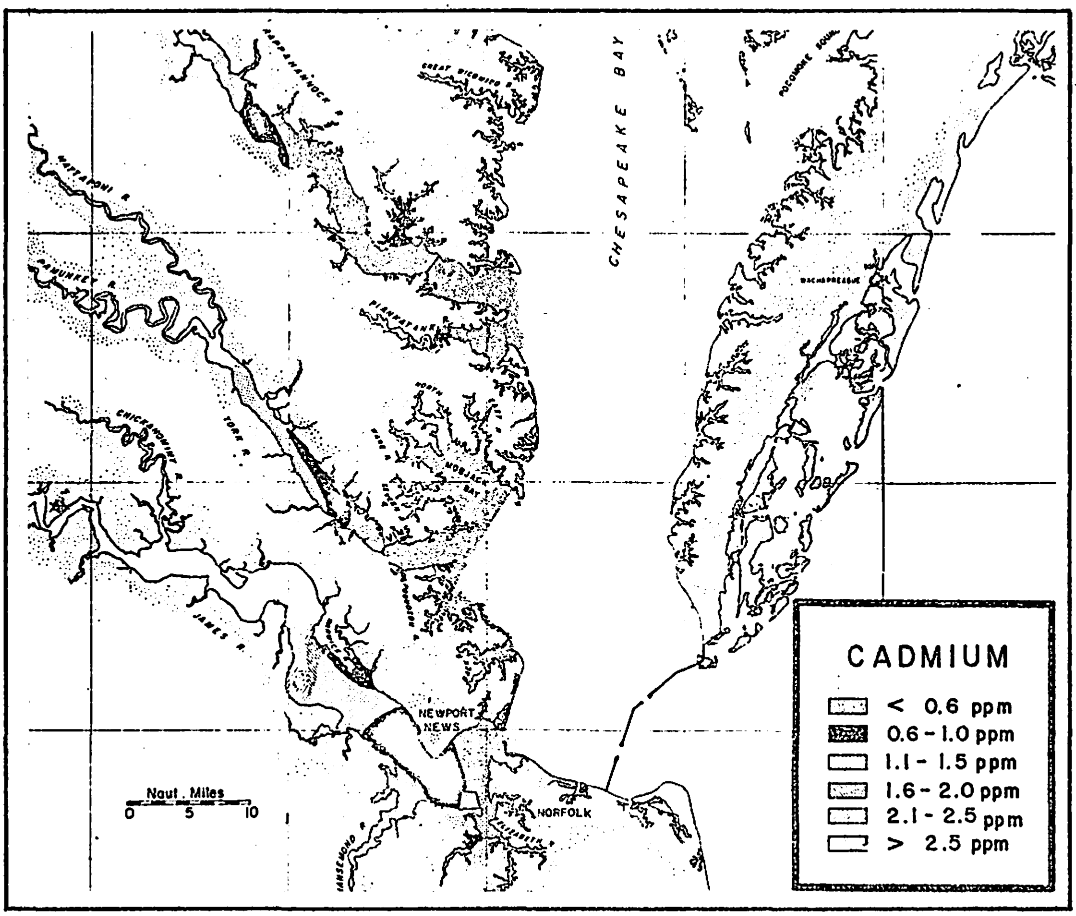

Figure 7

Distribution of cadmium in oysters sampled in January and February, 1971.

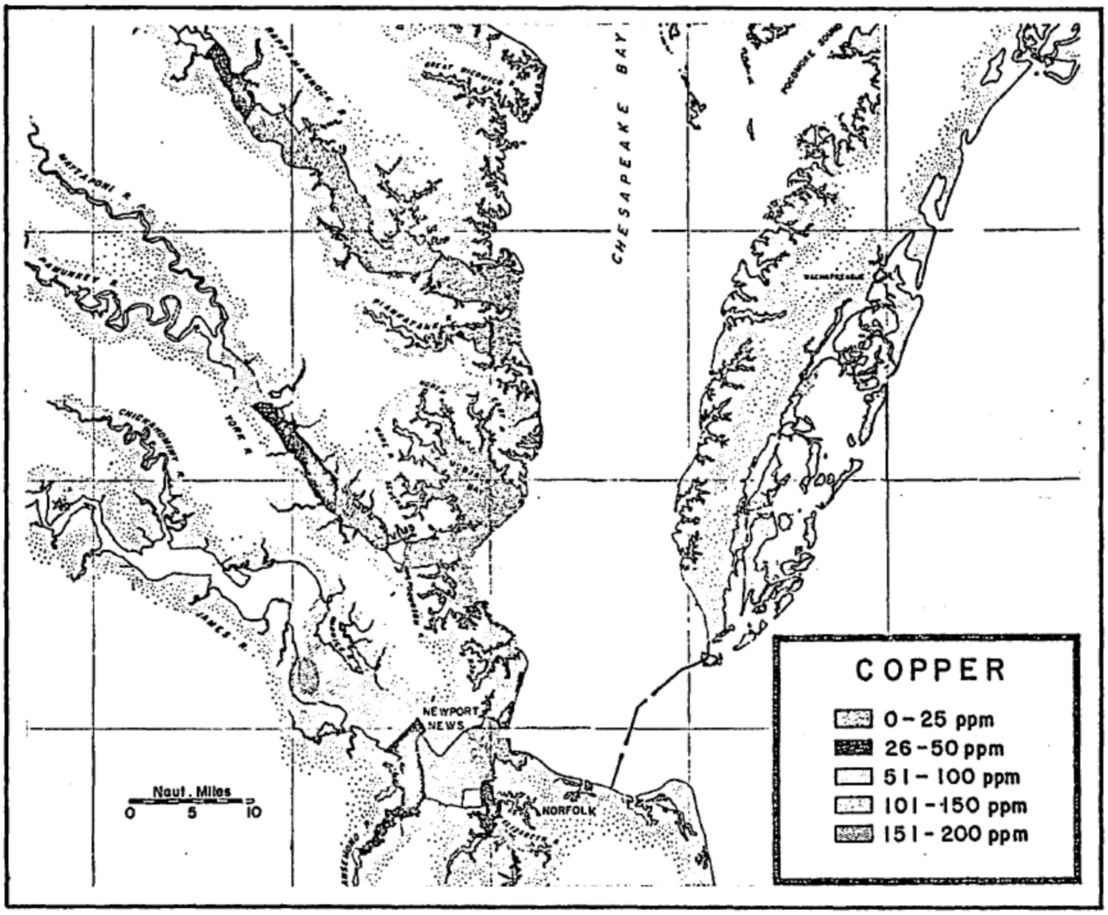

Figure 8

Distribution of copper in oysters sampled in January and February, 1971.

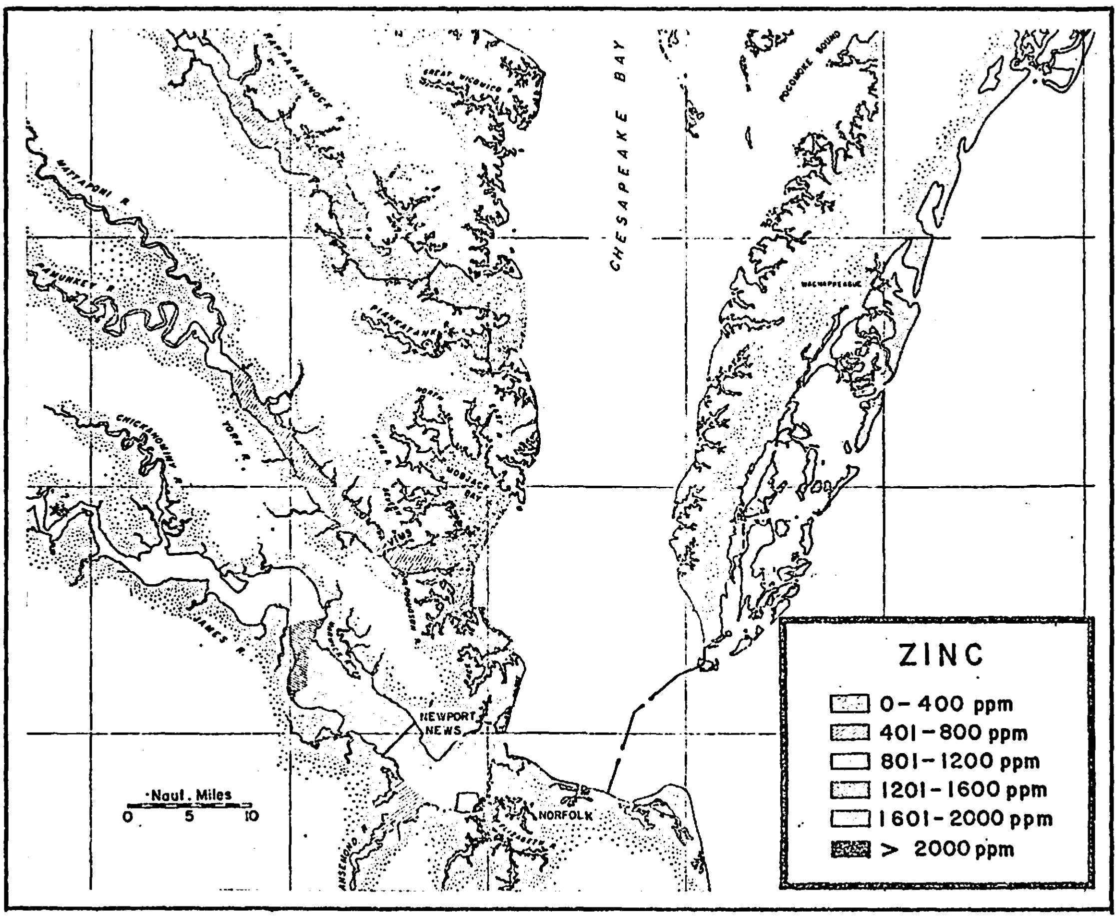

Figure 9

Distribution of zinc in oysters sampled in January and February, 1971.

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2. Huggett, R. J., M. E. Bender and H. D. Slone. 1971. Utilizing metal concentration relationships in the eastern oyster (Crassostrea virginica) to detect heavy metal pollution. Presented to: The 7th National Shellfish Sanitation Workshop, Oct. 21, 1971, Washington, D. C.