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The environment and biological community of the lower York River, Virginia : a literature review

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Contents

Section		Page
I	Physical and Chemical Parameters by R. A. Jordan	1
II	Phytoplankton and Primary Productivity by R. A. Jordan	51
III	Zooplankton and Meroplankton by R. A. Jordan	90
IV	Benthos and Shellfish by M. E. Bender	101
V	Finfish by Douglas Markle	161
VI	Appendices	231

Section I

Physical and Chemical Parameters

by R. A. Jordan

Temperature

Water temperatures in the lower York River have been recorded more or less continuously since May 1952 at a station located at the end of the VIMS tide gauge pier. From May 1952 to the summer of 1971 the instrument employed was a Foxboro temperature recorder, the sensor of which was located at a water depth of approximately five feet (McHugh, 1959). In 1971 an Interocean recording salinity and temperature unit was installed to replace the Foxboro unit (John Boon, personal communication).

Because of corrosion problems the Foxboro unit was out of operation for several months during 1952 and 1953. Consequently the temperature readings for the first year of its use have been omitted from the present analysis. Also, since the month was the time unit of interest for this analysis, data from individual months for which readings for seven or more days are missing from the record have been omitted, to avoid biasing the means and frequency distributions obtained. The analysis includes, therefore, all usable data accumulated from July 1, 1953 through June 30, 1971, a period of eighteen years.

The Foxboro unit recorded temperature continuously on circular charts. From these charts a maximum and a minimum temperature for each day of record have been tabulated, and these tables are maintained in the files of the Department of Physical Oceanography at VIMS. Since for the present analysis it was desirable to use one observation per day, the two tabulated values for each day were averaged, yielding a table of daily "mean temperatures." These were then used to derive the monthly means and frequency distributions that appear in Tables 1 and 2. Although averaging the daily maximum and daily minimum temperatures did not yield the true daily mean temperatures, it was the only practical way to reduce the data to one observation per day. Future data can be treated in the same way and compared with the results of the present analysis to detect changes in lower York River temperature conditions.

Table 1 includes lists of monthly mean temperatures and standard deviations calculated from the "daily means." The monthly maximum and minimum temperatures and the maximum daily range for each month were obtained from the original lists of daily maximum and minimum temperatures. The mean temperatures in the last column of the table were derived from the "daily means" rather than the monthly means in order to give proper weight to months with missing observations. Linear regression analyses of the separate monthly means versus the years of record (e.g. the separate January means versus the years 1954 through 1971) were carried out to test for the existence of long term

Table 1

York River Water
Temperatures Recorded at VIMS Pier

(°C)

	Year	1954	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	All Years Combined
Jan	$\bar{x}$	4.30	4.02	1.93	4.36	3.42	3.20	5.27	2.80	3.95	2.47	3.13	4.93	4.36	4.95	2.69	2.94	1.52	3.22	3.53
	s	1.05	1.56	.412	1.12	1.20	1.36	.943	1.25	1.02	1.13	.986	1.60	2.46	.975	1.13	.645	1.33	1.10	1.65
	max	6.7	7.5	3.3	7.8	7.2	6.4	7.5	5.0	7.2	5.6	5.8	7.8	8.1	8.3	5.6	5.3	4.7	6.1	8.3
	min	2.2	0.8	0.8	1.1	1.1	0.0	2.8	-.3	1.1	0.0	0.3	1.7	-1.4	3.1	0.6	1.2	-1.1	0.3	-1.4
	max range	2.0	2.2	1.8	3.4	1.7	3.9	3.3	2.0	3.6	2.5	2.7	1.7	2.2	3.4	1.9	2.0	3.0	2.3	3.9
Feb	$\bar{x}$	5.44	3.11	5.26	5.50	1.85	5.29	4.70	3.25	3.87	2.26	4.00	3.79	2.37	4.63	3.11	3.36	3.44	3.55	3.83
	s	1.66	1.30	1.33	.724	1.29	1.02	.778	2.38	.977	.581	.457	1.05	1.93	1.07	.715	.653	.632	.197	1.67
	max	9.7	6.7	7.9	8.3	4.4	7.8	7.8	9.2	7.2	4.4	6.1	6.7	5.6	7.2	5.7	5.0	5.8	8.6	9.7
	min	2.2	0.0	1.5	4.4	-1.4	2.5	3.1	-0.6	1.7	0.6	2.5	0.8	-1.1	1.1	1.1	2.2	0.6	0.3	-1.4
	max range	2.8	3.3	2.7	2.3	3.2	2.8	2.5	4.8	2.5	3.6	2.5	3.1	4.7	2.0	2.3	2.2	2.2	3.4	4.8
Mar	$\bar{x}$	8.26	8.83	7.61	8.36	5.34	8.48	3.64	8.88	6.50	7.16	7.82	6.33	7.68	6.95		5.36	6.64	7.40	7.15
	s	1.31	1.18	.807	1.52	1.01	1.48	1.72	1.21	2.18	2.65	1.34	1.58	1.40	1.76		2.16	1.31	.967	1.95
	max	12.2	12.7	10.7	11.8	9.0	13.3	10.0	13.9	13.3	13.3	11.4	10.8	11.9	11.7		10.6	12.2	10.3	13.9
	min	5.6	5.1	5.5	5.6	2.3	5.3	0.8	6.1	3.3	1.7	3.3	4.2	3.9	1.7		2.2	4.1	4.7	0.8
	max range	3.1	4.1	4.6	3.5	2.4	4.4	3.9	5.0	4.2	4.2	4.7	3.9	3.6	3.4		3.3	4.4	2.8	5.0
Apr	$\bar{x}$	14.34	13.49	11.02	13.90	11.54	14.14	13.13	11.46	12.56	13.34		11.20	11.80	12.35		13.32	12.03	11.96	12.60
	s	3.92	2.60	1.43	3.10	2.86	1.86	2.75	1.80	2.24	1.51		1.71	2.27	1.07		1.78	2.17	1.91	2.64
	max	20.8	18.3	15.8	21.7	17.3	18.6	19.2	16.4	19.7	17.5		15.0	16.7	16.1		17.2	16.7	16.1	21.7
	min	8.3	7.8	6.7	8.9	6.4	9.7	6.4	8.6	8.6	10.6		6.7	7.8	8.9		7.8	7.8	6.7	6.4
	max range	4.4	4.1	5.4	4.8	4.0	4.2	4.8	4.4	4.5	4.7		3.3	3.9	3.6		4.1	3.3	3.9	5.4
May	$\bar{x}$	18.59	19.35	17.49	20.15	18.21	20.44	19.22	18.23	20.33	18.12		19.21	17.66	15.90		18.75	18.74	17.81	18.64
	s	1.69	1.97	1.95	1.97	1.92	1.84	2.27	2.23	1.96	1.54		2.19	1.98	1.28		1.84	2.33	2.12	2.42
	max	23.9	24.6	21.7	24.4	22.9	24.7	24.4	22.2	24.7	22.2		24.2	22.2	20.6		24.4	23.8	22.2	24.7
	min	15.3	15.2	10.6	15.6	14.2	16.1	15.2	12.7	16.1	14.2		13.9	13.3	12.8		13.9	13.9	13.1	10.6
	max range	3.6	4.1	3.9	6.0	5.5	4.1	3.3	4.2	5.0	3.6		4.8	4.1	3.9		3.9	6.7	2.8	6.7
Jun	$\bar{x}$	23.56	22.75	23.52	24.69	22.29	24.84	24.29	22.79	23.52	23.10		21.91	21.79	22.64	23.60	24.09	23.87	22.95	23.30
	s	1.13	1.80	2.15	2.14	1.11	1.70	1.17	1.43	1.08	1.47		1.07	1.67	2.00	1.18	1.34	1.02	1.84	1.72
	max	27.5	26.9	28.3	29.7	25.6	29.2	27.2	27.2	26.4	27.8		25.0	27.3	26.7	26.8	29.1	27.2	27.8	29.7
	min	21.1	19.3	18.9	19.4	18.6	21.1	21.1	17.8	21.1	20.3		19.2	17.8	16.1	18.9	21.1	21.1	17.8	16.1
	max range	4.2	4.0	3.5	6.6	5.1	3.9	2.9	4.2	3.7	5.2		3.6	4.5	4.5	3.6	3.9	3.3	5.0	6.6

Table 1 (continued)

	Year	1953	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	All Years Combined
Jul	$\bar{x}$	26.72	25.58	27.13	25.90	26.30	25.70	27.28	26.11	25.84	25.35	26.30		25.35	26.29	25.04	26.01	26.72	25.51	26.06
	s	.948	.937	1.15	.771	.606	1.18	1.02	.617	1.56	1.07	.952		.770	.809	.896	.722	.634	.879	1.32
	max	29.2	29.2	30.6	29.7	28.3	30.5	30.3	28.3	30.6	27.3	29.7		28.1	29.4	27.8	28.3	29.3	28.6	30.6
	min	23.1	23.6	23.6	22.4	24.1	22.4	25.3	23.9	21.9	21.7	23.6		22.5	23.9	22.2	23.9	25.0	23.9	21.7
max	range	3.0	3.6	3.8	5.0	3.0	3.4	3.0	2.8	4.2	5.5	4.4		3.3	4.1	3.0	3.3	2.9	3.0	5.5
Aug	$\bar{x}$	26.39	25.73	27.39	25.56	25.56	26.37	27.87	26.42	26.64	25.31	26.37	25.19	25.96	25.23	25.31	26.86	25.87	26.54	26.18
	s	.769	.665	1.22	.938	1.63	1.02	1.23	.938	1.08	.536	.588	.691	.697	1.03	.852	1.18	.502	.675	1.22
	max	29.4	28.3	31.1	29.1	29.4	29.5	30.6	28.9	29.2	28.3	28.9	27.8	28.1	27.8	27.8	30.0	27.8	28.9	31.1
	min	24.2	23.9	23.1	23.0	21.3	23.4	25.3	23.9	24.2	23.9	24.4	22.8	23.3	23.2	22.8	23.3	23.9	24.4	21.3
max	range	3.3	2.5	4.4	6.1	3.1	2.9	2.8	3.1	3.1	3.6	3.6	2.8	3.1	2.5	2.8	2.5	2.8	2.8	6.1
Sep	$\bar{x}$	23.70	24.70	23.76	23.24	24.73	23.56	25.90	24.48	25.61	23.18	22.62	23.74	24.34	22.75	22.06	23.42	23.44		23.84
	s	2.09	1.32	1.22	2.82	1.58	.986	1.69	1.65	2.52	2.07	1.94	1.63	1.00	2.07	1.49	.690	1.98		2.11
	max	29.2	28.6	27.7	28.9	27.4	26.7	29.4	29.4	30.0	27.2	26.7	27.2	27.2	27.1	25.6	25.7	27.5		30.0
	min	20.3	21.7	21.1	17.5	19.6	20.6	22.5	21.1	21.1	18.3	19.4	20.8	21.7	19.7	19.2	21.4	20.0		17.5
max	range	3.1	2.7	2.9	3.1	2.8	3.2	2.0	3.8	3.1	3.3	3.1	3.3	2.3	2.2	2.8	2.2	2.9		3.8
Oct	$\bar{x}$	19.26	20.19	19.36	18.09	16.81	17.76	21.43	19.20	19.36	19.53	18.93		18.02	17.55	18.09	19.76	18.46	19.71	18.90
	s	1.94	3.09	2.16	1.19	1.96	1.50	3.09	2.44	2.12	1.95	.880		1.96	1.50	1.69	2.08	2.28	2.23	2.30
	max	23.6	25.0	22.9	21.1	20.7	22.2	25.8	22.5	23.6	21.7	21.1		22.2	20.6	21.7	23.9	21.7	23.1	25.8
	min	15.8	14.2	15.5	15.8	11.9	14.2	15.6	13.6	15.3	13.9	15.3		13.3	13.3	14.6	14.4	13.1	15.2	11.9
max	range	4.2	6.7	2.3	2.2	4.1	2.8	2.3	2.2	2.5	1.9	2.5		2.2	2.1	2.8	2.5	1.9	2.3	6.7
Nov	$\bar{x}$	12.48	11.59	11.87	13.21	12.17	13.62	12.95	12.38	14.05		13.32	14.00	12.27	12.30	11.12	12.10		13.20	12.66
	s	1.78	1.24	2.03	3.00	1.03	.971	2.40	1.01	2.75		1.04	1.04	1.24	1.53	2.54	2.35		2.27	2.14
	max	17.2	15.0	16.9	19.1	14.9	16.0	17.8	15.0	19.2		16.4	15.6	14.4	15.8	16.4	16.7		16.7	19.2
	min	8.6	7.8	6.7	7.5	9.6	9.6	8.1	10.6	8.3		10.6	10.0	10.0	8.9	7.1	8.3		8.3	6.7
max	range	2.8	2.8	4.0	2.9	2.6	2.3	2.8	1.9	2.7		2.8	2.8	1.6	2.8	1.8	2.3		1.9	4.0
Dec	$\bar{x}$	8.14	5.33	5.00	9.16	7.14	5.69	7.02	5.52	7.08	5.21	5.90	8.44	7.69	6.62	7.29	5.66		8.26	6.76
	s	2.24	1.66	2.07	.755	1.40	2.29	.974	2.79	1.50	2.63	2.99	1.15	.852	1.83	.937	2.25		1.12	2.26
	max	11.9	9.7	9.3	10.9	10.5	10.6	8.9	11.9	10.3	10.3	12.8	11.1	10.3	10.6	9.4	10.6		10.8	12.8
	min	4.4	2.2	1.2	6.7	3.4	2.3	4.7	1.9	3.1	-.28	1.7	5.3	5.6	2.8	4.9	2.6		5.2	-.28
max	range	2.0	2.5	2.3	1.8	2.7	2.6	2.0	2.2	1.6	3.0	4.1	2.8	1.7	2.3	3.4	2.3		2.0	4.1

temperature trends. While most of the analyses revealed slightly declining trends, none of the regression or correlation coefficients were statistically significant (largest correlation: -.395 for September; smallest correlation: .0524 for November). Thus the monthly mean temperatures for all years combined, appearing in the last column of Table 1, are valid representations of the average temperature conditions for the period of record.

Figure 1 consists of plots of the maximum, mean, and minimum temperatures recorded in the last column of Table 1. These curves illustrate the fact that the annual temperature cycle in the lower York River consists of mid-summer and mid-winter periods of relatively stable temperature conditions separated by spring and autumn periods of rapid change. The standard deviations appearing in Table 1 also reflect this pattern, being smaller in the summer and winter months than in the spring and autumn months.

Table 2 consists of frequency distributions of the daily mean temperatures grouped into 1°C intervals, and tabulated separately for each month of each year. Each temperature interval actually begins with the first temperature listed and extends to but does not include the second temperature (e.g. 1° - 2° is actually 1° - 1.999...°). In the last four columns of the table, the frequency distributions for the individual months are combined, the combined

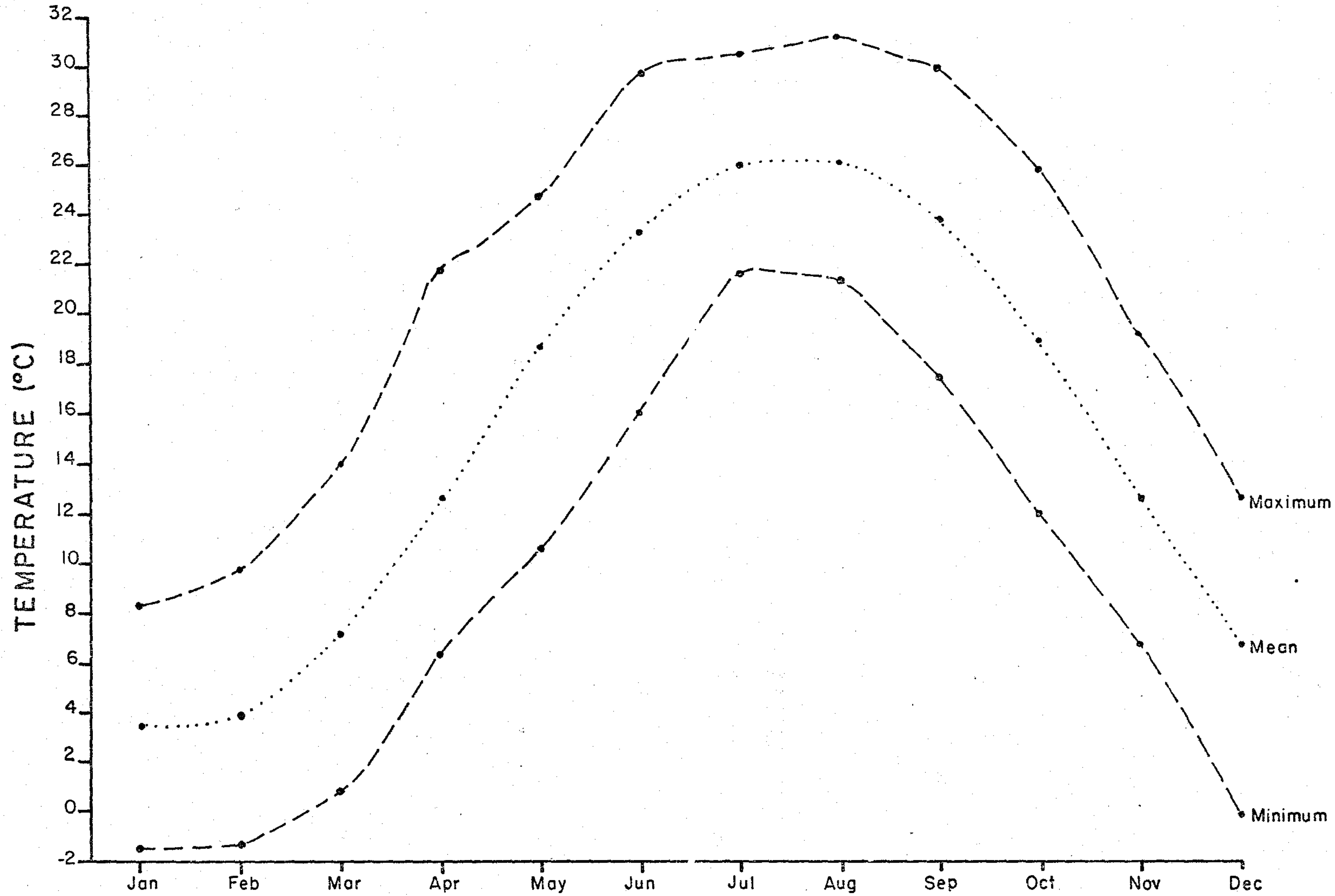


Figure 1. VIMS pier water temperatures: July 1953 - June 1971

distributions are converted to percent frequencies, and the percent frequency distributions are cumulated. The resulting cumulative percent frequency distributions, plotted on arithmetic probability paper, appear as Figures 2 - 13. The lines pass through the calculated mean monthly temperatures, but otherwise were fitted by eye. The high degree of linearity apparent in these plots verifies that the "daily mean" temperatures are normally distributed. Future temperature measurements, after being converted to "daily mean" temperatures, can be compared with these distributions to determine to what extent they approximate the average temperature conditions of the recent past.

Since this study is concerned with the effects of future increases in lower York River water temperatures on the estuarine ecosystem, temperature extremes as well as average temperatures should be considered. Extreme temperatures, particularly during the summer months, can be expected to present the greatest immediate hazard to the organisms present. Accordingly, Table 3 has been prepared, which indicates the frequency of occurrence, on a daily basis, of temperatures greater than or equal to 25°C, in the VIMS pier records. Since daily temperature ranges often included more than one of these temperature intervals, the number of observations recorded for each month often exceeds the number of days in the month. Future measurements can be compared with

Table 2. Frequency of Occurrence of Daily Mean Temperatures Recorded in the York River at VIMS Pier

Jan	Temp Interval (°C)	Year	1954	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	All Years Combined	% Frequency	Temp (°C)	Cumulative % Less Than
	-1-0														2				4		6	1.08	0	1.08
	0-1							1		5		2			1				9		18	3.24	1	4.32
	1-2			2	19		2	8		2	1	11	5		1		12	1	7	5	76	13.69	2	18.02
	2-3		2	9	12	4	12	5		6	6	7	5	3	4		6	14	4	7	106	19.10	3	37.12
	3-4		14	7		7	12	8	3	14	7	6	13	9	6	4	8	14	7	12	151	27.21	4	64.32
	4-5		4	2		14	1	6	8	4	13	5	6	5	3	14	4	2		5	96	17.30	5	81.62
	5-6		9	5		4	2	3	13		2			11	6	9	1			2	67	12.07	6	93.69
	6-7		2	5		1	2		7		2			3	1	3					26	4.68	7	98.38
	7-8					1									6	1					8	1.44	8	99.82
	8-9														1						1	.18	9	100.00
		N	31	30	31	31	31	31	31	31	31	31	29	31	31	31	31	31	31	31	555			
Feb	-1-0						3			1					6						10	2.00	0	2.00
	0-1						3			6		1			3					2	15	3.00	1	5.00
	1-2			7			8			4		10		3	1				1	5	39	7.80	2	12.80
	2-3		1	7	1		7	1		2	6	15		3	5	2	14	7	3	6	80	16.00	3	28.80
	3-4		7	6	6		6	1		4	9	2	13	7	4	3	13	13	20	4	118	23.60	4	52.40
	4-5		6	6	3	6	1	8	20	2	8		12	12	9	13	2	3	2	2	115	23.00	5	75.40
	5-6		1	2	7	17		9	7	5	3		1	3		6			2	4	67	13.40	6	88.80
	6-7		7		10	3		9	1	2	2					4				4	42	8.40	7	97.20
	7-8		5		2	2			1	2										1	13	2.60	8	99.80
	8-9		1																		1	.20	9	100.00
		N	28	28	29	28	28	28	29	28	28	28	26	28	28	28	29	23	28	28	500			

Table 2. (continued)

Mar	Temp Interval (°C)	Year	1954	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	All Years Combined	% Frequency	Temp (°C)	Cumulative % Less Than
	0-1								1												1	.19	1	.19
	1-2								1												1	.19	2	.38
	2-3								9			2				2		2			15	2.87	3	3.26
	3-4						1		10		2	3	1					12			29	5.56	4	8.81
	4-5						12		2		6	2	1	2	1	2		3	1		32	6.13	5	14.94
	5-6						12	1	2		9	2	1	13	3	3		1	9	2	58	11.11	6	26.05
	6-7		3	2	7	10	3	3	1	1	3	4	2	7	6	8		4	13	10	87	16.67	7	42.72
	7-8		14	6	15	2	3	9	1	3	3	7	6	3	7	6		3	3	9	100	19.16	8	61.88
	8-9		6	6	6	1		6	1	15	3	2	14	3	6	7		4	3	8	91	17.43	9	79.31
	9-10		3	14	3	15		6		7	2	5	3	3	6	2		2	1	2	74	14.18	10	93.49
	10-11		3	3		3		5		3	2	1	1		2	1			1		25	4.79	11	98.28
	11-12		2					1		2	1	2									8	1.53	12	99.81
	12-13											1									1	.19	13	100.00
		N	31	31	31	31	31	31	28	31	31	31	29	31	31	31	23*	31	31	31	522			
Apr	6-7						1														1	.21	7	.21
	7-8						3							1						1	5	1.04	8	1.25
	8-9				1		4		1					1	2				1		10	2.08	9	3.33
	9-10		1	5	7		4		3	6	1			7	6			1	5	5	51	10.62	10	13.95
	10-11		5	4	8	4	2	3	8	10	6	1		4	6	2		5	5	3	76	15.83	11	29.78
	11-12			1	10	10	2	2		5	10	5		4	3	11		1	6	3	73	15.21	12	44.99
	12-13		4	1	1	1	3	3	2	1	6	8		8	2	7		4	3	8	62	12.92	13	57.91
	13-14		4	1	1	3	1	5	1	3	1	6		4	2	9		7	1	7	56	11.67	14	69.58
	14-15		3	4	2	2	7	3	6	5	1	4		1	8	1		4	6	3	60	12.50	15	82.08
	15-16		2	10		1	3	10	3		1	4			1			8	3		46	9.58	16	91.66
	16-17			4		3		3	4		2	2									18	3.75	17	95.41
	17-18		5			1		1	2		2										11	2.29	18	97.70
	18-19		4			2															6	1.25	19	98.95
	19-20		2			2															4	.84	20	99.79
	20-21					1															1	.21	21	100.00
		N	30	30	30	30	30	30	30	30	30	30	9*	30	30	30	15*	30	30	30	480			

Table 2. (continued)

May	Temp Interval (°C)	Year	1954	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	All Years Combined	% Frequency	Temp (°C)	Cumulative % Less Than
	12-13				1																1	.20	13	.20
	13-14				1					2						1					4	.81	14	1.01
	14-15				2		1			3		2		1	2	7		1	1	4	24	4.86	15	5.87
	15-16		2	1	2		6			2				2	6	10		1	2	4	38	7.69	16	13.56
	16-17		2	2	5	3	3		7	1		5		3	8	5		3	7	2	56	11.34	17	24.90
	17-18		8	4	2	1	2	2	5	4	4	7		4	1	7		5	2	3	61	12.35	18	37.25
	18-19		9	9	11	4	6	4	4	4	8	4		3	2	1		6	3	8	86	17.41	19	54.66
	19-20		2	4	6	6	6	11	2	4	1	9		6	6			5	3	4	75	15.18	20	69.84
	20-21		4	4	1	5	6	2	3	11	6	4		4	6			8	3	6	73	14.78	21	84.62
	21-22		3	3		6	1	4	6		3			6				1	6		39	7.89	22	92.51
	22-23		1	2		3		4	3		6			2				1	2		24	4.86	23	97.37
	23-24			2		3		4	1		3										13	2.63	24	100.00
		N	31	31	31	31	31	31	31	31	31	31	0	31	31	31	0	31	29	31	494			
Jun	16-17															1					1	.20	17	.20
	17-18															1					1	.20	18	.40
	18-19															1					1	.20	19	.60
	19-20									1		1		2	4					2	10	2.00	20	2.59
	20-21			7	4	1	4			3		1		5	5	2	1			1	34	6.79	21	9.38
	21-22		4	6	4	2	8			3	2	2		10	11	3	1	1	2	5	64	12.77	22	22.15
	22-23		5	3	5	6	9	4	6	9	7	12		7	3	2	3	4	4	10	99	19.76	23	41.91
	23-24		8	3	3	3	9	8	5	9	10	6		5	2	16	14	7	8	3	119	23.75	24	65.67
	24-25		11	7	5	3		6	9	3	8	3			4	4	5	8	12	4	92	18.36	25	84.03
	25-26		2	4	4	3		4	9	2	3	4			1		3	2	4	2	47	9.38	26	93.41
	26-27				4	7		3	1			1						2		3	21	4.19	27	97.60
	27-28				1	4		4										1			10	2.00	28	99.60
	28-29					1		1													2	.40	29	100.00
		N	30	30	30	30	30	30	30	30	30	30	0	29	30	30	27	25	30	30	501			

Table 2. (continued)

Month	Temp Interval (°C)	Year	1953	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	All Years Combined	% Frequency	Temp (°C)	Cumulative % Less Than
Jul	22-23											2									2	.38	23	.38
	23-24			1				1			2	3			[illegible]		4				12	2.29	24	2.67
	24-25		3	5	2	1	1	7			9	1	2		[illegible]	1	9	1		10	61	11.64	25	14.31
	25-26		3	17	3	19	5	15	2	15	9	17	10		1[illegible]	9	14	16	4	14	187	35.69	26	50.00
	26-27		9	5	7	7	21	3	12	14	2	8	12		[illegible]	16	4	9	20	4	159	30.34	27	80.34
	27-28		16	3	10	4	4	3	9	2	2		6			3		3	6	3	74	14.12	28	94.47
	28-29				7			2	6		7		1			2			1		26	4.96	29	99.43
	29-30				1				2												3	.57	30	100.00
		N	31	31	30	31	31	31	31	31	31	31	31	17*	3[illegible]	31	31	29	31	31	524			
Aug	22-23						2														2	.36	23	.36
	23-24						5				1			1		3	3				13	2.36	24	2.72
	24-25			4		10	5	3		3	2	1		9	4	12	3	3	1	1	61	11.05	25	13.77
	25-26		8	12	3	10	4	6	2	7	3	18	10	18	[illegible]	6	17	3	17	4	153	27.72	26	41.48
	26-27		17	14	9	8	8	14	7	12	11	11	16	3	2[illegible]	10	4	10	12	17	204	36.96	27	78.44
	27-28		4	1	9	3	5	7	5	8	13	1	5		[illegible]			11		9	82	14.86	28	93.30
	28-29		1		5		2	1	10	1	1							4			25	4.53	29	97.83
	29-30				5				7												12	2.17	30	100.00
		N	30	31	31	31	31	31	31	31	31	31	31	31	3[illegible]	31	27	31	30	31	552			

Table 2. (continued)

Month	Temp Interval (°C)	Year	1953	'54	55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	All Years Combined	% Frequency	Temp (°C)	Cumulative % Less Than
Sep	17-18					1															1	.20	18	.20
	18-19					3															3	.60	19	.80
	19-20					1						2									3	.60	20	1.40
	20-21						2					5	8			7	8		4		34	6.79	21	8.18
	21-22		6		2	4	1	2		4	1	2	6	6		7	9		7		57	11.38	22	19.56
	22-23		7	4	6	2	1	7		2	6		3	6	3	4	3	8	1		63	12.57	23	32.14
	23-24		7	4	10	7	1	10	4	5	6	7	3	2	8	3	5	11	6		99	19.76	24	51.90
	24-25		2	12	6	4	7	8	5	7	2	8	5		12	2	5	7	3		95	18.96	25	70.86
	25-26		2	5	5	1	14	3	8	4	1	3	5	11	5	3			5		75	14.97	26	85.83
	26-27		1	2	1	3	4		2	7	5	2		1	2	4			4		38	7.58	27	93.41
	27-28		5	3		4			8	1	7										28	5.59	28	99.00
	28-29								3		2										5	1.00	29	100.00
		N	30	30	30	30	30	30	30	30	30	29	30	26	30	30	30	26	30	22*	501			
Oct	12-13						1														1	.19	13	.19
	13-14						3												1		4	.77	14	.96
	14-15			1			1	1		3		2			3	1			2		14	2.70	15	3.66
	15-16			1		1	3	3		2		1			3	5	3	2	4	3	31	5.97	16	9.63
	16-17		3	2	6	4	8	6	3	3	6		2		1	4	7	3	1	1	60	11.56	17	21.19
	17-18		6	7	5	13	6	4	2	1	4		1		6	6	3	1	2	3	70	13.49	18	34.68
	18-19		5		3	4	5	9	3	1	4	2	12		13	11	7		5	7	91	17.53	19	52.21
	19-20		9	2	1	7	2	7	5	2	3	6	13		1	3	6	11	2	1	81	15.61	20	67.82
	20-21		2	1	5	2	2		3	11	3	11	3			1	5	7	12	2	70	13.49	21	81.31
	21-22			3	10			1		8	8	4			4			3	2	7	50	9.63	22	90.94
	22-23		6	4	1				1		3							3		7	25	4.82	23	95.76
	23-24			4					3									1			8	1.54	24	97.30
	24-25			3					9												12	2.31	25	99.61
	25-26								2												2	.39	26	100.00
		N	31	28	31	31	31	31	31	31	31	26	31	23*	31	31	31	31	31	31	519			

Table 2. (continued)

	Temp Interval (°C)	Year	1953	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	All Years Combined	% Frequency	Temp (°C)	Cumulative % Less Than
Nov	7-8				1												1				2	.42	8	.42
	8-9			1	1	3			1								4				10	2.10	9	2.52
	9-10		1	2	4	4			1		1					1	10	5		2	31	6.51	10	9.03
	10-11		1	3	5	1	5	1	7		4				6	6		9		5	53	11.13	11	20.17
	11-12		13	14	4		9	2	4	15	5		3	1	6	6	5	5		5	97	20.38	12	40.55
	12-13		8	8	8	7	8	3	7	7			11	7	5	6	3	1		2	91	19.12	13	59.66
	13-14		2		3	4	7	14	3	5	3		6	1	12	7	1	1		7	76	15.97	14	75.63
	14-15			2	1	2	1	9	3	3	7		8	19		3	2	1		4	65	13.66	15	89.29
	15-16		1		3	1		1	3		2		2	2		1	4	8		2	30	6.30	16	95.59
	16-17		4			4			1		1										10	2.10	17	97.69
	17-18					3					4										7	1.47	18	99.16
	18-19					1					3										4	.84	19	100.00
		N	30	30	30	30	30	30	30	30	30	14*	30	30	29	30	30	30	18*	27	476			
Dec	0-1											1									1	.19	1	.19
	1-2																						2	
	2-3			1	5					6		2	8								22	4.21	3	4.40
	3-4			5	8			11		7		14	4			6		6			61	11.66	4	16.06
	4-5		1	9	3		2	6		5	2	2	2			1		12			45	8.60	5	24.67
	5-6		8	9	4		5	3	6	1	5		2			1	6	3		1	54	10.32	6	34.99
	6-7		5	2	1		7	1	6	1	10	3	1	5	6	9	1	1			59	11.28	7	46.27
	7-8				8	2	9	1	13	2	5	2	4	7	13	5	17	2		14	104	19.89	8	66.16
	8-9		2	4	2	10	4	5	6	2	6	2	4	8	11	7	7	2		6	88	16.83	9	82.98
	9-10		4	1		15	4	4		6	3	4	3	8	1	2		2		2	59	11.28	10	94.26
	10-11		11			4				1		1	2	3				3		4	29	5.54	11	99.81
	11-12												1								1	.19	12	100.00
		N	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	31	23*	27	523			

*Omitted because of insufficient N

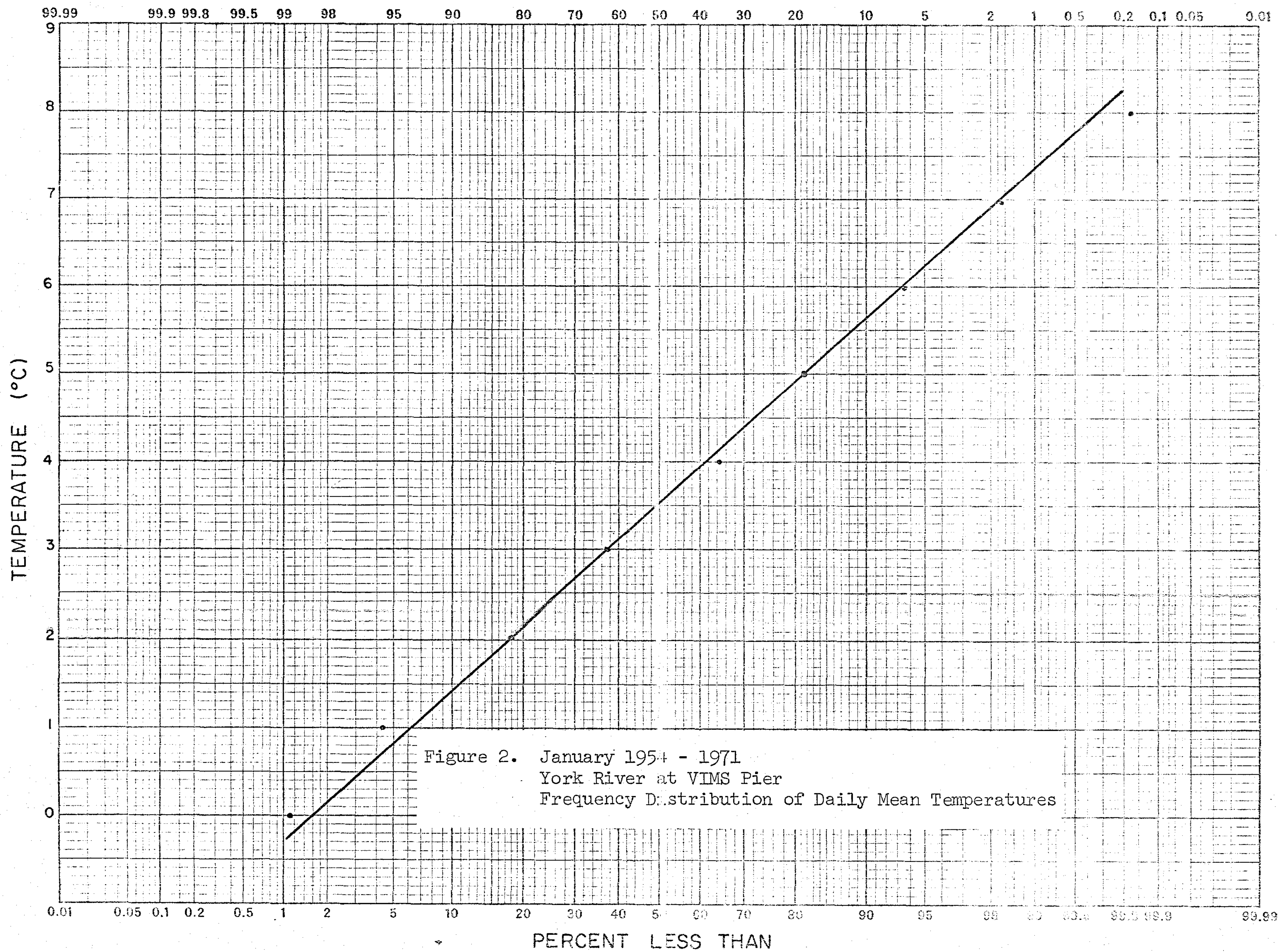


Figure 2. January 1954 - 1971
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

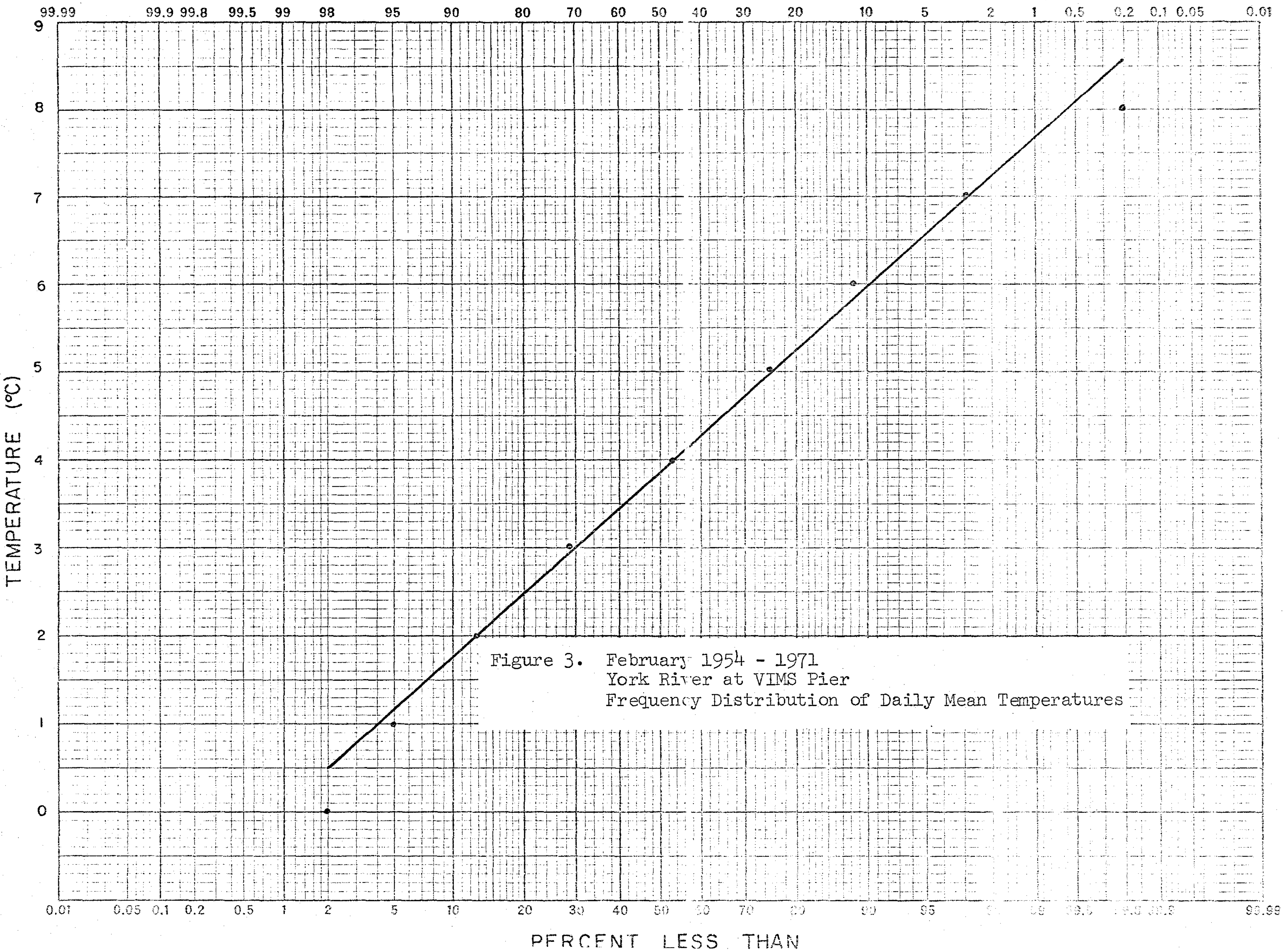


Figure 3. February 1954 - 1971
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

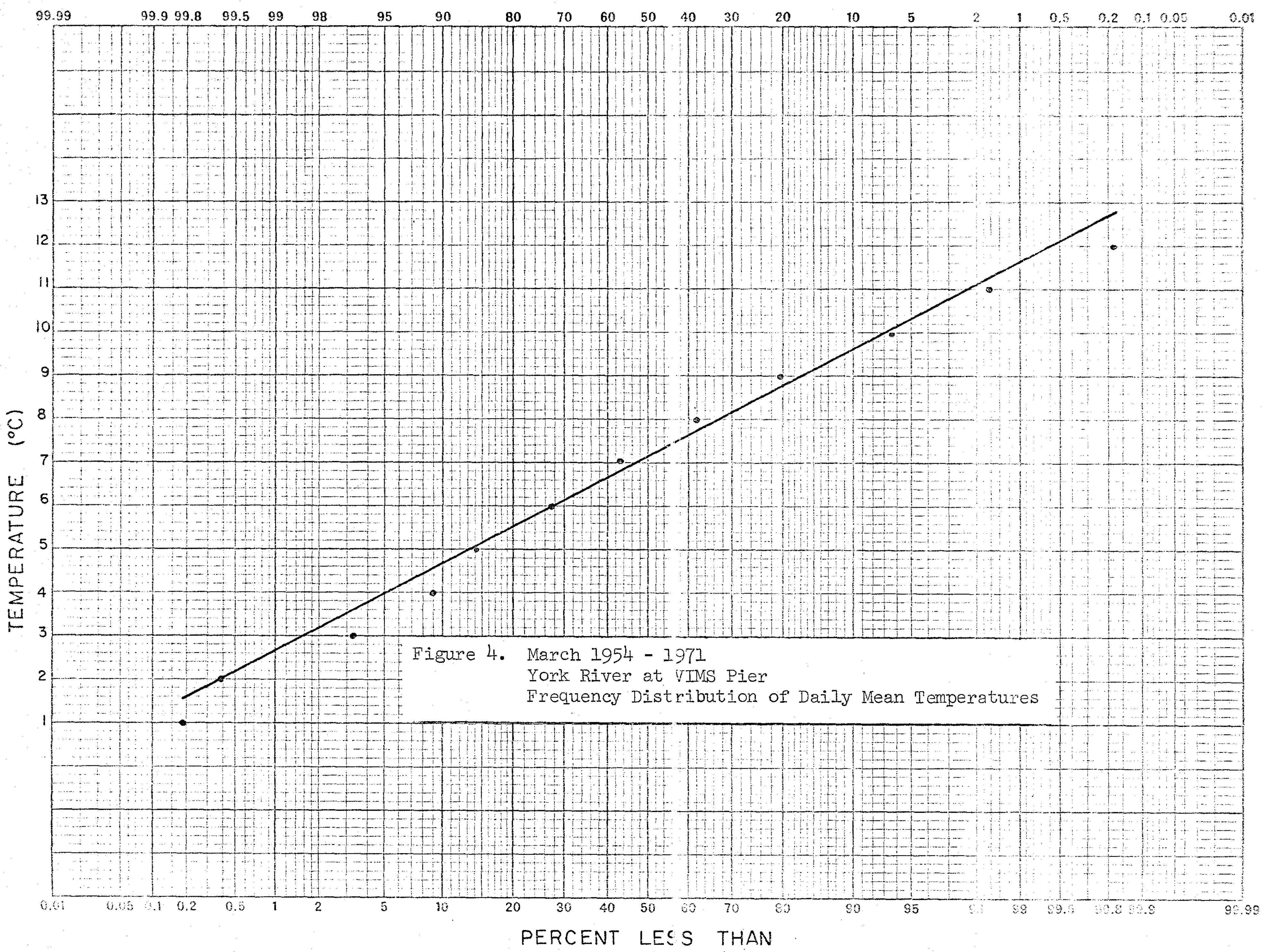


Figure 4. March 1954 - 1971
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

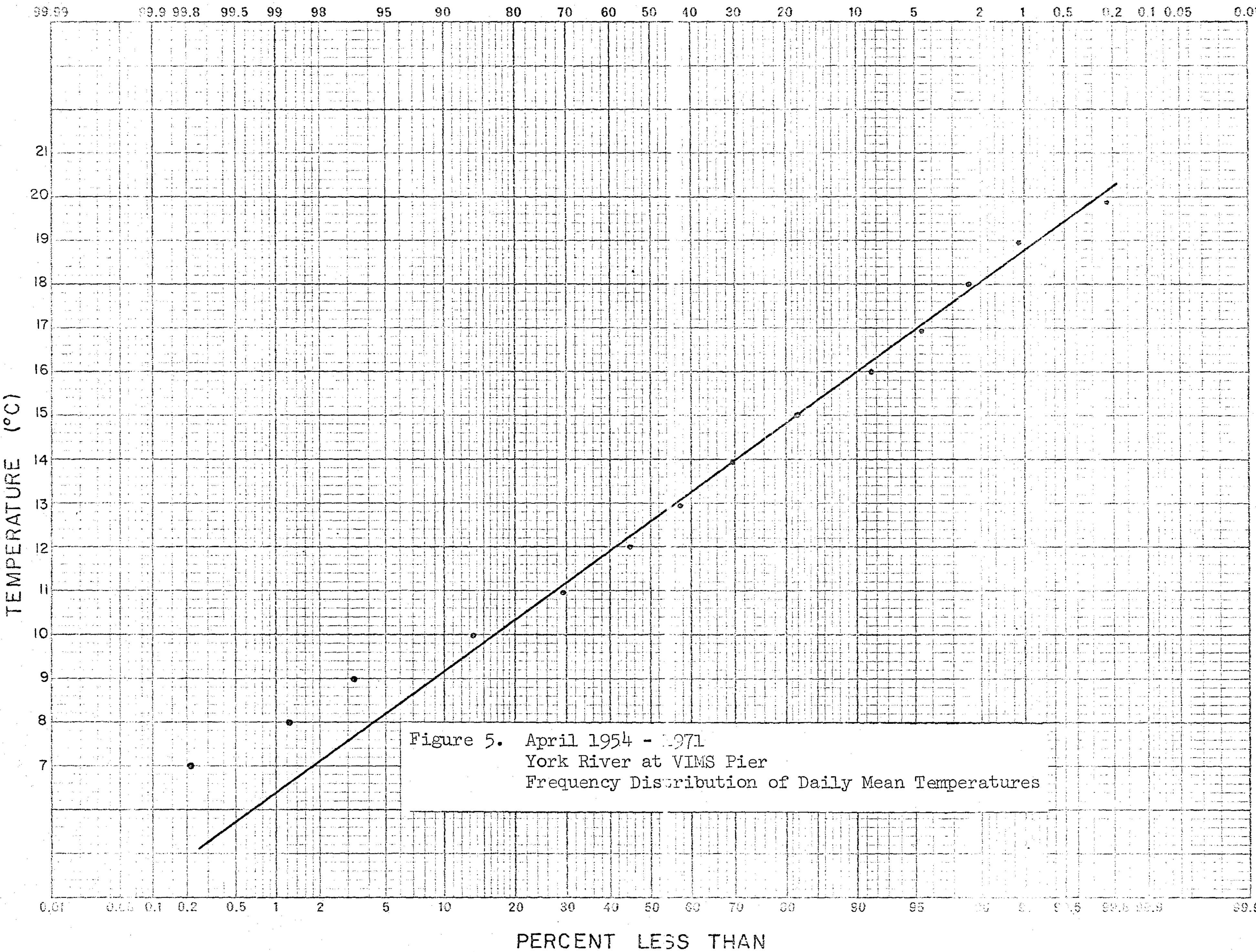


Figure 5. April 1954 - 1971
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

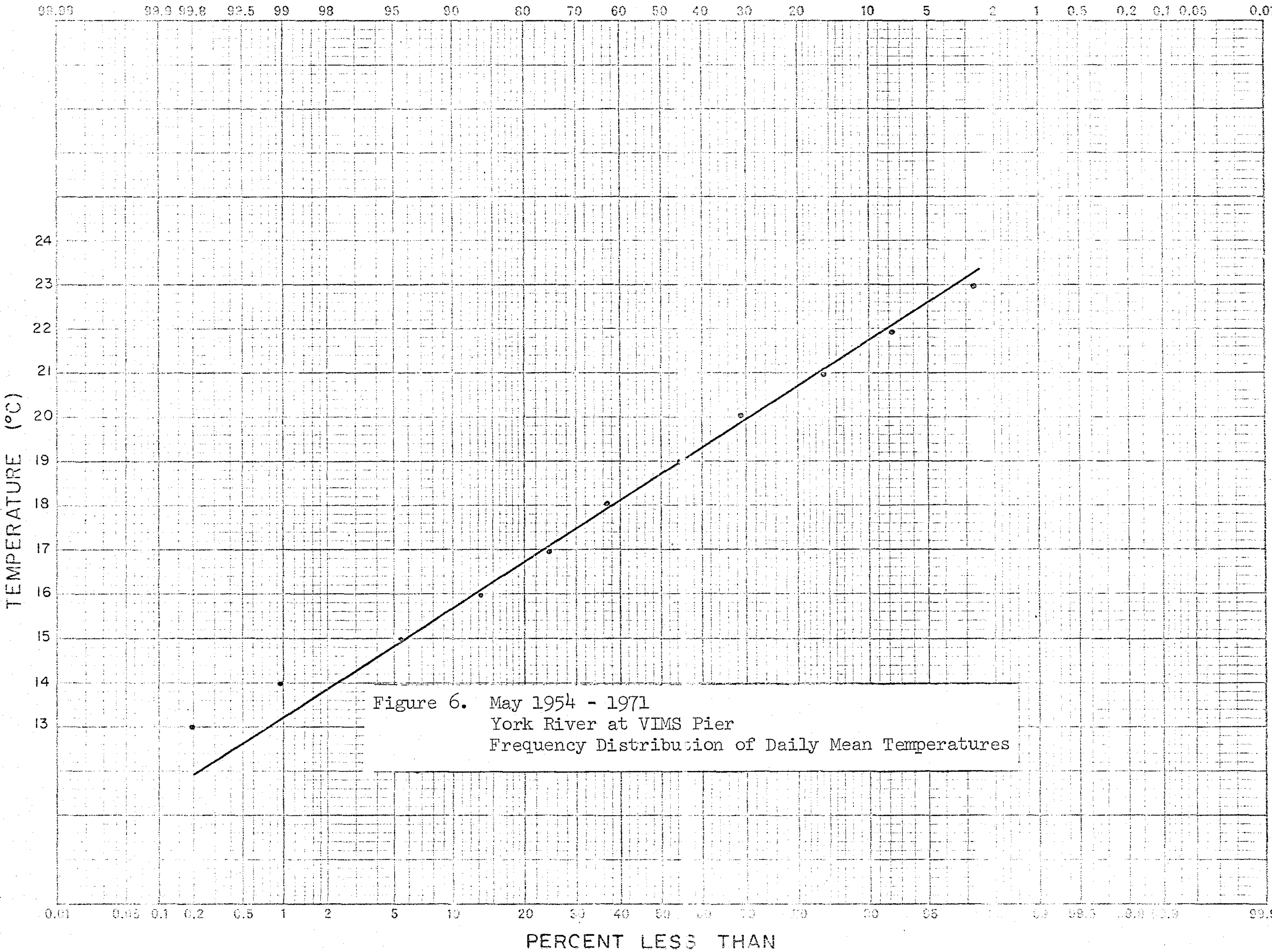


Figure 6. May 1954 - 1971
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

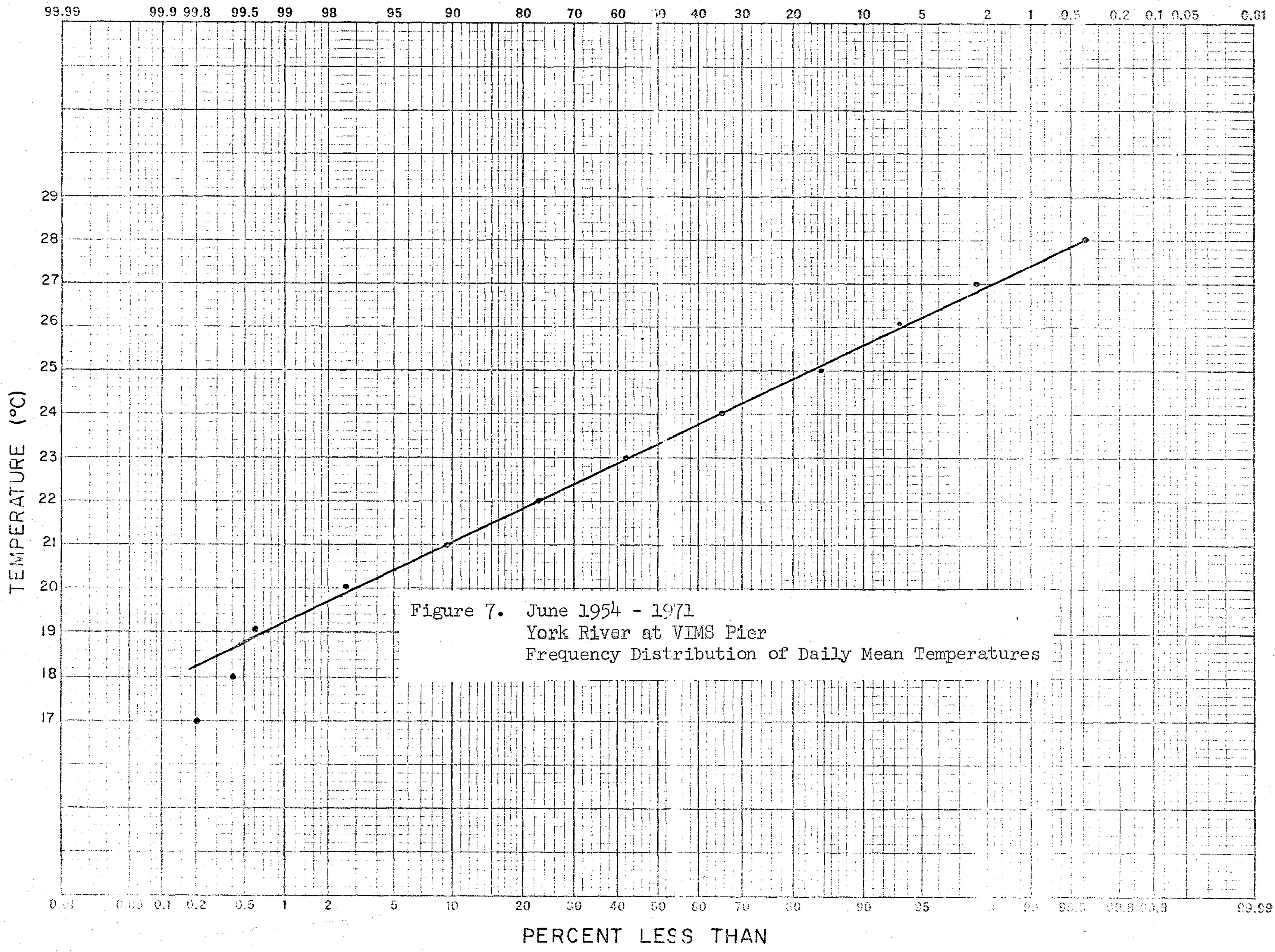


Figure 7. June 1954 - 1971
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

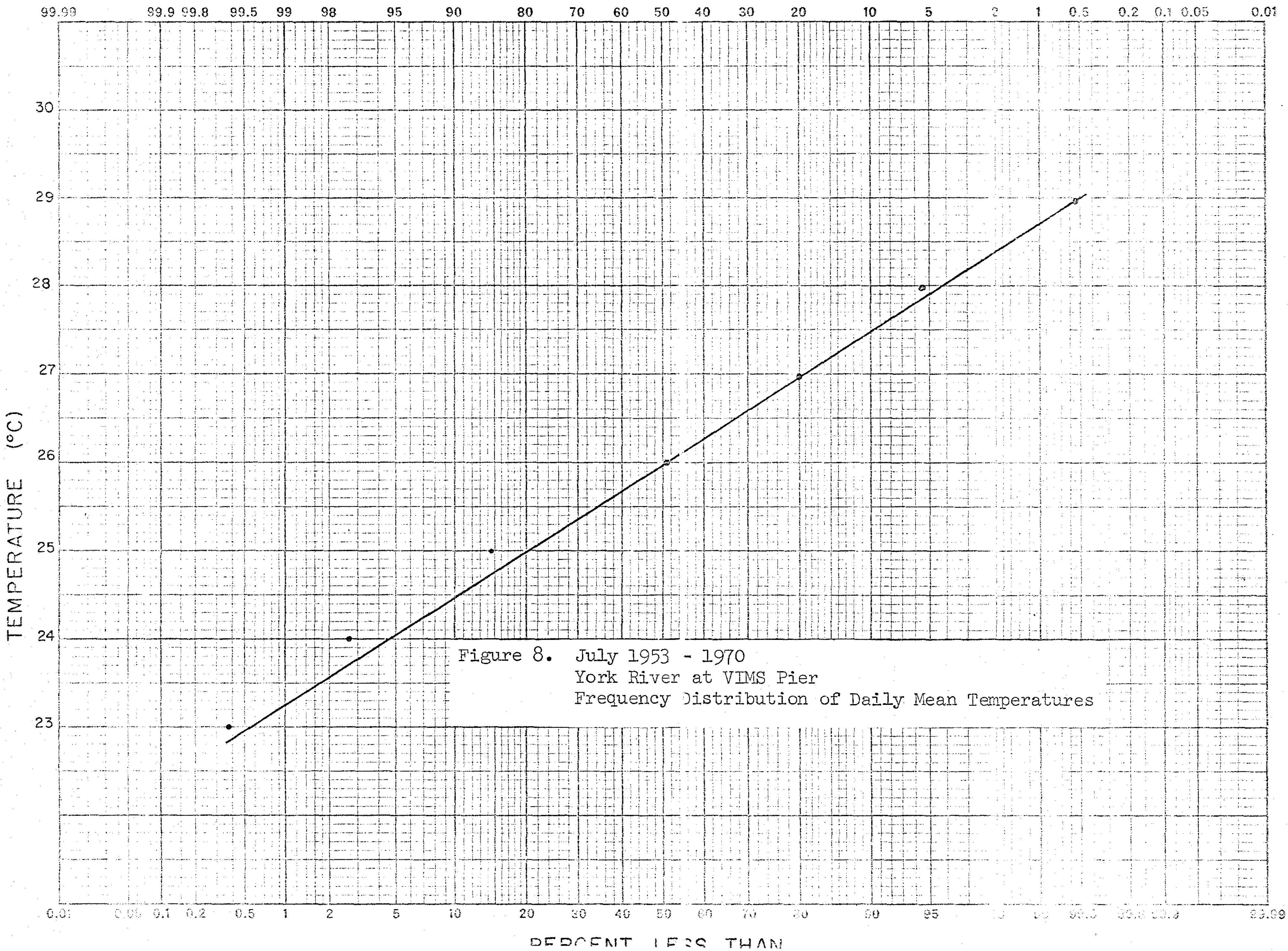


Figure 8. July 1953 - 1970
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

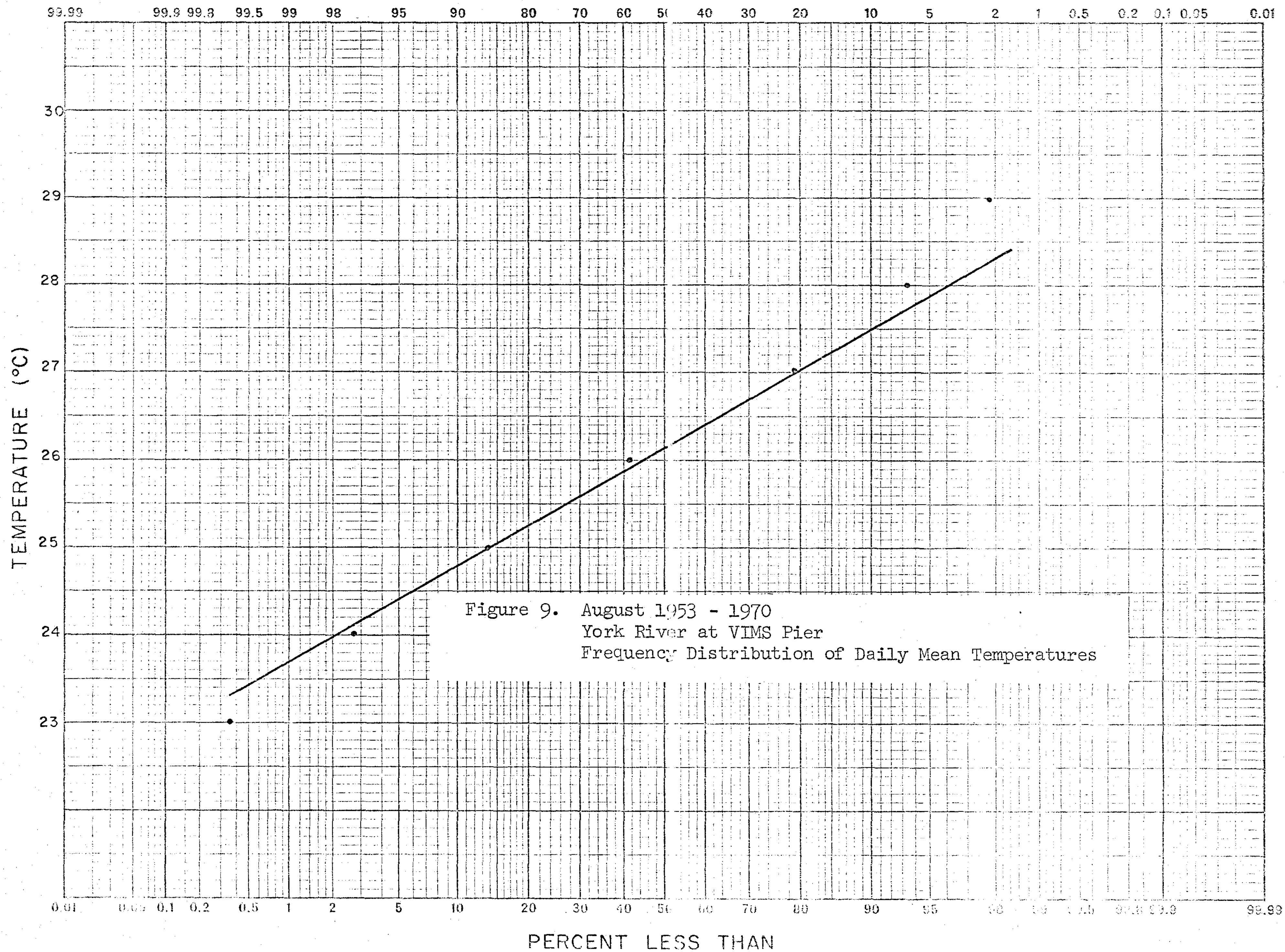


Figure 9. August 1953 - 1970
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

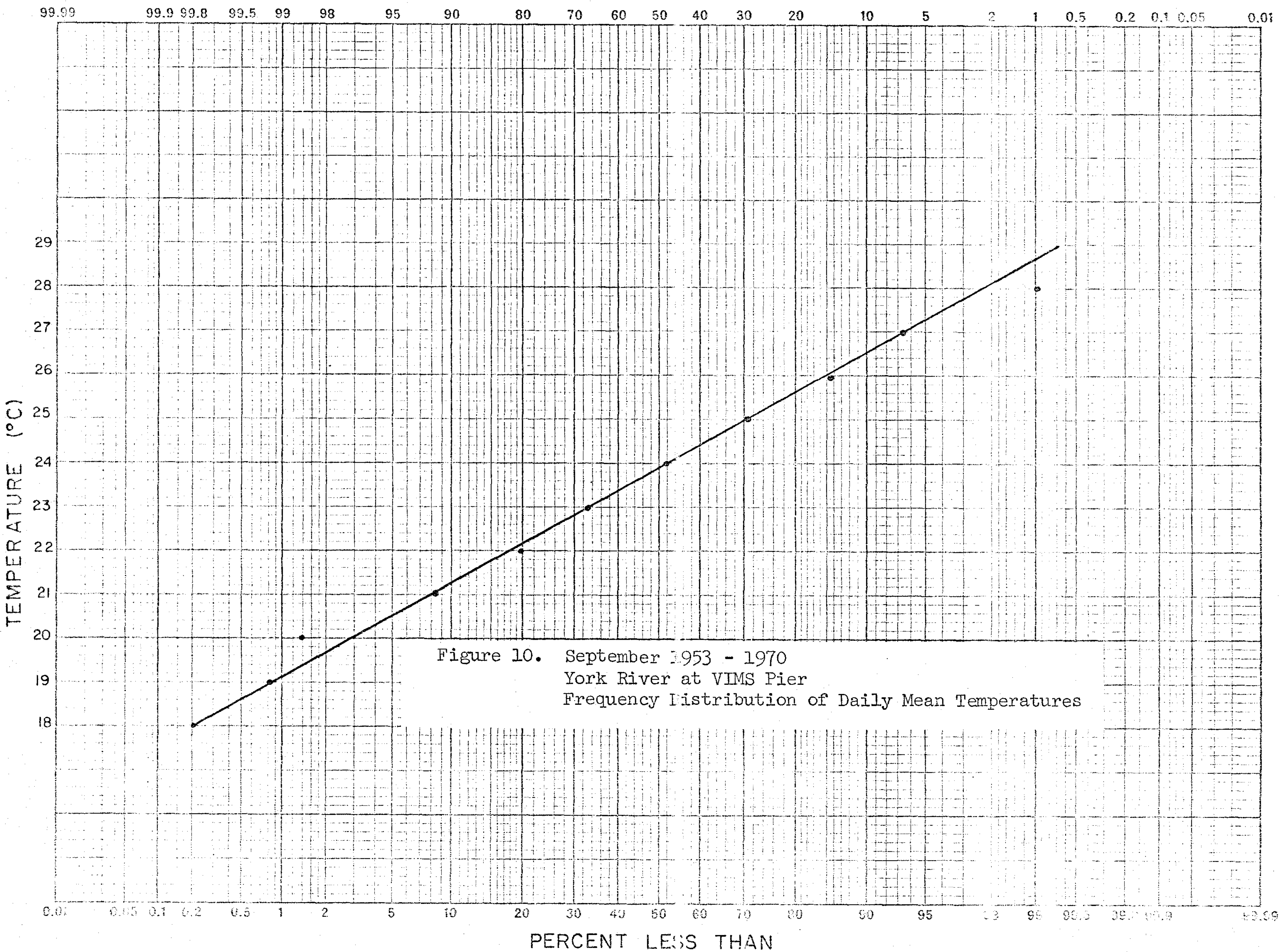


Figure 10. September 1953 - 1970
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

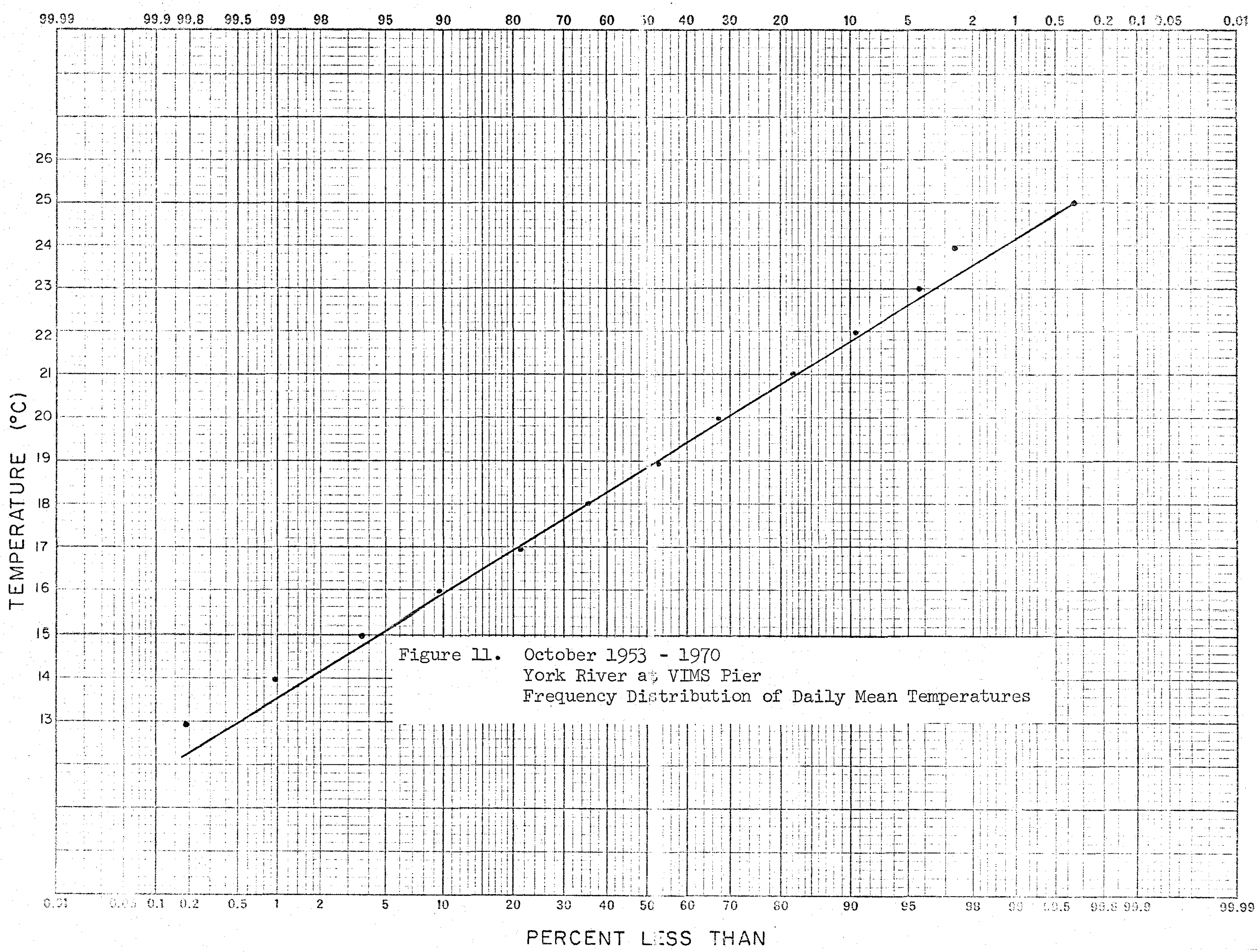


Figure 11. October 1953 - 1970
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

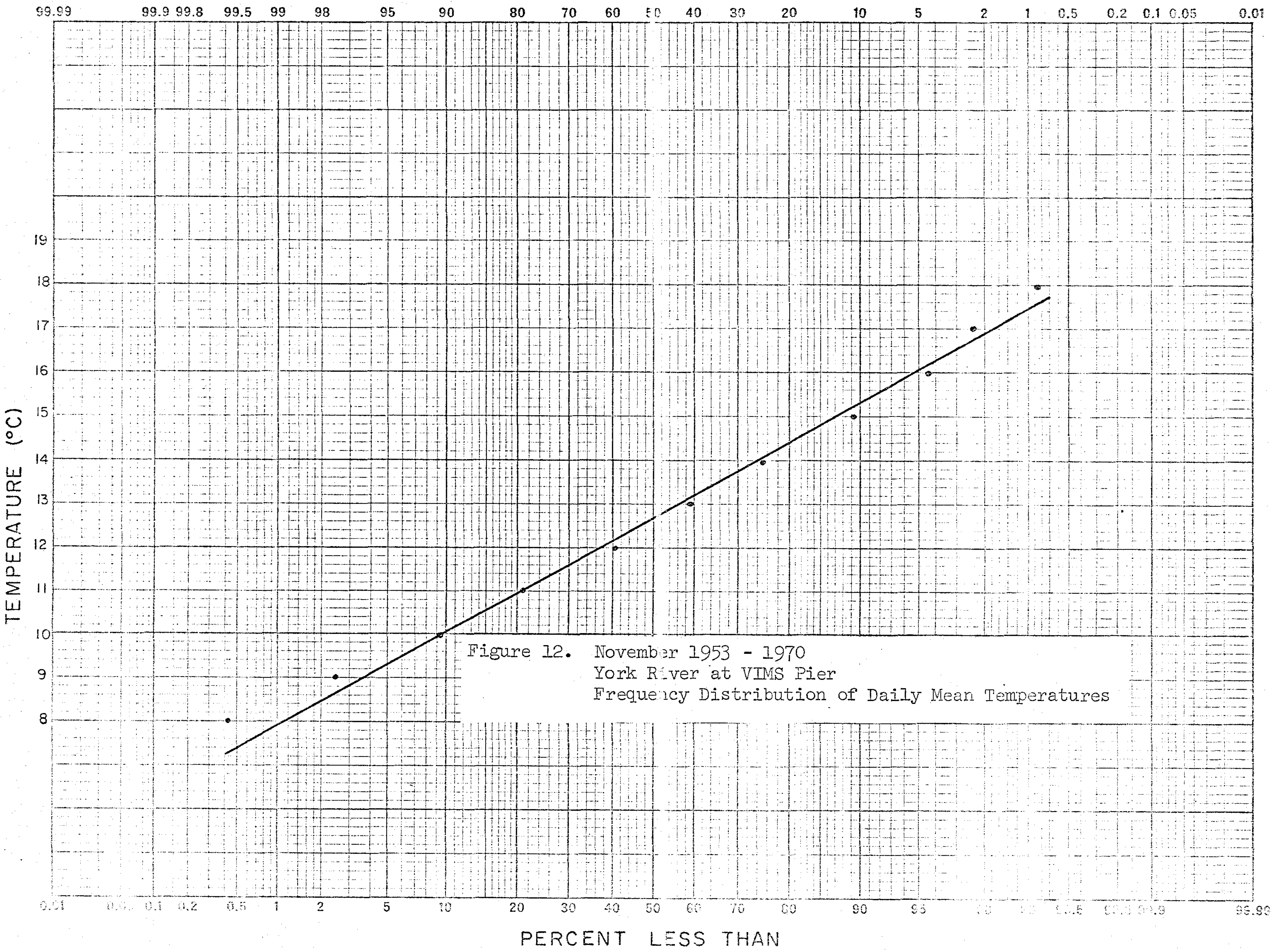


Figure 12. November 1953 - 1970
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

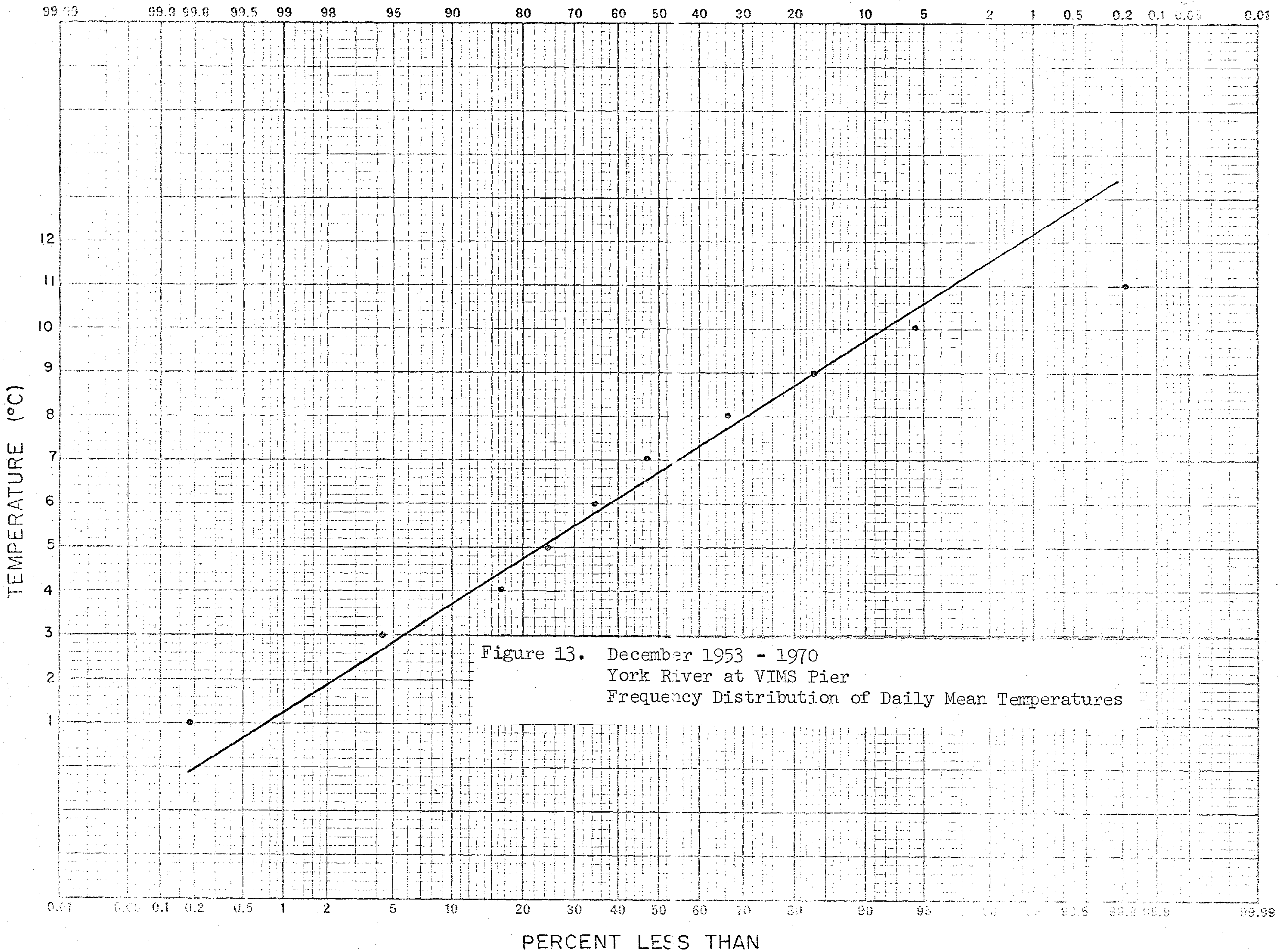


Figure 13. December 1953 - 1970
York River at VIMS Pier
Frequency Distribution of Daily Mean Temperatures

Table 3

High Temperature Extremes:
Number of Days on Which Temperatures ≥ 25°C Were Recorded at VIMS Pier

Month	Temp Interval (°C)	Year 1953	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	Σ	% of Total Days
Jun	25-26		12	11	15	17	3	16	19	7	11	13	*	1	6	13	14	13	18	8	197	39.32
	26-27		3	5	11	17		12	7	3	2	6	*		1	1	5	7	6	5	91	18.16
	27-28		1		5	13		11	1	2		3	*		1			4	1	3	45	8.98
	28-29				1	9		6					*					2			18	3.59
	29-30					2		1					*					1			4	.80
Jul	25-26	12	27	14	27	25	25	14	28	21	27	25	*	30	25	27	25	20	26		398	75.95
	26-27	29	21	23	27	30	23	23	28	20	23	29	*	21	29	17	24	30	20		417	79.58
	27-28	24	8	26	13	22	10	20	13	12	8	21	*	4	19	4	13	23	8		248	47.33
	28-29	15	4	20	5	5	5	20	4	10		12	*	1	8		4	11	3		127	24.24
	29-30	1	1	9	1		2	7		6		2	*		2			2			33	6.30
	30-31			1			1	4		2			*								8	1.53
Aug	25-26	27	28	14	28	16	16	8	19	15	31	25	30	25	23	23	11	31	14		384	68.94
	26-27	25	21	22	19	17	27	14	25	24	23	30	17	26	16	15	22	29	29		401	71.99
	27-28	19	4	26	10	14	19	15	17	24	12	20	2	14	8	4	24	12	21		265	47.58
	28-29	7	1	19	4	6	8	22	9	12	1	7		3			12		8		119	21.36
	29-30	1		10	1	2	2	14		2							3				35	6.28
	30-31			6				7									1				14	2.51
	31-32			2																	2	.36
Sep	25-26	6	17	11	8	22	9	14	18	4	12	9	12	16	7	4	5	13	*		187	37.33
	26-27	7	9	3	7	16	3	9	9	10	4	3	8	6	6			8	*		108	21.56
	27-28	5	4	1	5	4		11	5	12	1		1	2	1			3	*		55	10.98
	28-29	5	3		3			10	1	12									*		34	6.79
	29-30	1						2	1	9									*		13	2.59
	30-31									3									*		3	.60
Oct	25-26		2					9													11	2.12

these distributions to detect changes in the frequencies of extreme temperatures.

Thus far in this discussion it has been implicitly assumed that the VIMS pier temperature recorder has been adequately maintained and accurately calibrated throughout the period of record. There is some uncertainty about this, however, particularly for recent years (John Boon, personal communication), and it was considered advisable to compare VIMS pier records with other available temperature records. Table 4 provides such comparisons with measurements obtained by Patten and his associates during their various studies conducted at a station 300 m off the end of VIMS pier, and with measurements of surface water temperatures made by Mackiernan at the end of the pier. The last column in the table indicates the percent of the measurements obtained by these investigators, during any one year, that fell between the corresponding daily maximum and minimum temperatures recorded by the Foxboro unit. As the Table shows, correspondence between the sets of measurements was generally close, but in no year was there complete agreement. However, since disagreements were on the whole infrequent, they could be attributed to random errors introduced by the individuals interpreting the instruments employed or to the slight differences in the depths at which the independent measurements were made. The extent of agreement was essentially the same

Table 4

Calibration of the VIMS Pier Unit
vs
Independent Temperature Readings

Year	Station	Depth	Investigator	No. Independent Measurements Taken	No. Independent Measurements Between VIMS Pier Max. and Min. for Same Date	Percent of Independent Measurements Between VIMS Pier Max. and Min. for Same Date
1960	300m off VIMS Pier	2 ft.	Patten and Associates	22	21	95.5%
1961	"	"	"	30	25	83.4%
1962	"	"	"	9	7	77.9%
1966	VIMS Pier	Surface	Mackiernan	17	14	82.4%
1967	"	"	"	43	41	95.4%

in the period 1966-67 as it was in the period 1960-61, implying that the calibration of the Foxboro unit had remained stable during the intervening years.

Another consideration relevant to the VIMS pier temperature measurements is their relationship to temperature conditions inthe lower York River as a whole. Accordingly comparisons have been made between VIMS pier values and values obtained in the open water at mile 0 and mile 5. Most of the latter measurements were made during surveys conducted by the Departments of Ichthyology and Crustaceology or by the Department of Ecology and Pollution at VIMS. Table 5 shows that the VIMS pier measurements corresponded closely with the surface temperatures measured at both of the open water stations, and less closely, as is to be expected, with the bottom temperatures. Of the open water surface temperatures that did not fall within the corresponding VIMS pier ranges, most were above the pier ranges. This is probably attributable to the fact that the VIMS pier measurements were made at 5 ft. depth and not at the surface.

Thermal stratification usually exists for most of the year in the lower York River, tending to be strongest in the spring and summer periods when the water is warming or is already at the seasonal maximum. A typical spring or summer temperature profile, shown in Figure 14 for June 7, 1971, has been drawn from data obtained by the Department of Physical Oceanography. During the late summer and autumn,

Table 5

Comparison of VIMS Pier Temperature Readings with Readings from Other Stations in the Lower York River

YEAR	STATION							
	Mile 5 Surface		Mile 5 Bottom		Mile 0 Surface		Mile 0 Bottom	
	Number of Readings	Number within VIMS Pier Range for Same Date	Number of Readings	Number within VIMS Pier Range for Same Date	Number of Readings	Number within VIMS Pier Range for Same Date	Number of Readings	Number within VIMS Pier Range for Same Date
1955					4	4		
1956	8	8	8	6	7	7	7	6
1957	9	8	9	7	8	8	7	6
1958	12	11	12	9	12	11	12	8
1959	8	7	8	5	7	7	7	4
1960	11	10	11	9	11	10	11	8
1961					10	7	9	5
1962					9	7	8	3
1963					11	9	11	6
1964					7	5	7	6
1965					12	10	12	7
1966					11	10	11	10
1967	3	3	1	1	12	10	12	11
1968	10	5	10	6	11	11	11	8
1969	10	9	10	10	10	10	10	10
1970					12	10	12	8
1971	3	3	3	1	7	6	7	4
TOTAL	74	64	72	54	161	142	154	110
% within		86.5		75.2		88.3		71.5
% above		12.2		12.4		8.7		7.1
% below		1.3		12.4		3.0		21.4

when the water is cooling, periods of homothermy and also of inverse stratification occur, as shown in Figure 14 for September 22, 1971. During the winter, periods of weak stratification, as shown for December 14, 1971, can occur, as can periods of homothermy or inverse stratification, as a function of prevailing weather conditions.

The VIMS pier temperature records can therefore be regarded as being closely representative of the surface temperature conditions of the lower York River, except during periods of strong thermal stratification when surface temperatures differ significantly from temperatures at 5 ft. depth, and except for areas in the river, such as near the present VEPCO effluent (Warinner and Brehmer, 1966), where localized influences on temperature conditions prevail. If the future VEPCO effluent affects only the surface temperature conditions of the lower York River as a whole (Nystrom et al., 1971), its influence will not necessarily be detectable in the records obtained at the VIMS pier station.

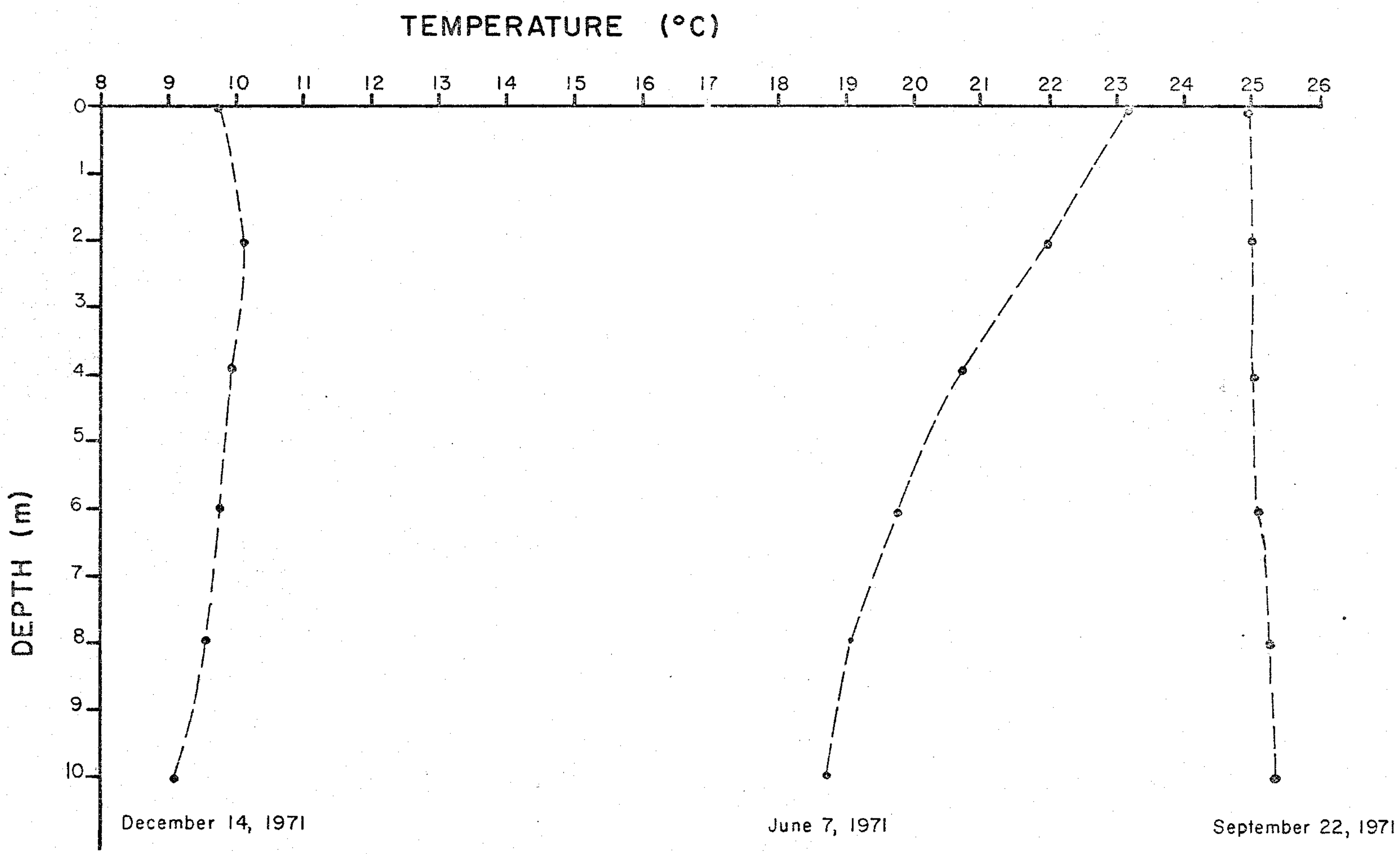


Figure 14. York River Temperature Profiles at Mile Point 4.8

Salinity

The salinity structure of the lower York River is influenced by the interaction of the freshwater discharge with the tidal flux. Salinity gradients between the surface and bottom waters tend to increase with increasing freshwater discharge in the winter and spring, and to decrease in the summer and fall when freshwater discharges are reduced (Brehmer, 1970). Figure 15 presents three salinity profiles for mile 4.8 in the York River, selected from data supplied by the Department of Physical Oceanography. Surface salinities in the lower York normally range between 15 and 25‰, while bottom salinities normally range between 17 and 27‰, according to records maintained by the Departments of Ichthyology and Crustaceology. The magnitude of the salinity change with distance downstream in the lower York increases with increasing freshwater discharge, which results in "compression" of the estuary (Brehmer, 1970). Data obtained by the Department of Physical Oceanography for 1971 show a change in surface salinity of 0.22‰ from mile 4.8 to mile 0 on September 2, compared to a change of 2.45‰ on December 17.

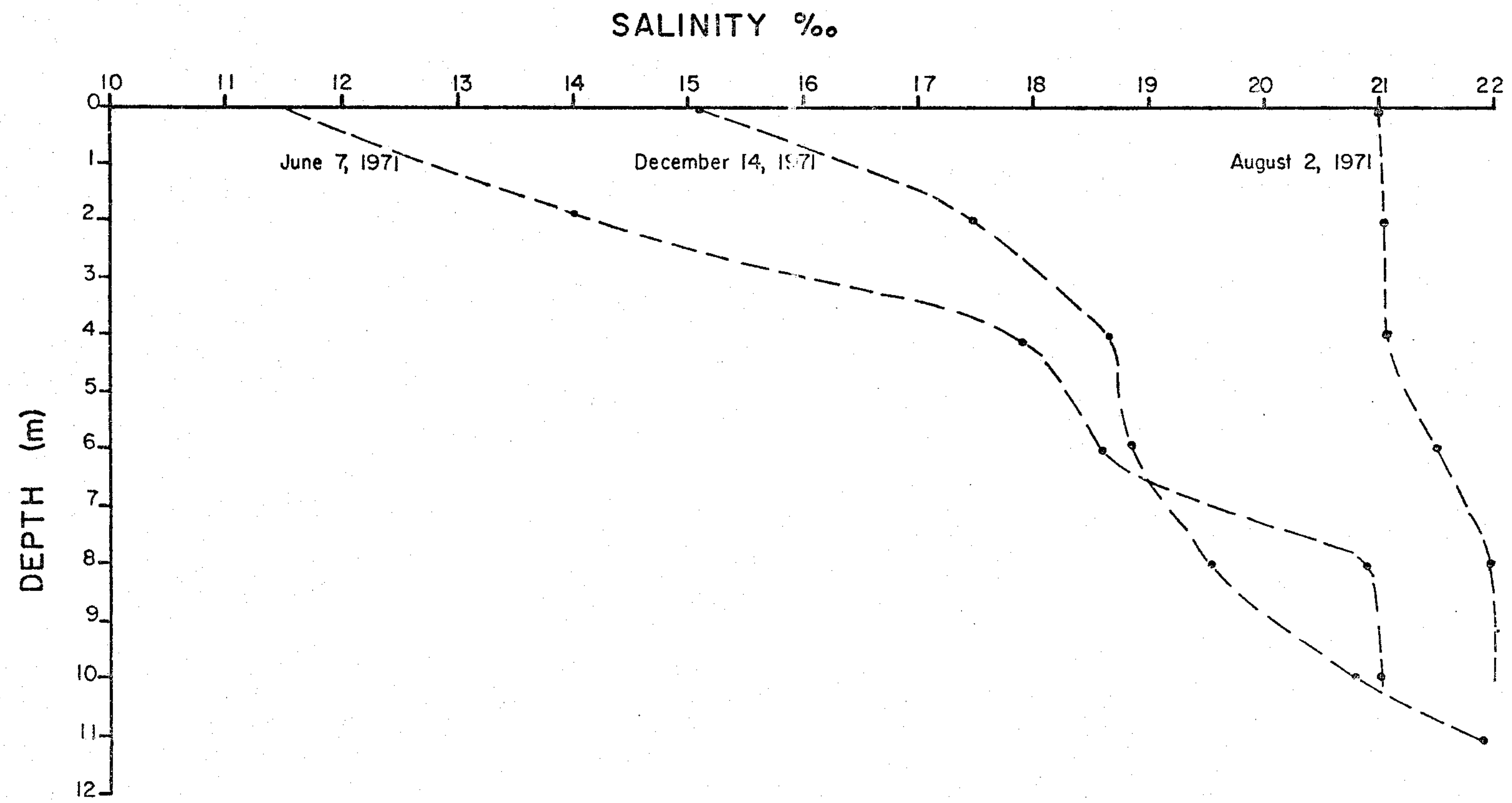


Figure 15. Salinity Profiles at Mile 4.8 in the York River

Dissolved Oxygen

Dissolved oxygen concentrations in an estuarine system are influenced by the solubility of oxygen as determined by the ambient salinity and temperature conditions, as well as by the biotic processes of photosynthesis and respiration. In the lower York River, surface concentrations of dissolved oxygen generally exceed bottom values, due to greater photosynthetic activity near the surface and higher salinity and respiration in the bottom layers (Brehmer, 1970). Likewise, the dissolved oxygen levels near the surface usually exceed 80% of the saturation values, while levels near the bottom are sometimes far below saturation. Figure 16 presents dissolved oxygen depth profiles measured by the Department of Physical Oceanography at mile 3.6 on June 7, and December 17, 1971. The June profile exhibits oxygen depletion in the lower layers to less than 40% saturation, while the December profile shows essentially no change with depth. Examination of dissolved oxygen data available from various sources at VIMS indicates that in the summer months of June, July and August the largest gradients of dissolved oxygen concentrations with depth as well as the lowest bottom water dissolved oxygen concentrations occur. Figure 17 illustrates this pattern in a plot of surface and bottom dissolved oxygen concentrations measured during the study conducted by Brehmer (1970).

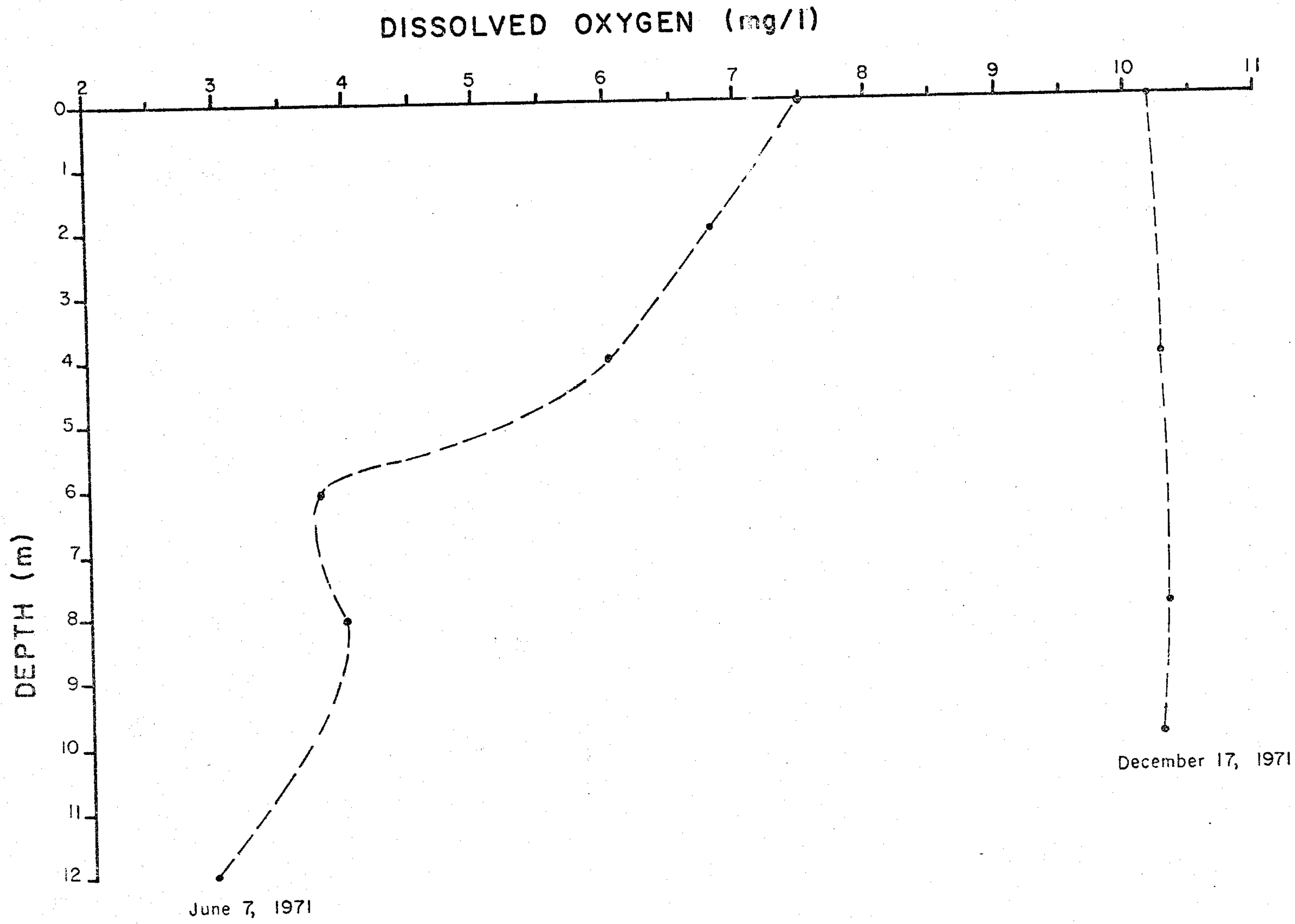


Figure 16. Dissolved Oxygen Profiles at Mile 3.6 in the York River

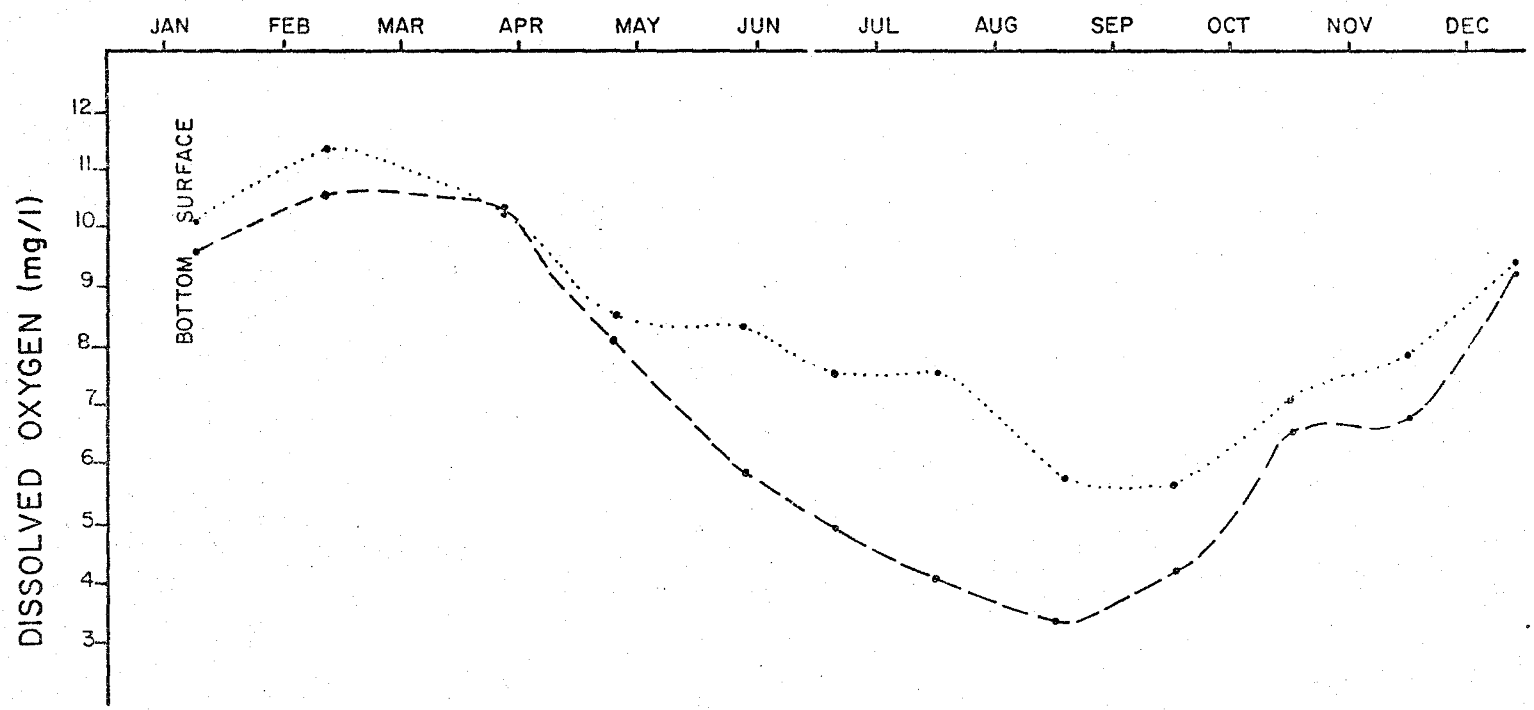


Figure 17. Surface and Bottom Dissolved Oxygen Concentrations Measured at Mile 5 in the York River in 1969.

Alkalinity and pH

Proximity to the ocean exerts a stabilizing effect on these two parameters. Thus at stations in the lower York River, the ranges observed are narrower than at stations further upstream. Table 6 presents the results obtained in the study conducted by Brehmer (1970), for a station at mile 5.

Table 6

Alkalinity and pH Levels Recorded at Mile 5 in the York Estuary

Year			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
	(Day)									(30)	(25)	(23)	(21)	
1967	ALK meq/l	1m								1.63	1.63	1.60	1.60	
		Bottom											1.60	
	pH	1m								8.1	7.8	7.6		
		Bottom												
1968	(Day)		(4)	(7)	(6)		(17)	(14)	(16)	(13)	(10)	(9)	(6)	(11)
	ALK meq/l	1m	1.45	1.34	1.52		1.61	1.55	1.56	1.60	1.76	1.63	1.58	
		Bottom	1.45	1.34	1.52		1.60	1.48	1.55	1.60	1.70	1.64	1.66	
	pH	1m	7.7	7.9			7.9	8.0	7.7	7.8	7.6	7.7	7.7	7.8
		Bottom	7.4	7.3			7.4	7.7	7.6	7.5	7.5	7.4	7.9	
1969	(Day)		(8)	(11)	(25)	(23)	(26)	(19)	(15)	(18)	(16)	(14)	(14)	(11)
	ALK meq/l	1m	1.61	1.56	1.51	1.43	1.56	1.31	1.58	1.58	1.72	1.57	1.70	1.70
		Bottom	1.61	1.56	1.56	1.63	1.69	1.68	1.67	1.65	1.63	1.62	1.66	1.70
	pH	1m	8.0	7.4	8.0	8.0	7.9	8.0	7.9	7.9	7.6	7.8	7.9	7.4
		Bottom	8.0	7.6	7.7	7.6	7.3	7.8	7.5	7.6	7.5	7.7	7.9	8.0

Nitrogen

Results of determination of various forms of inorganic and organic nitrogen in the lower York River are presented in Table 7. From these data it is apparent that the most abundant form of inorganic nitrogen in both the surface and the bottom layers was usually ammonia, while nitrate tended to be second in abundance, and nitrite third. The 1968 and 1969 data, obtained by Brehmer (1970), show erratic fluctuations in amounts present from month to month, and maximum levels occurring in the fall. Organic nitrogen forms also fluctuated widely, with the soluble fraction usually more abundant than the particulate fraction.

Recent studies carried out by Zubkoff and Warinner (unpublished) on nitrate and nitrite levels at mile 0 indicate that wide fluctuations can occur from week to week as well as from month to month. Maximum levels were once again found in the fall.

Table 7

Nitrogen Concentrations Recorded at Mile 5 in the York River (µg-at/l)

Year			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960 (Patten)	NO_3	Surface (2 dates)							1.03	4.37	0.00	3.40	6.72	
									4.00	0.00			0.92	
1961 (Patten)	NH_3	Surface (2 dates)		2.30	1.15	4.95								
				.88	2.00	1.98								
		Bottom (2 dates)		.80	2.47	1.30								
				1.64	2.76	2.31								
	NO_3	Surface (2 dates)		0.3	0.7	0								
				0.9	1.8	0.3								
		Bottom (2 dates)		0.3	0.8	0								
				0.1	1.3	0.4								
1967 (Brehmer)	NH_3	1m								2.00	14.0	10.0	12.0	
		Bottom											12.0	
	NO_2	1m								.10	.20	.50	.25	
		Bottom											.25	
	NO_3	1m								.25	.55	2.15	1.70	
		Bottom											1.70	
	Sol. Org.	1m								4.00	12.5	5.20	2.20	
		Bottom											2.20	
	Part. Org.	1m								6.90	6.80	1.90	2.30	
		Bottom											2.30	
	Tot. Org.	1m								10.9	21.1	7.10	4.50	
		Bottom											4.50	
1968 (Brehmer)	NH_3	1m	10.0	8.00	2.00		10.0	20.5	4.00	10.0	24.0	20.0	24.5	6.00
		Bottom	10.0	8.00	2.00		2.0	8.00	4.00	10.0	22.0	16.0	18.0	6.00
	NO_2	1m	.15	.20	.20		.15	.20	.25	.05	.35	.75	.80	.35
		Bottom	.15	.20	.20		.10	.20	.25	.05	.30	.50	.75	.35
	NO_3	1m	2.10	2.75	.80		.70	.70	1.45	.15	.74	1.90	3.60	5.60
		Bottom	2.10	2.75	.80		1.20	.80	.70	.05	.71	1.85	2.90	5.60
	Sol. Org.	1m	11.5		11.2		10.5	10.0	18.5	6.20	4.50	3.50	2.50	12.5
		Bottom	11.5		11.2		14.2	18.5	18.5	28.5	8.50	16.5	6.30	12.5
	Part. Org.	1m	3.20		8.50		5.90	7.40	10.3	9.20	3.00	3.50	2.60	5.70
		Bottom	3.20		8.50		5.90	8.00	6.3	9.70	3.50	3.50	4.00	5.70
	Tot. Org.	1m	14.7	6.20	19.7		16.4	17.4	28.8	15.4	7.50	7.00	5.10	18.2
		Bottom		6.20	19.7		20.1	26.5	24.8	38.2	12.0	20.0	10.3	18.2

Table 7 (continued)

Nitrogen Concentrations Recorded at Mile 5 in the York River (μg-at/l)

Year			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1969 (Brehmer)	NH_3	1m	8.00	4.00	6.00	8.00	4.00	4.00	8.00	4.00	8.00	1.20	12.0	4.00
		Bottom	8.00	4.00	2.00	4.00	4.00	4.00	12.0	2.00	6.00	4.00	18.0	8.00
	NO_2	1m	.25	.30	.20	.05	.20	.10	.05	.35	2.40	1.50	.89	.66
		Bottom	.25	.30	.25	.10	.30	4.0	.20	.45	4.15	1.40	1.12	.46
	NO_3	1m	.25	.50	1.30	.15	.25	.30	.10	.50	1.30	1.35	6.16	18.2
		Bottom	.25	.50	2.30	.30	.10	1.35	.35	2.05	1.30	1.75	4.76	24.7
	Sol. Org.	1m	14.5	6.00	45.0	2.20	24.5	12.2	11.5	2.00	4.00	.22	1.30	12.3
		Bottom	14.5	6.00	32.5	2.00	28.5	12.2	3.20	22.5	14.2	22.5	2.30	7.3
	Part. Org.	1m	6.30	14.5	13.2	8.20								
		Bottom	6.30	14.5	7.50	6.20								
	Tot. Org.	1m	20.8	20.5	58.2	10.4	34.9		57.3	6.70	8.00	9.30	53.0	55.0
		Bottom			40.0	8.20	33.7		42.7	25.3	15.3	23.3	44.0	60.0

Phosphorus

Table 8 presents data for soluble and total phosphorus in surface and bottom waters at mile 5 in the York River. As with the nitrogen data, large month to month fluctuations are evident. However, there does appear to be a consistent trend of increasing phosphorus levels during the summer, followed by a decline in the fall. The data for 1960 and '61 appeared in various publications of Patten and his associates, while the 1967, 68, and 69 data are from Brehmer (1970).

Unpublished data made available by Zubkoff and Warinner for mile 0 indicate that changes in orthophosphate levels of more than four fold can occur within a week's time during the fall. Winter and spring levels were much lower than fall levels.

Table 8

Phosphorus Concentrations Recorded at Mile 5 in the York River (μg-at/l)

Year			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1960 (Patten)	Surface	Soluble	.12	.02	.07	.08	.07	.09	.26	.62	.66	2.26	.46	.28
		Total	.38	.48	.52	.53	.65	.79	1.15	1.26	.70	2.26	.68	1.39
1961 (Patten)	Surface	Soluble	.15	.127	.331	.143	.099	.500						
		Total	1.16	1.596	1.254	1.73	.984	1.375						
1967 (Brehmer)	1m	Soluble												
		Total								1.74	1.43	1.94	1.50	
	Bottom	Soluble												
		Total											1.50	
1968 (Brehmer)	1m	Soluble	.60	.15	.15		.49	.55	1.07	1.28	1.53	1.15	.82	
		Total	1.20	1.00	1.00		1.05	1.57	1.95	2.66	3.08	2.24	1.87	1.73
	Bottom	Soluble	.60	.15	.15		.33	.60	1.30	1.32		1.30	1.06	
		Total	1.20	1.00	1.00		.97	1.46	2.07	2.96	3.00	2.38	1.97	1.73
1969 (Brehmer)	1m	Soluble	.18	.33	1.32	.35	.25	.35	.64	1.08	2.95	.99	1.12	.37
		Total	1.50	1.85	2.17	1.32	1.50	2.27	2.93	2.40	5.00	2.19	1.48	1.25
	Bottom	Soluble	.18	.33	23.1	.35	.44	.76	.94	1.58	1.32	.70	.75	.30
		Total	1.50	1.85	34.0	1.43	1.55	2.10	2.57	2.83	2.87	2.13	1.56	1.25

Chlorophyll a and Transparency

Chlorophyll a was used as an index of phytoplankton biomass in the study by Brehmer (1970). Table 9 presents the data obtained in that study, along with Secchi disk transparencies measured concurrently. A negative relationship between Secchi disk depth and chlorophyll a concentration is suggested. Recent determination by Zubkoff and Warinner at mile 0 yielded chlorophyll a levels similar in magnitude to the levels determined by Brehmer.

Table 9

Chlorophyll _a_ and Secchi Disk Depth Readings
Recorded at Mile 5 in the York River

Year		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1967 (Brehmer)	Chl _a_ µg/l 1m								2.90	5.80	2.40	2.20	
	Bottom											2.20	
	Secchi Depth											2.5m	
1968 (Brehmer)	Chl _a_ µg/l 1m	2.90	4.90	7.50		4.30	3.60	5.40	14.1	3.90	2.30	2.90	5.10
	Bottom					2.20	3.00	2.00	14.4	3.00	2.40	1.80	5.10
	Secchi Depth	1.8m	1.8m	1.5m		2.1m	2.9m	2.3m	1.2m	2.0m	1.8m	2.1m	
1969 (Brehmer)	Chl _a_ µg/l 1m	9.00	10.2	4.10	5.90	12.2	12.0	12.4	6.30	10.0	3.20	2.90	6.40
	Bottom			6.10	7.80	5.80		8.8	3.70	9.70	3.20	2.70	9.70
	Secchi Depth	1.4m	0.8m	2.4m	2.3m	1.8m	1.5m	1.5m	1.7m	1.5m	1.4m	1.8m	1.1m

Miscellaneous Pollutants

The Virginia Water Control Board has made a few determinations of levels of certain heavy metals and pesticides and of coliform concentrations in the lower York River. Table 10 presents the metal and pesticide data, which indicate that levels of most of these substances were near or below the limits of detection of the methods employed. The coliform determinations indicated that with few exceptions densities of total coliforms were lower than 30/100 ml, and densities of fecal coliforms were lower than 100/100 ml.

A study of mercury levels in bottom sediments of the James, York, and Rappahannock rivers (Huggett, Bender, and Slone, 1971) yielded a level of 2.02 µg Hg/g of sediments for a station at mile 5 in the York. Most of this was associated with the organic fraction of the sediment. Of the three rivers, the York had the highest average mercury content for all sediment samples collected (1.49 ppm), but statistical analysis yielded no significant difference among the rivers.

Table 10

Heavy Metal and Pesticide Concentrations
Recorded in the Lower York River

River Mile	Date	Depth	Metals (mg/l) Cr	Zn	Cu	Mn	Hg	Pb	As	Pesticides (µg/l) Chlorinated Pesticides	DDT	Thio-phosphate Pesticides
1.38	3-19-70	m*	.01	.02	.01	.04						
1.88	3-19-70	m	.03	.02	.03	.04						
2.92	3-19-70	m	.02	.01	.02	.06						
1.88	5-7-70	m	.01	.01	.02							
2.92	5-7-70	m	.02	<.01	.03							
1.38	9-10-70	m					<.0005					
1.88	9-10-70	m					<.0005					
2.92	9-10-70	m					<.0005					
1.88	6-28-71	m					.0006	<.01	<.005	<.1	.05	<.1
1.88	8-1-71	m								<.1		<.1

* m = mid

Literature Cited

Brehmer, M. L. 1970. Biological and Chemical Study of Virginia's Estuaries. OWRR Project No. B003 Va.

Huggett, R. J., M. E. Bender, and H. D. Slone. 1971. Mercury in sediments from three Virginia estuaries. Chesapeake Sci. Vol. 12: 280-282.

McHugh, J. L. 1959. Daily maximum and minimum water temperatures, Gloucester Point, Virginia, May 28, 1952 to December 31, 1958 Inclusive. VIMS Special Scientific Report No. 16.

Nystrom, J. B., J. Larsen and G. E. Hecker. 1971. Hydrothermal Model Studies for Yorktown Power Station, Virginia Electric and Power Company. Holden, Mass. Alden Research Laboratories.

Patten, B. C. - see Phytoplankton section.

Warinner, J. E. and M. L. Brehmer. 1966. The effects of thermal effluents on marine organisms. Air and Water Pollut. Int. J. Vol. 10: 277-89.

Section II

Phytoplankton and Primary Productivity

by R. A. Jordan

Phytoplankton

Studies yielding information on the species composition and seasonal changes of the phytoplankton community of the lower York River began with a series of 24 sampling cruises conducted in the Chesapeake Bay region between January 1960 and January 1961 (Patten et al., 1963). Two stations were located in the lower York River, one at a point 300 m off the VIMS pier and one at the river mouth. Samples for net phytoplankton determinations were obtained from oblique hauls with a #20 bolting cloth net attached to a Clarke-Bumpus sampler. The plankton concentrates were preserved with 4% formalin, and used to prepare permanent slide mounts from which species identifications, mostly of diatoms, and a few dinoflagellates, and notations of relative abundance were made. Because of the procedure used, it is more precise to designate the organisms found as the preservable net phytoplankton, since certain unarmored flagellates are destroyed by the preservative. Cell counts were not performed.

Samples for total phytoplankton determinations were taken from the surface water with a Kemmerer bottle. Aliquots of unconcentrated, live material were examined in Sedgwick-Rafter cells, and species determinations, in many cases tentative, were made. In addition, morphological units (cells, chains, or colonies) were counted. Organisms encountered included flagellates of several groups (Euglenophyta, Chlorophyta, Chrysophyta, Pyrrophyta), as well as diatoms. These organisms constitute the phytoplankton that could be identified by sight in living mounts and represent actually a fraction of the total phytoplankton, since many species were missed in this counting procedure (Patten 1966).

The species lists for both net and total phytoplankton identified in the 1960 samples are included in Patten et al., 1963. However, the York River data are pooled with data from the Chesapeake Bay stations, so the composition of the river flora is obscured. The abundance data for two groups of species, diatoms and flagellates, are presented for each station separately, and indicate that in the York River, diatom populations dominated in the winter and early spring, while flagellates peaked in the summer. Population levels of both groups were generally low in the fall. On an annual basis, it was concluded that diatoms and flagellates are of comparable significance in the surface waters of the lower Chesapeake Bay region. This conclusion departed from results of earlier investigations of Chesapeake Bay phytoplankton (Wolfe et al., 1926, Cowles 1930, and Morse 1947), in which diatoms were found to be generally dominant, especially in the winter, and in which a bimodal pattern of abundance, with spring and autumn peaks, was noted. This discrepancy was attributed to the exclusive use of net collections in the earlier studies. It was further noted that in the experience of the present investigators, nannoplankton in most seasons numerically exceeded the net plankton by as much as 10^3 or more times.

Various sets of plankton data from the 1960 cruises have appeared in several publications. In Patten and Warinner (1961), total counts of morphological units for each "total plankton" sample taken at each station on each cruise are included in one table, and total numbers of taxa recorded are included in a second table. Counts for individual species do not appear. Patten (1961) consists of separate tables of the "total phytoplankton" data for each sampling station. These are the same data for which all stations are combined in Patten et al., 1963. Thirty five species of flagellates are listed for the lower York River, and the occurrence or degree of dominance of each species on each sampling date is indicated. Eleven different species are indicated as dominant at some time of year. Cell counts of individual species are not included, and many identifications are tentative at the genus level.

Diatom data from the 1960 net samples appear in Mulford (1962) which also includes results from similar samplings performed in 1961. The total number of species collected from the lower York River during this two year period was 144, and of these, 22 species were dominants at some time of year. Temperature and salinity ranges within which each species was found are recorded. Data for species of the genus *Ceratium* collected in the net samples are included in Mulford (1963a). Only three species are indicated as having been found in estuarine waters, but one of these, *C. furca*, dominated the preservable net phytoplankton in June 1960.

Additional "total phytoplankton" species determinations were performed during a productivity study conducted between June 1960 and June 1961 (Patten 1966). One station, located 300 yards off the VIMS pier, was used and samples from five depths (surface, 2 ft., 6 ft., 10 ft., and bottom) were examined in Sedgwick-Rafter cells during each of 37 productivity runs. Identifications and counts of morphological units of live diatoms, dinoflagellates, and microflagellates were attempted, and consequently many species were missed.

In all, 96 taxa were recorded, and these are listed in a table that indicates relative abundance of each taxon at each depth on each sampling date. Actual morphological unit counts from one of the sampling dates have been published in Patten (1963). Using the species data from this study, Patten (1966) divided the annual phytoplankton cycle into five parts, summer (SU, mid-June to mid-September), fall-winter (FW, mid-September through January), winter-spring (WS, February and March), spring bloom (SB, first half of April), and post bloom (PB, mid-April to mid-June), and listed the dominant species found in each part. On an annual basis, flagellates dominated (at least according to his numerical indices) at all times, particularly in the surface layers. Diatom populations did not achieve as large numbers in the winter of 1960-61 as they had in the winter of 1959-60 (reported in Patten et al., 1963). The vertical distribution of organisms was homogeneous during the FW and WS periods, but was stratified during the SU, SB, and PB periods, with greater numbers of individuals near the surface. Diatoms tended to increase in relative importance with increasing depth, during periods of stratification.

Between June 1961 and July 1962, the seston at the VIMS pier station was studied as a whole, and apparently no "total phytoplankton" determinations were made (Patten et al., 1966). A figure in this publication indicates that the VIMS pier station is in an eddy system during ebb tide, and therefore may not be representative of the lower York River as a whole.

Mulford(1963b) presents data for preservable net phytoplankton for samples taken at the mouth of the York River from January - December 1962. Some 55 diatom species and 10 dinoflagellate species were collected at the river mouth station--substantially fewer diatoms than in the previous two years. Fifteen diatom species are listed as dominants.

From June 1962 - May 1963, "total phytoplankton" counts were once again performed on samples taken from 0.6 m and 3 m depths at the VIMS pier station (Fournier 1966). Dominant species are listed, and the annual abundance cycles of flagellates and diatoms are plotted, this time in terms of cells per ml. The flagellates were dominant from June through December, and in May, but were overshadowed at 0.6 m by diatoms from late December to late April--a pattern similar to that reported for 1960 (Patten et al., 1963). At 3 m flagellates were always numerically more important than were diatoms.

From June - August 1963, "total phytoplankton" counts were performed in conjunction with eight productivity experiments, and included depths of 0, 2, 6, 10, 14, 18, and 22 ft. (Patten and Chabot 1966). The species and their numerical abundances are tabulated in morphological units per ml. Various species of flagellates dominated the flora during this period, while Skeletonema costatum was the only diatom species that was consistently important. The depth distribution of species and individuals was nonuniform more often than it was uniform.

Thus from January 1960 through August 1963, a large amount of plankton data was accumulated, and general seasonal patterns of species abundance emerged. Extensive species lists for diatoms were compiled, but are limited mostly to species that were retained by plankton nets. Temperature ranges for most of these species were recorded. Lists of flagellates were also compiled, but are admittedly incomplete since the "total phytoplankton" samples were observed in Sedgwick-Rafter mounts of live material, resulting in underestimation due to counting difficulties, and the formalin used to preserve the net samples destroyed unarmored forms.

During the period August 1963 - September 1966, no phytoplankton sampling programs were undertaken.

There was one study of the effects of temperature increases on phytoplankton productivity (Warinner and Brehmer 1966), conducted between June 1963 and May 1964. The results showed that at low ambient river temperatures (0-5 C), temperature increases of 8 C stimulated productivity and at ambient temperatures of 5-10 C increases of 2.5 - 14 C stimulated productivity. At intermediate ambient temperatures (10-15 C) an increase of 3 C stimulated productivity while increases of 5.6 or 14 C depressed productivity. Finally, at higher ambient temperatures (15-20 C) productivity was depressed by temperature increases greater than 5.6 C , while in the hottest summer months, increase of only 3.5 C depressed productivity. Thus as the thermal tolerance limits of phytoplankton species were approached, they became more sensitive to further temperature increases.

The next major phytoplankton sampling program was conducted by Mackiernan (1968) in the period September 1966 - November 1967. Her samples were taken weekly, from the end of VIMS pier, and in most cases consisted of No. 20 plankton net hauls. Dinoflagellates were studied in detail, while other phytoplankton and zooplankton organisms encountered were recorded incidentally. The dinoflagellates were observed alive, when possible, under higher magnification than was possible with the Sedgwick-Rafter mounts used in the earlier studies. Also, use of live mounts permitted unarmored forms to be determined. The resulting list includes 118 species and varieties, 84 of which were identified with "some certainty", and 43 of which were not previously recorded in Chesapeake Bay. Relative counts of individual species were made, and the resulting tables indicate occurrence and relative dominance of different forms on the separate sampling dates.

In discussing the seasonality of the phytoplankton, Mackiernan divided the year into four floral periods: winter (early December to mid-April), spring (mid-April through May), summer (June through September), and fall (October and November). In common with the results of the earlier studies, she found that diatoms dominated the net phytoplankton during the winter period, followed by dinoflagellate peaks in the spring and summer. Dinoflagellates and, at times, euglenoid flagellates continued to dominate the phytoplankton until the fall when temperatures declined steadily and diatom blooms developed.

Mackiernan divided the dinoflagellate species into five groups; year-round species with constant abundance, year-round species that varied in abundance, winter cold-water species, summer warm-water species, and transition species of the spring and fall. In connection with this categorization, she tabulated temperature ranges for the species that she had found. In considering temperature and salinity as factors that could influence the temporal distribution of phytoplankton species, she concluded that both factors were important, and that certain species may not appear unless both temperature and salinity requirements are satisfied.

Overlapping the Mackiernan study, and extending through March 1969 was a monthly sampling program conducted by Brehmer (1970). A sampling station was located in the lower York River at approximately the fifth river mile, and was sampled for phytoplankton and water quality parameters. Up to five dominant phytoplankton genera were recorded for each month.

Between August 1969 and November 1970, Gibson (1971) processed 10 sets of phytoplankton samples, four of which were taken in the lower York River, near VIMS. Samples were taken from the river surface with a screen sampler, and from 1 m depth with a 1 liter Frautschy bottle, and were preserved with formalin. Settled concentrates were counted, and percent of the total number counted was determined for each species. In all, 98 species were identified, and these are listed in one table, while a second table indicates the occurrence and relative dominance of each of the 36 major species in each sample. Diatoms dominated the flora in the surface samples between August 1969 and June 1970, while dinoflagellates peaked in August 1970. Surface samples not associated with "slicks" generally had higher concentrations of organisms than did the associated 1 m samples, while diversity at the surface was generally less than at 1 m. These results have been confirmed in a study initiated in February 1971 (Stofan *et al.*, 1972), in which four stations have been sampled at the surface, .5 m, and 1 m, and dinoflagellate population densities and species composition have been determined. Surface microlayer samples have exhibited higher cell densities and lower species numbers than have subsurface samples.

Finally, a study of diatom and dinoflagellate spatial and temporal distribution was initiated in September 1971 and is still in progress (J. L. DuPuy, personal communication).

In summary, therefore, comprehensive species lists exist for diatoms and dinoflagellates in the lower York River. Both of these lists were compiled from net plankton samples, and both include data on temperature and salinity ranges associated with the occurrence of each species. Data for nannoplankton species are sketchy at best, but there are indications in the early studies by Patten and associates that nannoplankters are two or three orders of magnitude more abundant than the net phytoplankters. Thus reliable data on the dominant phytoplankton species of the lower York River may still be awaiting a detailed study of the nannoplankton.

The concluding section is an attempt to assemble the existing phytoplankton data in a series of figures and tables that indicate (1) the gross seasonal fluctuations in abundance of major groups of species in the lower York River, (2) the monthly fluctuations in abundance of the species that have been identified, and (3) the species that have been found to dominate the phytoplankton or particular subdivisions of the phytoplankton in any given month.

Figure 1 consists of representative plots of total cell numbers versus month or season for two gross categories of species for two depths in the lower York. The samples were taken at the station 300 m off VIMS pier by Fournier, and the present plots have been adapted from Figure 2 in his paper (1966). The seasonal breakdown is that of Mackiernan (1968).

The flagellate category consists of dinoflagellates as well as the poorly known microflagellates of the nannoplankton, and the plots illustrate the observation of Patten et al. (1963) that flagellates equaled or exceeded

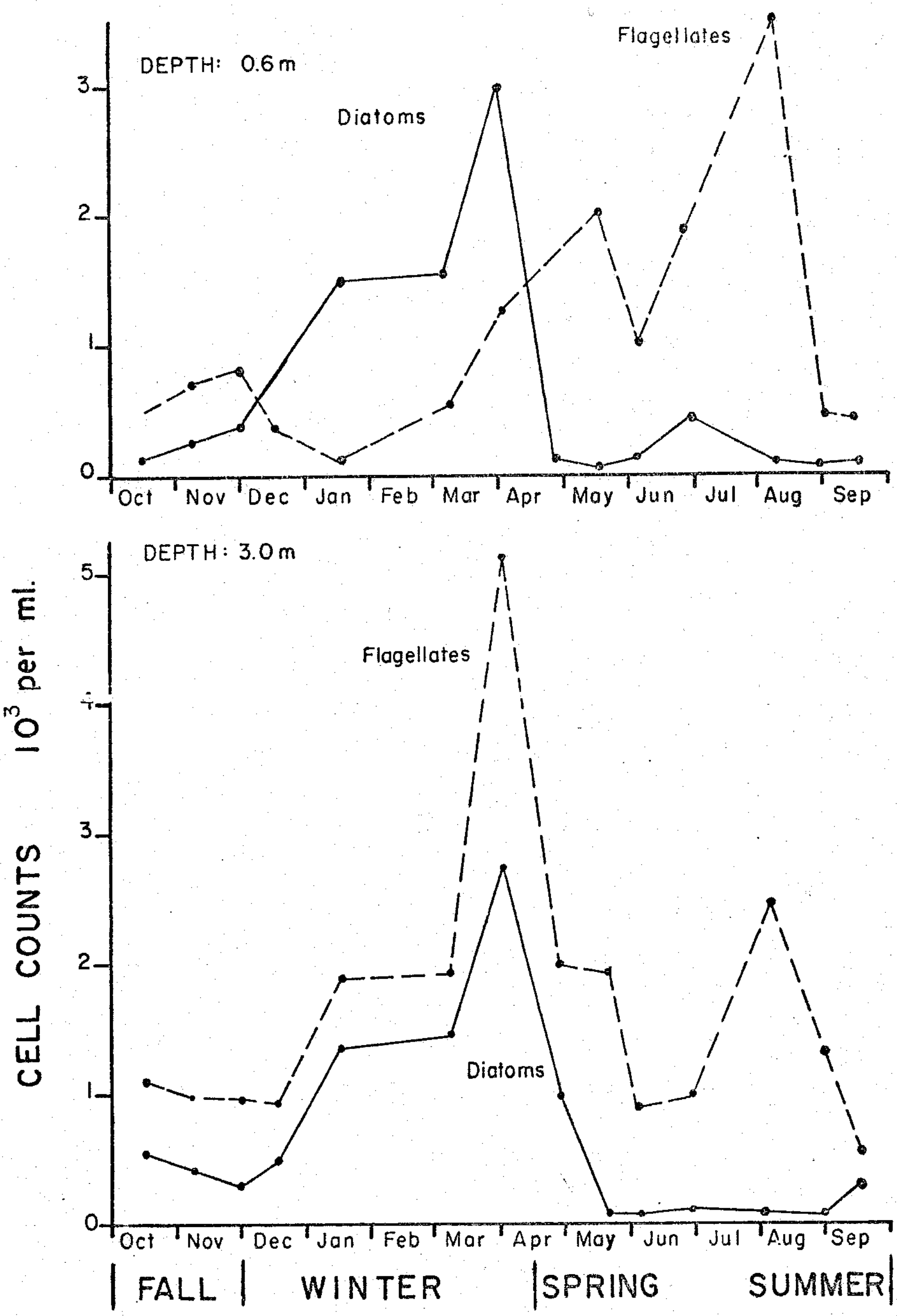


Figure 1. Seasonal changes in phytoplankton abundance at the VIMS pier station, lower York River. Adapted from Fournier (1966), Figure 2, with addition of the floral periods of Mackiernan (1968).

diatoms in abundance during most of the year, but especially in the spring and summer. Diatoms achieved maximum abundance in the winter.

Table 1 shows the temporal distributions reported for organisms of five major taxonomic groups, most of which occur in the nannoplankton. Occurrence as one of the dominant organisms in any given month is signified by a "D". The data for the Cryptophyta, Euglenophyta, Chlorophyta, and most of the Chrysophyceae were taken from the various papers of Patten and his associates, while those for the Cyanophyta were taken from Brehmer (1970). Two members of the Cryptophyta, Chilomonas sp. and Cryptomonas sp., both of which are probably actually groups of species, were reported as frequent dominants of the "total phytoplankton" by Patten. Cryptomonas sp. was recorded as a dominant in Brehmer's study more frequently than was any other organism. The two silicoflagellates, Dictyocha fibula and Ebria tripartita, were recorded incidentally by Mackiernan (1968) and Gibson (1971).

Table 2 summarizes the more extensive distributional data for the dinoflagellates found in the papers of Mackiernan (1968), Patten and his associates, Mulford (1963b), and Gibson (1971). Temperature ranges determined by Mackiernan (1968) are included. The list has been broken down into year round species with essentially continuous distributions, year round species with more scattered distribution, species occurring mostly in one season, and species recorded only once. Once again "D" signifies occurrence as a dominant, but since most determinations were made on net samples, dominance in this case refers to the net phytoplankton. Table 3 is a list of other species recorded by Mackiernan (1968), but for which monthly distributions were not given. In total 108 dinoflagellate species are listed in the two tables. In addition, 31 more "separable forms" were recognized by Mackiernan (1968), but identified only to genus. Thus, relative to the five taxonomic groups listed in Table 1, extensive data exist on the dinoflagellate flora of the lower York River. One reason for the particular interest in the dinoflagellate flora is the bloom phenomenon known as "red water". Blooms of this type, consisting of one or more dinoflagellate species, occur almost constantly in the summer in the lower York River, according to Mackiernan (1968), and during her study eight different species were involved. Six of these were species with distributions essentially restricted to the summer (Table 2).

Table 4 is a compilation of the diatom species recorded in the papers of Mulford (1962,1963b), Patten and associates, Mackiernan (1968), and Gibson (1971). Temporal distributions are indicated, as are temperature ranges when available. The first section of the table includes all of the species that have been listed as dominants (of the net phytoplankton) in any of the papers. The contents of the other sections are as indicated. The total number of species listed is 170, and most of these have either continuous or scattered year round distributions. Most of the species with restricted distributions were encountered in the winter and spring, when the peaks of diatom abundance occurred (Figure 1).

If Tables 1, 2, and 4 are scanned briefly, it becomes apparent that most of the species that have been recorded as dominants of the nannoplankton or of the dinoflagellate or diatom segments of the net phytoplankton have essentially year round distributions. With regard to temperature tolerances, they would be classed as eurythermal species. Thus it would seem unlikely that subtle changes in the temperature regime of the lower York River will exert a significant direct influence on the structure of the dominant phytoplankton community of the river, at least during most of the year. The critical period will be late summer, when water temperatures are highest and when, as Warinner and Brehmer (1966) have shown, the phytoplankton is the most sensitive to further temperature increases. High temperature seems to be one of a set of conditions favorable to the development of red water (Mackiernan, 1968), so the frequency of this phenomenon could be increased by changes in summer temperature conditions.

Table 1. Temporal Distributions of Nanroplankton Species, Lower York River

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se
CRYPTOPHYTA												
Chilomonas sp.	x	D	D	D	x	D	x	D	D	x	D	x
Cryptomonas sp.	x	D	x	x	x	D	x	D	x	D	x	x
Rhodomonas sp.									x	x		
EUGLENOPHYTA												
Eutreptia sp.		x							x	x	x	x
Peranema sp.									x	x	x	
Phacus sp.									x			
CHLOROPHYTA												
Carteria sp.		x										
Dunaliella sp.						x	x	x	x			
Halosphaera viridis					x							
Pyramimonas spp.	x	x	x		x	x	x	x	x	x	x	x
Stichococcus sp.						x			x			
CYANOPHYTA												
Anacystis sp.	x											
Gomphosphaeria sp.									x	x		
CHRYSOPHYTA												
Cl. Chrysophyceae												
Dinobryon setularia			x									
Prymnesium sp.		x										
Unidentified sp. I (Patten)					x	x	x					
Unidentified sp. II (Patten)		x						x			x	
Dictyocha fibula		x		x								
Ebria tripartita			x	x	x	x						

Table 2. Temporal Distributions of Dinoflagellate Species, Lower York River

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
PYRROPHYTA													
Year round species													
Amphidinium fusiforme	x	x	x			x	x		D	x	x	x	
Ceratium furca	x	D	D	D	x	x		x	D	D	D	D	1-27
Ceratium fuscus		x	x	x	x	x	x	x	x	x			2-27
Ceratium tripos				x	x	x	D	D	x	x	x		2-27
Diplopsalis lenticula f. *minor*				x	x	D	x	x	x	x	x	x	1-27
Diplopsalis rotundata			x	x	D	x	x	x	x	x	x	x	1-26
Gonyaulax spinifera	x	x	x	x	x			x	x	x	x	x	3-27
Gymnodinium simplex	x	x		x	x		x	x	x	x	x		
Gyrodinium aureum		x	x			x	x		x	D	D	x	
Katodinium rotundatum			x	x		x	x	x	x		x	x	5-27
Massartia rotundata	x	D	x	x	x	x	x	x	D	D	D	D	
Peridinium marielebourae	x	D	x	x	x	x	x	x	x	x	x	x	1-26
Peridinium pentagonum v. *latissimum*	D	D	D				x	x	x	x	x	D	9-27
Peridinium subinerme	x	x	x	x	x	x	D	x				x	1-22
Peridinium triquetrum	x	x	x	D	D	D	D	x	x				1-18
Polykrikos kofoidi	x	x	x	x	x			x	D	x	x	x	5-26
Prorocentrum micans	x	x	D	D	D	D	D	D	D	D	D	x	1-27
Prorocentrum minimum				x	x	x	x	D	x	x	x	x	2-27
Prorocentrum triangulatum	x	x	x	x		x	x	x		x	x	D	
Other year round species with more scattered distributions													
Amphidinium sphenoides		x	x	x							x		
Ceratium lineatum					x		x	x		x	x		
Dinophysis acuminata	x					x		x		x		x	
Diplopsalis orbicularis	x		x	x	x			x				x	2-20
Gonyaulax diacantha					x			x		x			5-25
Gonyaulax diegensis-digitale	x	D	x							D	D	D	12-27

Table 2 (continued)

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
Gonyaulax unicornis		x	x	x	x	D	D	x					
Gymnodinium splendens	x					x	x	x	x	x	x	x	
Katodinium glaucum	x	x	x	x				x					4-18
Peridinium breve			x	x		x					x		
Peridinium claudicans	x	x	x							x	D	x	8-27
Peridinium conicum	D	x	x							x	x	x	8-27
Peridinium deficiens	x			x	x			x			x	x	5-26
Peridinium depressum	D	x					x	x		x			
Peridinium pentagonum	x	x	x					x	x	x	x	D	8-21
Peridiniopsis rotunda		x					x			x		x	
Warnowia parva			x			x		x	x	x			7-27
Species occurring mostly in the fall													
Dinophysis caudata	x	x	x										7-26
Noctiluca scintillans	x		x									x	8-25
Peridinium curtipes	D	x	x										8-25
Peridinium excentricum		x	x										7-23
Peridinium oblongum "A"	x	x											12-20
Peridinium pellucidum	x	x										D	9-25
Peridinium perbreve	x											x	17-22
Peridinium sp. 8 (Mackiernan)	D	x											17-20
Species occurring mostly in the winter													
Gyrodinium calyptoglyphe		x				x							
Peridinium oblongum "B"				x	D	x							3-13
Peridinium sp. 1 (Mackiernan)					x	x							2-6
Species occurring mostly in the spring													
Ceratium longipes							x	x					
Ceratium macroceros							x	x				x	

Table 2 (continued)

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
Gyrodinium dominans								x	x				
Massartia asymmetrica							x	x					
Peridinium achromaticum							x	x					12-16
Species occurring mostly in the summer													
Cochlodinium heterolobatum									x		D	D	23-27
Exuviella lima								x	x	x	x	x	20-26
Glenodinium foliaceum									x	x	x		20-27
Glenodinium sp. 3 (Mackiernan)									x	x	x		18-27
Gonyaulax monilata											x	x	20-26
Gonyaulax monocantha									x	x	x	x	20-27
Gonyaulax polyedra											x	x	23-26
Gymnodinium nelsoni							x		x	x	x	x	
Gyrodinium pingue								x	D		x	x	20-25
Peridinium quinquecorne											x	x	20-26
Peridinium trichoideum								x	D	D	D	D	20-27
Species recorded only once													
Ceratium arcticum	x												
Ceratium bucephalum								x					
Ceratium minutum					x								
Cochlodinium catenatum											x		
Cochlodinium helicoides										x			
Cochlodinium pupa											x		
Cochlodinium vinctum									x				
Dinophysis acuta								x					
Gymnodinium brevis									x				

Table 2 (continued)

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
Nematodinium armatum								x					
Oxyrrhis marina		x											
Peridinium monospinum											x		
Peridinium pyriforme						x							
Pronoctiluca pelagica						x							
Prorocentrum dentatum								x					
Prorocentrum redfieldi								x				x	

Table 3. Additional Dinoflagellate Species Recorded, Lower York River

Amphidinium carteri
Amphidinium flexum
Amphidinium operculatum
Amphidinium ovum
Amphidinium pellucidum
Cochlodinium achromaticum
Exuviella compressa
Glenodinium danicum
Glenodinium gymnodinium
Gonyaulax alaskensis
Gonyaulax orientalis
Gonyaulax polygramma
Gonyaulax triacantha
Gymnodinium pygmaeum
Gymnodinium variable
Gyrodinium aureolum
Gyrodinium capsulatum
Gyrodinium lebourae
Gyrodinium pellucidum
Gyrodinium spirale
Gyrodinium stratissimum
Peridinium leonis
Peridinium leonis f. matzenauri
Peridinium pallidum
Peridinium punctulatum
Peridinium steinii
Phalachroma kofoidi
Protoceratium reticulatum
Warnowia panamensis

Table 4. Temporal Distributions of Diatom Species, Lower York River

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
CHRYSOPHYTA													
Bacillariophyceae													
Year round species listed as dominants													
Actinocyclus ehrenbergii	x	x	x	x	x	x	x	D	D	x	x	x	2.5 - 29.0
Asterionella japonica	x	D	D	D	D	D	D	x	x		x	x	2.5 - 27.0
Biddulphia mobiliensis	D	x	x	x	x	x	x	x	x	x	x	D	3.6 - 28.5
Cerataulina bergonii	x	x	x	x	D	D	D	x	x	x	x	x	3.5 - 28.5
Chaetoceros compressus	x	x	x	x	x	x	x	x	x	x	D	D	2.5 - 29.0
Chaetoceros danicus	x	D	x	x		x	x	x	x	x	x	x	10.1 - 28.7
Chaetoceros lorenzianus	D	D	x				x			x	x	x	6.9 - 28.5
Coscinodiscus asteromphalus	D	D	x	x	x	x	D	D	D	x	D	x	2.0 - 29.0
Coscinodiscus perforatus	x	x	x	x	x	x	x	x	D	x	x	D	2.0 - 28.1
Ditylum brightwellii	D	D	x	D	x	x	x	x	x	x	D	D	1.7 - 28.5
Nitzschia pungens atlantica	x	x	D	D	D	D	D	D	D	x	x	x	2.5 - 23.1
Rhizosolenia alata	x	x	x	D	x	x	x	x	x	x	x	x	3.8 - 23.2
Rhizosolenia calcar avis	x	x	x	x	D	D	D	x	x	x	x	x	1.7 - 26.8
Rhizosolenia imbricata	x	x		D	D	D	D				x	x	1.7 - 18.0
Rhizosolenia setigera	D	D	D	D	D	D	D	x	x	x	x	x	2.5 - 29.0
Skeletonema costatum	D	x	D	D	D	D	D	D	D	D	D	D	1.7 - 29.0
Thalassionema nitzschioides	x	x	D	D	D	D	D	D	x	x	D	x	2.5 - 29.0
Year round species with essentially continuous distributions													
Actinoptychus undulatus	x	x	x	x	x	x	x	x	x	x	x	x	2.5 - 28.5
Biddulphia rhombus	x	x	x	x	x	x	x				x	x	3.2 - 27.0
Chaetoceros affinis	x	x	x	x	x	x	x	x	x	x	x	x	7.9 - 27.0
Chaetoceros didymus	x	x	x	x	x	x	x		x	x	x	x	6.0 - 16.0
Chaetoceros peruvianus	x	x	x	x	x	x	x	x	x	x	x	x	2.5 - 29.0

Table 4 (continued)

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
Chaetoceros subtilis	x	x	x	x	x	x		x	x	x	x	x	
Cocconeis scutellum	x	x	x	x	x	x	x	x	x	x	x	x	2.0 - 29.0
Diploneis puella				x	x	x	x	x	x		x	x	2.3 - 28.7
Grammatophora marina	x	x		x	x	x	x	x			x		1.7 27.4
Guinardia flaccida	x		x	x	x	x	x	x	x			x	2.0 - 27.0
Gyrosigma balticum	x	x	x	x	x	x	x	x	x		x	x	1.7 - 28.5
Gyrosigma fasciola			x		x	x	x	x	x	x		x	2.0 - 28.5
Leptocylindrus danicus	x	x	x	x	x	x	x		x	x	x	x	2.5 - 28.5
Lithodesmium undulatum	x	x	x			x	x	x	x		x	x	8.1 - 26.0
Melosira jurgensii	x	x	x	x	x	x	x	x	x	x	x	x	1.7 - 29.0
Melosira sulcata	x	x	x	x	x	x	x	x	x	x	x	x	1.7 - 29.0
Nitzschia closterium	x	x	x	x	x	x	x	x	x		x	x	1.7 - 28.5
Nitzschia longissima		x	x		x	x	x	x	x	x	x	x	1.7 - 29.0
Nitzschia paradoxa	x	x	x	x	x	x	x	x	x	x	x	x	1.7 - 28.5
Pleurosigma angulatum	x	x	x	x	x	x	x	x	x	x	x	x	1.7 - 29.0
Rhabdonema adriaticum	x	x			x	x	x	x	x	x	x	x	1.7 - 28.0
Rhaphoneis amphiceros	x	x	x	x	x	x	x	x			x	x	1.7 - 28.7
Rhizosolenia fragilissima		x	x		x	x	x	x		x	x	x	1.7 - 24.7
Surrirella gemma		x		x	x		x	x	x	x	x		2.5 - 27.0
Thalassiosira gravida	x	x	x	x	x	x	x	x	x	x	x	x	
Thalassiosira rotula		x	x	x	x	x	x	x		x	x	x	2.5 - 27.0
Triceratium favus	x	x	x		x	x	x	x	x	x	x	x	2.3 - 27.8
Year round species with more scattered distributions													
Achnanthes clevei						x	x		x				8.1 - 23.1
Achnanthes hauckiana						x	x		x				8.1 - 23.1
Amphiprora alata		x	x				x			x	x		7.9 - 29.0
Amphiprora gigantea	x						x						9.7 - 23.4
Amphiprora paludosa	x	x				x	x		x		x		8.1 - 27.0

Table 4 (continued)

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
Auliscus caelatus	x	x	x		x		x	x		x		x	2.3 - 28.5
Bacteriastrum delicatulum	x	x			x				x	x	x	x	2.3 - 28.5
Biddulphia granulata	x				x		x	x	x	x	x		2.3 - 27.2
Biddulphia sinensis	x	x		x	x						x	x	3.4 - 27.2
Biddulphia turgida	x	x	x		x		x	x					4.6 - 21.2
Campylosira cymbelliformis	x	x			x			x					2.3 - 22.1
Chaetoceros atlanticus						x	x				x	x	8.1 - 28.5
Chaetoceros brevis	x	x					x				x	x	9.7 - 27.8
Chaetoceros decipiens	x				x	x				x	x	x	
Chaetoceros fragilis			x								x		
Chaetoceros pendulus			x			x	x						
Chaetoceros septentrionalis				x	x	x	x			x			1.7 - 26.3
Chaetoceros similis		x	x	x	x	x	x			x			1.7 - 26.2
Chaetoceros socialis			x	x						x	x	x	
Corethron hystrix	x	x	x				x	x					
Coscinodiscus concinnus	x	x	x				x				x	x	7.8 26.8
Coscinodiscus excentricus	x					x	x		x		x		8.1 - 27.0
Coscinodiscus granii							x	x	x				9.8 - 23.0
Coscinodiscus lineatus							x		x		x		7.4 - 28.5
Coscinodiscus marginatus					x				x				
Coscinodiscus oculus iridis				x	x	x	x	x			x	x	2.5 - 28.5
Coscinodiscus radiatus		x	x						x			x	10.9 - 28.7
Coscinodiscus subtilis				x		x	x	x	x	x			
Coscinodiscus wailesii	x	x	x				x					x	9.7 - 28.7
Cyclotella meneghiniana						x	x	x	x	x	x		8.1 - 29.0
Cyclotella striata	x				x	x			x		x	x	1.7 - 28.5
Diploneis bombus minor					x		x				x		1.7 - 27.0
Diploneis suborbicularis intermedia			x								x		7.9 - 27.0
Eucampia zoodiacus	x	x	x				x				x		

Table 4 (continued)

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
Gyrosigma diaphanum							x		x				9.7 - 23.8
Gyrosigma simile			x					x	x		x	x	7.9 - 28.7
Gyrosigma spenceri					x	x	x	x			x		2.3 - 27.3
Lauderia borealis	x				x								
Licmorpha abbreviata					x	x	x	x	x	x	x		1.7 - 29.0
Licmorpha lyngbyei	x	x	x	x	x		x	x					2.5 - 22.0
Melosira borreri	x		x							x	x		
Navicula irrorata						x		x					2.0 - 21.2
Navicula spicula				x	x	x	x		x	x			1.7 - 28.5
Nitzschia circumsuta		x	x		x								2.3 - 14.9
Nitzschia panduriformis							x			x			9.7 - 29.0
Nitzschia seriata					x	x	x						
Nitzschia sigma					x	x	x		x				2.0 - 24.5
Nitzschia sigmoidea		x	x	x	x	x					x		2.3 - 27.0
Plagiogramma vanheurckii					x	x	x		x				2.3 - 23.8
Pleurosigma formosum				x	x	x	x	x	x	x			1.7 - 29.0
Pseudonitzschia seriata				x	x	x	x		x		x		2.5 - 27.0
Rhaphoneis belgica	x	x	x		x				x		x		2.3 - 27.4
Rhizosolenia delicatula						x	x				x		
Rhizosolenia stolterfothii	x	x	x		x								1.7 - 27.2
Rhizosolenia styliformis				x	x	x		x				x	2.5 - 28.5
Schroederella delicatula	x	x	x	x	x	x							4.2 - 19.7
Stephanopyxis turris	x	x	x	x			x				x		10.1 - 18.0
Striatella interrupta					x		x			x	x		5.6 - 29.0
Thalassiosira balticus	x	x		x	x	x	x				x		1.7 - 29.0
Thalassiosira nana			x	x				x			x	x	
Thalassiosira nordenskioldii	x			x	x	x	x						10.7 - 19.2
Thalassiosira frauenfeldii	x		x	x	x	x	x				x		2.5 - 27.0
Tropidoneis lepidoptera				x	x	x			x	x	x	x	

Table 4 (continued)

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
Species occurring mostly in the fall													
Bacteriastrum hyalinum	x												
Chaetoceros filiformis	x												
Coscinodiscus centralis		x										x	
Hemiaulis hauckii	x	x											
Thalassiosira condensata	x												
Species occurring mostly in the winter and spring													
Achnanthes curvirostrum					x								5.6
Achnanthes brevipes						x							9.0
Amphiprora similis					x								3.7
Amphora acutiuscula					x	x							2.3 - 12.0
Amphora ovalis		x	x		x	x							3.6 - 9.5
Amphora sublaevis			x										8.2
Biddulphia aurita				x									15.8
Chaetoceros ceratosporus				x	x	x	x						2.3 - 12.0
Chaetoceros curvisetus						x							
Chaetoceros debilis		x											
Chaetoceros densus			x	x									
Chaetoceros gracilis				x	x	x	x						1.7 - 14.5
Chaetoceros pseudocurvisetus	x				x	x							
Cocconeis costata							x						10.1
Coscinosira polychorda						x							8.2 - 12.0
Cyclotella stelligera								x					8.5
Diatoma hiemale				x	x	x	x						1.7 - 14.5
Eucampia cornuta					x	x							
Fragilaria pinnata						x							8.5
Gyrosigma wansbeckii						x							8.5

Table 4 (continued)

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
Melosira moniliformis		x											
Navicula maculata					x								3.8
Navicula punctata						x							3.6
Navicula tuscula							x						9.7
Nitzschia acicularis						x							8.6
Nitzschia adducta					x								4.0
Nitzschia litoralis delawarensis					x								2.3 - 9.9
Nitzschia punctata						x							8.2
Rhizosolenia imbricata shrubsolei				x	x	x							3.8 - 6.3
Rhopalodia gibberula					x	x							1.7 - 12.0
Skeletonema subsalsum			x			x							7.8 - 12.1
Stephanodiscus astrea								x					13.4
Striatella unipunctata		x	x			x							2.0 - 14.6
Surrirella litoralis					x	x							1.7 - 5.9
Surrirella robusta marginata					x	x	x						3.0 - 10.2
Thalassiosira aestivalis					x	x	x						2.0 - 13.5
Thalassiosira condensata				x	x								
Thalassiosira decipiens			x	x		x	x						1.7 - 12.5
Thalassiosira kryophila				x	x	x	x						1.7 - 12.0
Species occurring mostly in the summer													
Amphora robusta										x			20.9
Asterionella formosa											x	x	
Bacteriastrum hyalinum													
Biddulphia longicrurus											x		26.2 - 27.0
Chaetoceros affinis willei												x	27.8
Chaetoceros constrictus	x										x	x	19.1 - 28.5

Table 4 (continued)

	Oc	No	De	Ja	Fe	Ma	Ap	Ma	Ju	Jl	Au	Se	Temp. range (°C)
Chaetoceros crinitus										x			
Chaetoceros criophilum										x			29.0
Chaetoceros eibenii												x	12.0 - 27.0
Chaetoceros teres										x			
Frustulia vulgaris									x				20.2
Leptocylindricus minimus										x		x	
Mastigloia lanceolata											x		27.0
Melosira islandica										x	x		
Melosira lineata											x		27.0
Melosira nummuloides												x	22.0
Rhizosolenia faereense												x	
Terpsinoe americana									x				20.9
Thalassiothrix longispina								x		x			

Primary Productivity

Measurements of phytoplankton primary productivity in the lower York River were performed, employing the light and dark bottle oxygen method, during several of the studies by Patten and his associates. Patten (1966) includes a discussion of various production parameters measured in a series of in situ experiments at the VIMS pier station during 1960 and 1961. Table 5 presents average values of integral gross productivity, respiration, and net productivity for the five seasonal periods of those years. Maximum levels of all three parameters were found during the brief spring bloom period, while levels during the summer were higher than for the other three longer periods. In the text of the paper, Patten (1966) emphasized that the net energy balance of the water column was positive during each of the five periods, while variation in net productivity was slight from period to period. Thus seasonal changes in environmental conditions and in the species composition of the phytoplankton had little effect upon its net energy balance.

While this implied energetic stability was true on the average, over seasons, net productivity within a given period was subject to large short term variations, as was exemplified by comparing two experiments performed during the spring bloom period. During the first experiment, the phytoplankton

Table 5.

Average Phytoplankton Productivity Parameters

(from Patten, 1966)

Seasonal Period	Integral Gross Productivity (g-cal/(cm^2 x day))	Integral Respiration (g-cal/(cm^2 x day))	Integral Net Productivity (g-cal/(cm^2 x day))
SU	9.52	7.31	2.21
FW	3.45	1.89	1.56
WS	5.64	2.19	3.45
SB	38.93	31.58	7.35
PB	2.62	1.28	1.34

was dominated by the dinoflagellate Peridinium triquetrum, and the following values were obtained: integral gross productivity 20.36 g-cal/(cm^2 x day), integral respiration 2.68 g cal/(cm^2 x day), and integral net productivity 17.68 g-cal/(cm^2 x day). One week later, when Peridinium triquetrum was joined by large populations of Chilomonas ? sp. and Cryptomonas ? sp., the values were integral gross productivity 57.49 g-cal/(cm^2 x day), integral respiration 60.53 g-cal/(cm^2 x day), and integral net productivity -3.04g-cal/(cm^2 x day). It was suggested that the latter negative energy balance was a prelude to the crash of the spring bloom.

In another paper (Patten and Chabot, 1966) which reported results from work done in the summer of 1963, negative integral net productivity values were obtained in six of the eight experiments performed. The authors were unwilling to accept the idea that the phytoplankton of the lower York River was in negative energy balance during most of the summer, and therefore questioned the accuracy of their methods.

In a study of phytoplankton nutrition in the lower York River, Fournier (1966) applied treatments of nitrate, phosphate, silicate, trace metals, vitamins, and a complete nutrient medium to samples incubated in an outdoor water tank. Significant stimulation of productivity by nitrate, phosphate and trace metals occurred in the spring and fall. The other treatments either had no effect or inhibited productivity, the latter resulting also from phosphate and trace metal enrichments at certain times. After considering these results and the limitations of the light and dark bottle oxygen method as a means of detecting responses in enrichment bioassays, mainly its low sensitivity, the author concluded that nitrate, phosphate, and trace metals were generally limiting to productivity throughout the year. However, he suggested that more knowledge of the physiological state of the organisms involved in each experiment would be required before precise evaluation of the results could be made.

The carbon-14 method of measuring primary productivity has been employed in the lower York River in a study begun in May 1971 and which is still in progress (Warinner and Zubkoff, 1972). Samples were obtained from a series of depths, including the surface micro-layer, and incubated under artificial light. Therefore the results represent "productivity potentials" rather than environmental levels. The values obtained were nearly always higher for samples from 0.5 or 1.0 m than for samples from any other depth. For a station located at the river mouth, measured productivity values have ranged between 1.8 and 142.3 mg C/(m^3 x hr). Spring bloom levels of carbon-14 productivity were reported elsewhere (Warinner and Zubkoff, 1971) for April 15, 1971. Productivity within a red water bloom of Peridinium trichoideum and Prorocentrum minimum was determined as 570 mg C/(m^3 x hr), while the level in an adjacent non-bloom area was 167 mg C/(m^3 x hr).

The extent to which the "potential productivities" demonstrated by the carbon-14 method are realized in nature, and the questions posed by the light and dark bottle oxygen work regarding the energy balance of the lower York River phytoplankton remain to be resolved.

Literature Cited

Brehmer, M. L., 1970. Biological and Chemical Study of Virginia's Estuaries. OWRR Project No. B003 Va.

Cowles, R. P., 1930. A biological study of the offshore waters of Chesapeake Bay. Bull. U. S. Bur. Fish. 46: 277-381.

Fournier, R. O., 1966. Some implications of nutrient enrichment on different temporal stages of a phytoplankton community. Chesapeake Sci., Vol. 7 #1: 11-19.

Gibson, V. R., 1971. Vertical distribution of estuarine phytoplankton in the surface microlayer and at one meter, and fluctuations in abundance caused by surface adsorption of monomolecular films. M. A. Thesis, U. of Va.

Mackiernan, G. B., 1968. Seasonal distribution of dinoflagellates in the lower York River, Virginia. M. A. Thesis, College of William and Mary.

Morse, D. C. 1947. Some observations on seasonal variations in plankton population, Patuxent River, Maryland. Chesapeake Biol. Lab., Publ. 65: 1-31.

Mulford, R. A., 1962. Diatoms from Virginia tidal waters 1960 and 1961. VIMS Special Scientific Report No. 30.

Mulford, R. A., 1963a. Distribution of the dinoflagellate genus Ceratium in the tidal and offshore waters of Virginia. Chesapeake Sci., Vol. 4 #2: 84-89.

Mulford, R. A., 1963b. The net phytoplankton taken in Virginia tidal waters January-December 1962. VIMS Special Scientific Report No. 43.

Patten, B. C., 1961. Nannoplankton records obtained from Chesapeake Bay cruises of the R/V Pathfinder and R/V Observer January 1960-January 1961. VIMS Special Scientific Report No. 21.

Patten, B. C., 1963. Plankton: optimum diversity structure of a summer community. Science, Vol. 140 #3569: 894-8.

Patten, B. C., 1966. The biocoenotic process in an estuarine phytoplankton community. Oak Ridge National Laboratory, ORNL - 3946.

Patten, B. C. and B. F. Chabot, 1966. Factorial productivity experiments in a shallow estuary: characteristics of response surfaces. Chesapeake Sci., Vol. 7 #3:117-36.

Patten, B. C., R. A. Mulford, and J. E. Warinner, 1963. An annual phytoplankton cycle in lower Chesapeake Bay. Chesapeake Sci., Vol. 4:1-20.

Patten, B. C. and J. E. Warinner, 1961. Hydrographic, nutrient, chlorophyll, seston, and cell count data from Chesapeake Bay plankton cruises of R/V Pathfinder and R/V Observer January 1960-January 1961. VIMS Special Scientific Report No. 20.

Patten, B. C., D. K. Young, and M. H. Roberts, Jr., 1966. Vertical distribution and sinking characteristics of seston in the lower York River, Virginia. Chesapeake Sci., Vol. 7 #1:20-29.

Stofan, P. E., V. R. Gibson, and J. L. DuPuy, 1972. The estuarine ecosystem: vertical and horizontal distributions of the near surface phytoplankton populations. Presented at the 35th annual meeting of the American Society of Limnology and Oceanography, Florida State University, Tallahassee, March 19-22, 1972.

Warinner, J. E. and M. L. Brehmer, 1966. The effects of thermal effluents on marine organisms. Air and Water Pollut. Int. J. Vol. 10: 277-89.

Warinner, J. E. III and P. L. Zubkoff, 1971. Primary productivity of a spring "red water" plankton bloom. Presented at the 162nd annual meeting of the American Chemical Society, Washington, D. C., September 12-17, 1971.

Warinner, J. E. and P. L. Zubkoff, 1972. The estuarine ecosystem: primary productivity in a Chesapeake Bay estuary. Presented at the 35th annual meeting of the American Society of Limnology and Oceanography, Florida State University, Tallahassee, March 19-22, 1972.

Wolfe, J. J., B. Cunningham, N. F. Wilkerson, and J. T. Barnes. 1926. An investigation of the microplankton of Chesapeake Bay. J. Elisha Mitchell Sci. Soc. 42: 25-54.

Section III

Zooplankton and Meroplankton

by R. A. Jordan

Zooplankton and Meroplankton

Most of the available data on the zooplankton of the York River are found in two studies by Burrell (1968, 1972). The first study, conducted in conjunction with an examination of the York-Pamunkey fish nursery grounds (Van Engel and Joseph, 1968), involved examination of monthly samples taken from September 1965 through December 1966. Normally eight stations were sampled, all located in the York and Pamunkey Rivers at and upstream from Pages Rock (Y10). The river mouth (YOO) was sampled occasionally. Samples were taken by towing a meter net of 750 μ mesh for five minutes at 1 m above bottom. Results obtained in numbers of organisms per tow were converted to numbers per cubic meter by multiplying by an estimated factor of .0033.

In the second study nine stations in the York and Pamunkey rivers (YOO, Y10, Y15, Y20, Y25, P30, P35, P40, and P50) and three stations in Chesapeake Bay (A05, COO, C10) were occupied monthly from January 1968 through December 1969. During each sampling run determinations of temperature, dissolved oxygen concentration, and salinity were made at one meter below the surface and one meter above the bottom at each station. Secchi disk transparency measurements were also taken. Plankton was sampled with a five inch diameter Clarke-Bumpus Quantitative Plankton Sampler fitted with a number 6 (235 μ) mesh Nitex net. Tows of five minutes duration were made just below the surface and at one meter above the bottom at each station.

The samples were preserved with 5% buffered formalin, and subsamples were taken such that at least one hundred of the dominant copepods were counted. Entire samples were counted for rare species. The counts were expressed as numbers of each species per liter.

Table 1 presents the temporal distributions of the zooplankton species collected at the Y00 station during the 1965-66 study. Table 2 presents the distribution for the copepod species collected at the same station during 1968-69. Comparison of the two tables indicates that several more copepod species were identified during the second study than during the first, and the frequency of occurrence of the species collected in both studies was generally greater in the second than in the first. These differences were probably more procedural than biological in origin, since in the second study the author's primary interest was in copepods, and he used a net of smaller mesh size. From the quantitative data presented in Burrell (1972) it is apparent that the two most important copepod species in the lower York River in 1968 and 1969 were Acartia tonsa, which was present most of the year and peaked in the fall, and Acartia clausi, which was present only in the winter and spring. The greatest numbers of copepod species occurred in the spring and fall, as did the peaks in numerical

Table 1

Monthly Occurrence of Zooplankton Species at the Mouth of the York River 1965-66

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Copepoda												
Acartia tonsa	X		X	X		X			X	X		X
Acartia clausi						X	X	X				
Eurytemora affinis	X					X						
Pseudodiaptomus coronatus												
Centropages hamatus						X	X		X			
Labidocera aestiva	X		X							X		X
Pseudocalanus minutus								X				
Cladocera												
Penilia avirostris	X											X
Evadne normanii									X			
Podon sp.												
Chaetognatha												
Sagitta tenuis	X		X									
Sagitta elegans												
Mysidaceae												
Neomysis americana	X											
Ctenophora												
Mnemiopsis leidyi				X				X	X	X		
Beroe ovata												
Decapoda												
Palaemonetes larvae	X											
Porcellanid larvae	X											
Rithropanopeus harrisii (zoea)												
Crangon larvae			X	X		X	X	X				
Caridean larvae										X		X
Coelenterata												
Chrysaora quinquecirrha										X		

Table 2

Monthly Occurrence of Zooplankton Species
at the Mouth of the York River 1968-69

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Copepoda												
Acartia tonsa	X	X	X	X	X	X	X		X	X	X	X
Acartia clausi					X	X	X	X	X			
Pseudodiaptomus coronatus	X	X	X	X	X	X	X				X	X
Centropages hamatus					X	X	X	X	X			
Labidocera aestiva		X							X			
Pseudocalanus minutus			X			X	X	X	X			
Paracalanus crassirostris	X		X	X			X		X			X
Temora longicornis								X	X	X		
Euterpina acutifrons							X					X
Oithona brevicornis					X				X			
Oithona similis				X			X		X			
Leptinogaster major											X	

-94-

abundance of individuals. On only one occasion (April 1969, Pseudocalanus minutus, surface sample) was a copepod species present at a concentration exceeding 100 individuals per liter, and in most cases fewer than 10 per liter were found.

Of the twelve species of copepods recorded at Y00, six are characteristically estuarine in occurrence, and six are typically marine. These designations are indicated in Table 3 (modified from Burrell, 1972, Figure 39), which also includes the salinity and temperature ranges observed for all copepod species recorded in the study.

In general in the 1968-69 study the species composition of surface samples differed little from that of bottom samples at Y00, and only one copepod species, Leptinogaster major, was found at only one of the two sampling depths. It was collected once, in a bottom sample in July 1968. Thus subsurface tows should provide adequate data on the community structure of the zooplankton of the lower York River for phase 2 of the present study.

Occurrence data for zooplankton species other than copepods, as well as for certain groups properly classed as meroplankton, appear in Table 1 and also in Table 4, which has been extracted from Mackiernan (1968). As indicated in Table 4, tintinnid species are consistent components of the York River zooplankton, and can be collected with fine nets, such as the number 20 (76 μ) net used by Mackiernan.

An extensive study dealing specifically with the

Table 3

Salinity and Temperature Ranges of Copepod Species
(from Burrell, 1972)

Species	Salinity Range (‰)	Temperature Range (°C)
Acartia clausi (E)	0 - 33	2 - 24
Acartia tonsa (E)	0 - 31	2 - 30
Centropages hamatus (M)	8 - 32	3 - 25
Euterpina acutifrons (M)	19 - 31	7 - 27
Labidocera aestiva (M)	12 - 32	15 - 29
Leptinogaster major (E)	7 - 30	17 - 28
Oithona brevicornis (M)	21 - 32	2 - 27
Oithona similis (M)	15 - 32	2 - 28
Paracalanus crassirostris (E)	15 - 32	5 - 30
Pseudocalanus minutus (E)	9 - 32	3 - 28
Pseudodiaptomus coronatus (E)	0 - 32	2 - 30
Temora longicornis (M)	18 - 32	3 - 28

(E): Estuarine species

(M): Marine species

Table 4

Monthly Occurrence of Zooplankton
Observed by Mackiernan at VIMS Pier
1966-67

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Rotifera												
Synchaete sp.	X	X	X	X			X	X				
Trichocerca sp.				X								
Copepoda												
Acartia tonsa									X			
Others								X	X			
Nauplii					X	X						
Cladocera												
Podon sp.		X										
Others								X				
Barnacle nauplii					X	X						
Polychaete larvae					X	X		X				
Bryozoan larvae					X	X		X				
Tintinnid spp.	X	X		X			X	X	X	X		

meroplankton of the York River system was conducted by Sandifer (1972). As part of the study he identified and quantified the decapod larvae present in the plankton samples taken by Burrell during his 1968-69 study of copepod distribution.

Table 5 presents the temporal distributions of the species of decapod larvae collected at the York River mouth (both years combined, surface and bottom samples combined). In most months surface and bottom samples were identical in species composition, although some species were considerably more abundant in bottom samples. On only one occasion were individuals of a species present at a concentration greater than 100 per 1,000 liters (Neopanope texana sayi, June 1969, bottom), and in most cases fewer than 10 of any one species per 1,000 liters were collected. With the exception of Crangon septemspinosa, larvae of all species were most abundant in the summer months and essentially absent for the remainder of the year.

In addition to studying the distribution and abundance of the decapod larvae, Sandifer conducted a study of the effects of temperature and salinity on the larval development of the grass shrimp, Palaemonetes vulgaris. A review of the literature pertaining to the influence of temperature and salinity on Chesapeake Bay decapod larvae was also accomplished. These sections are included in Appendix 1.

Table 5

Monthly Occurrence of Decapod Larvae at the Mouth of the York River
1968-1969

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug
Abundant species												
Crangon septemspinosa			X	X	X	X	X	X	X	X		
Upogebia affinis	X	X								X	X	X
Uca spp.	X									X	X	X
Hexapanopeus angustifrons		X								X	X	X
Neopanope texana sayi	X	X								X	X	X
Panopeus herbstii	X									X	X	X
Hippolyte pleuracantha	X	X							X	X	X	X
Other species												
Palaemonetes spp.		X								X	X	X
Ogyrides limicola	X	X								X	X	X
Pagurus longicarpus		X								X	X	
Euceramus praelongus		X								X		X
Polyonyx gibbesi											X	X
Libinia spp.	X										X	
Pinnixa chaetopterana											X	X
Pinnixa sayana	X									X	X	X
Pinnotheres maculatus	X	X									X	X
Pinnotheres ostreum	X										X	X
Callinectes sapidus										X	X	
Eurypanopeus depressus										X		
Brachyuran megalopae		X										X

LITERATURE CITED

Burrell, V. G. Jr. 1968. The ecological significance of a ctenophore, Mnemiopsis leidyi (A. Agassiz), in a fish nursery ground. M. A. Thesis, College of William and Mary.

Burrell, V. G. Jr. 1972. Distribution and abundance of calanoid copepods in the York River Estuary Virginia, 1968 and 1969. Ph.D. Thesis, College of William and Mary, 234 pp.

Mackiernan, G. B. 1968. Seasonal distribution of dinoflagellates in the lower York River, Virginia. M. A. Thesis, College of William and Mary.

Sandifer, P. A. 1972. Morphology and ecology of Chesapeake Bay decapod crustacean larvae. Ph.D. Thesis, University of Virginia, xxvii + 532 pp.

Van Engel, W. A. and E. B. Joseph. 1968. Characterization of coastal and estuarine fish nursery grounds as natural communities. VIMS final report to U. S. Dept. of Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries.

Section IV

Benthos and Shellfish

by M. E. Bender

York River Benthos

Introduction

The benthic populations of the York River estuary are of both direct and indirect importance to man. Certain members of the benthic community are of direct commercial value, e.g. clams, while others serve as important food organisms for higher trophic levels. Besides being of value in these regards the use of benthic animals to detect pollution or other forms of environmental stress has been documented by numerous authors.

Benthic and related communities, e.g. epifauna of eel grass, of the lower York have been studied by numerous investigators at VIMS. Some of these studies have not been formally published and were conducted as the theses research of graduate students (Boesch, 1971; Orth, 1971; Marsh, 1970; and Feeley, 1967) while others have been the result of staff research (Wass, *et al*. 1967; Haven *et al*. 1966; and Warinner and Brehmer, 1966). Studies of certain portions of the community are still underway e.g. clam populations (Loesch and Lucy) and a study of the effects of an oil spill which occurred in May of 1971 in the lower York (Bender).

In this review we will attempt to summarize the major findings of studies conducted on the benthic community in the lower York. Station locations for the studies referred to in this review are shown in Figure 1.

The first in depth study of the community was conducted by Wass, Kerwin and McCain between 1960 and 1966. In their study they followed seasonality and species composition at one station located off VIMS pier in soft substrate at a depth of 8 meters. During the study they identified 165 species of which polychaetes, crustaceans and mollusks comprised 83%. The most characteristic species were *Nephtys incisa*, *Ogyrides limicola* and *Retusa canaliculata*. Of the numerically abundant organisms, *Mulinia lateralis* had the greatest reproductive potential and exhibited the most striking fluctuations, which seem not to be as seasonally cyclic as in other species. Since this work has not been formally published and is of direct importance to the present study, we have included a copy as Appendix 2. Diversity indices were computed from these data and are shown in Figure 2. As can be seen from the Figure, except for a period in early 1961, the diversity remained remarkably constant throughout their study, and the drop at that time can be accounted for by the unusual abundance of *Mulinia*.

However, Haven et al. (1966) studied animal-sediment relationships in the lower York River. They

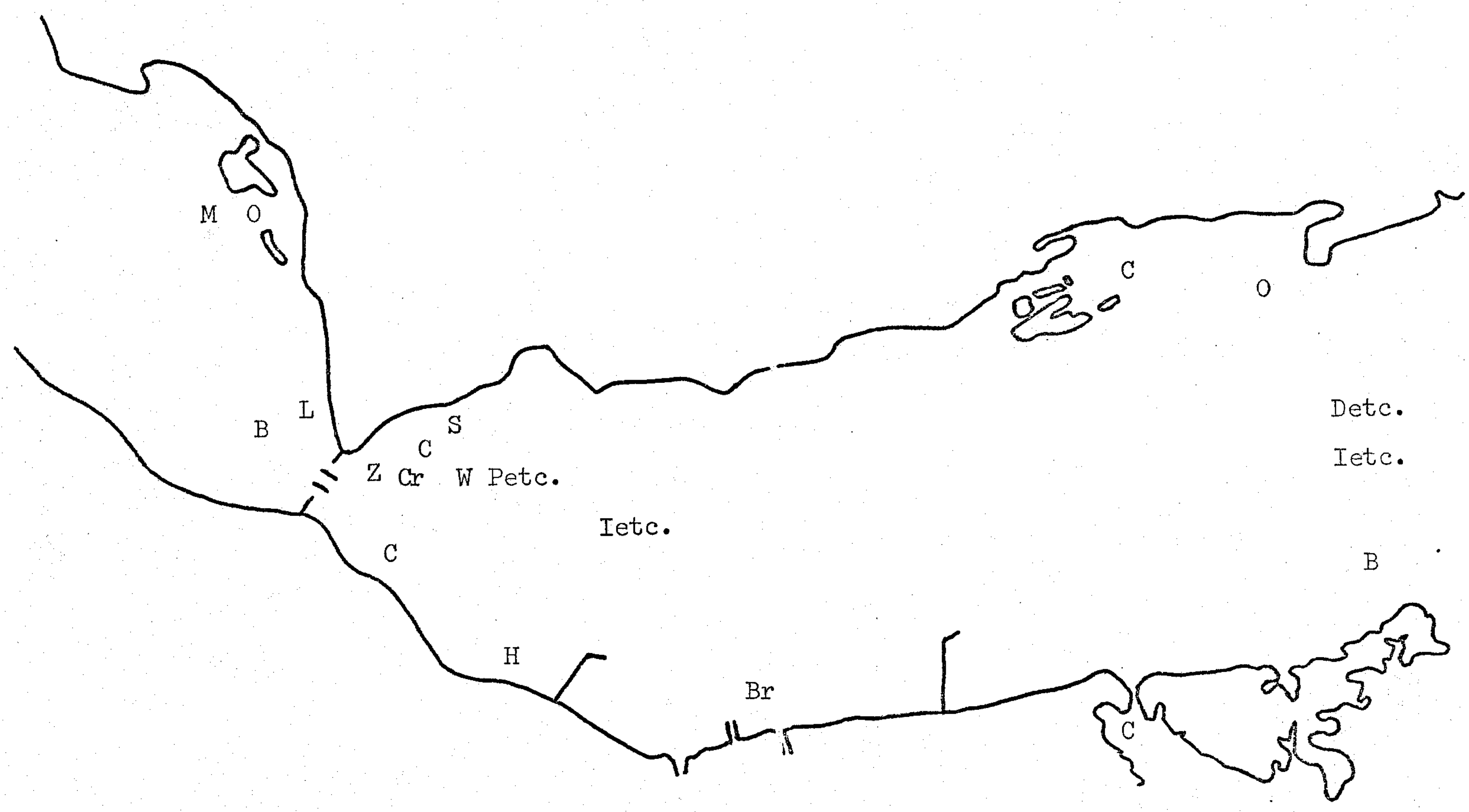


Figure 1. Station locations for VIMS benthic studies in the lower York River.

Map Key*

O	= eelgrass benthos (R. Orth)
Detc	= phytoplankton studies (DuPuy, Warinner and Zubkoff)
Ietc	= trawl stations (Ichthyology and Crustaceology)
C	= hard clam studies (Applied Biology)
Br	= benthos and phytoplankton (Warinner and Brehmer)
H	= benthos and sediments (Haven)
W	= seasonality of benthos (Wass)
Petc	= phytoplankton studies (Patten and Fournier)
L	= soft clam (Lucy)
B	= benthos (Boesch)
M	= epibiota of eelgrass (Marsh)
S	= shrimp
CR	= crab
Z	= monthly productivity and organics off VIMS pier

*The many studies which have been conducted off the pier are not shown.

YORK RIVER - PLANKTON BOUY STATION

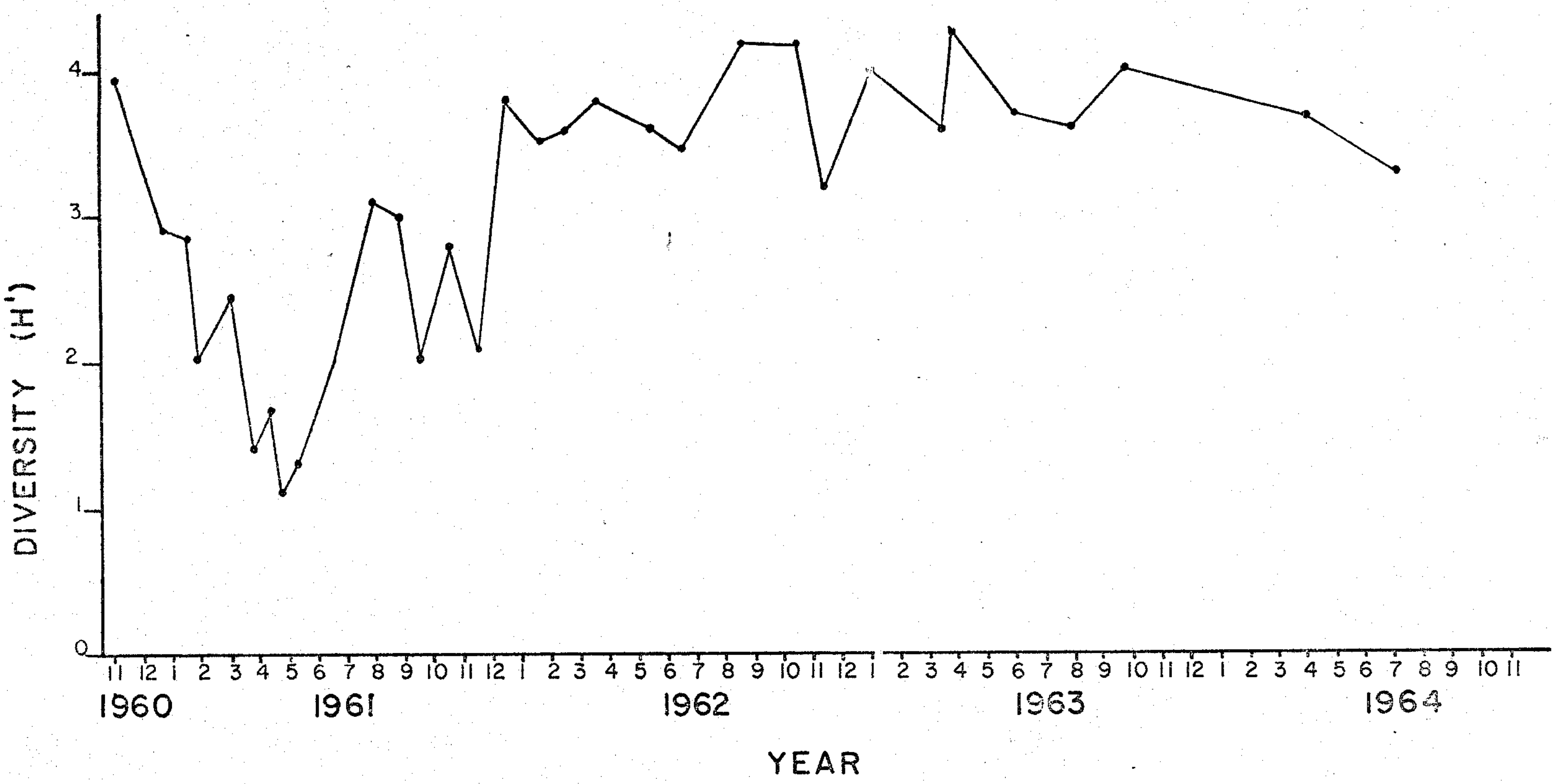


Figure 2. Benthic Diversity

established stations at four depths and evaluated the number of individuals and biomass at each station monthly for a period of one year.

Species diversity did not differ between any of the four depths but the number of individuals found at the various stations did show a trend toward increasing abundance in shallow water. Faunal homogeneity between stations was tested using an index of affinity. Highest affinities were found between the 1.5 and 3.0 m stations ($\overline{x}$ = 54.73%) while the affinity between the deeper stations (6.1 m and 12.2 m) was lower ($\overline{x}$ = 32.23%).

Dominant species at the deep station 12.2 m were Cirriformia filigera, nematodes, Sarsiella zostericola, Retusa canaliculata, Maldanopsis elongata, Nephtys incisa, Sigambra bassi, Brania sp., Pseudeurythoe sp., copepods, and Lumbrineris tenuis.

The number of individuals, species and biomass were lower at the 6.1 m station than any other sampled during the study. Copepods, nematodes and Retusa canaliculata made up the majority of the individuals found at this station.

Stations at 1.5 m and 3.0 m were quite similar in terms of species composition, with the same five species ranking high at each station. These were nematodes, Phoronis architecta, Loxoconcha impressa, copepods and Retusa canaliculata.

Seasonal changes in abundance for 13 species were documented.

Boesch (1971) studied the benthic populations of the lower Chesapeake Bay and the York and Pamunkey rivers. In his study he prepared a table listing the known distribution of 360 macrobenthic species from the region as a function of distance up the estuary. This table is included as Table 1 of this report with an added line demarking the specific area of interest for this review.

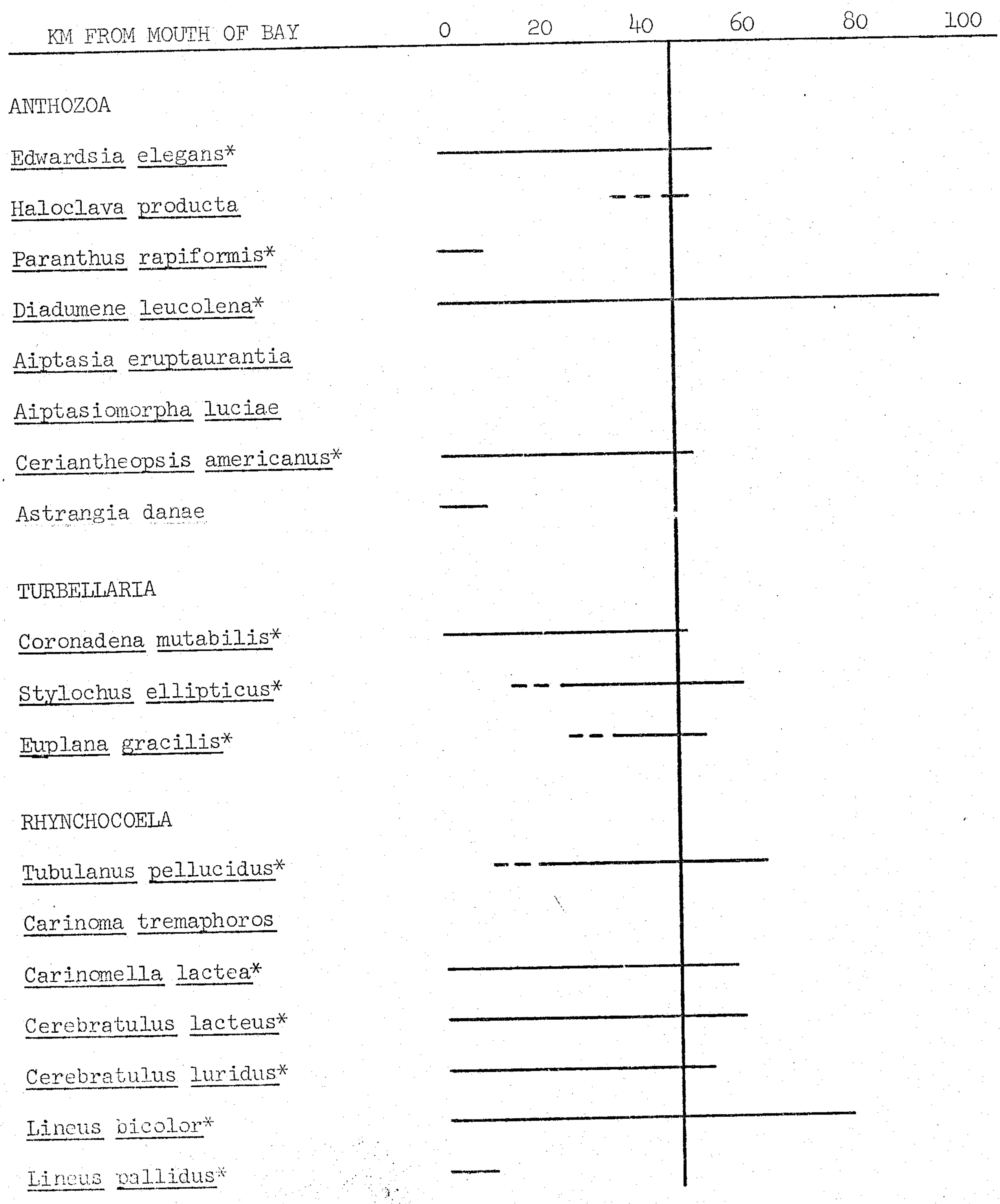
In the study 10 stations were established from the Bay mouth extending to the oligohaline section of the Pamunkey. Sampling was conducted quarterly. Analyses of station similarity and faunal affinity showed that communities were virtually continuous along the estuarine gradient and that species were generally distributed independently. Community structure analyses indicated that community complexity is constant throughout the long polyhaline zone but decreases continuously into the mesohaline and oligohaline zone.

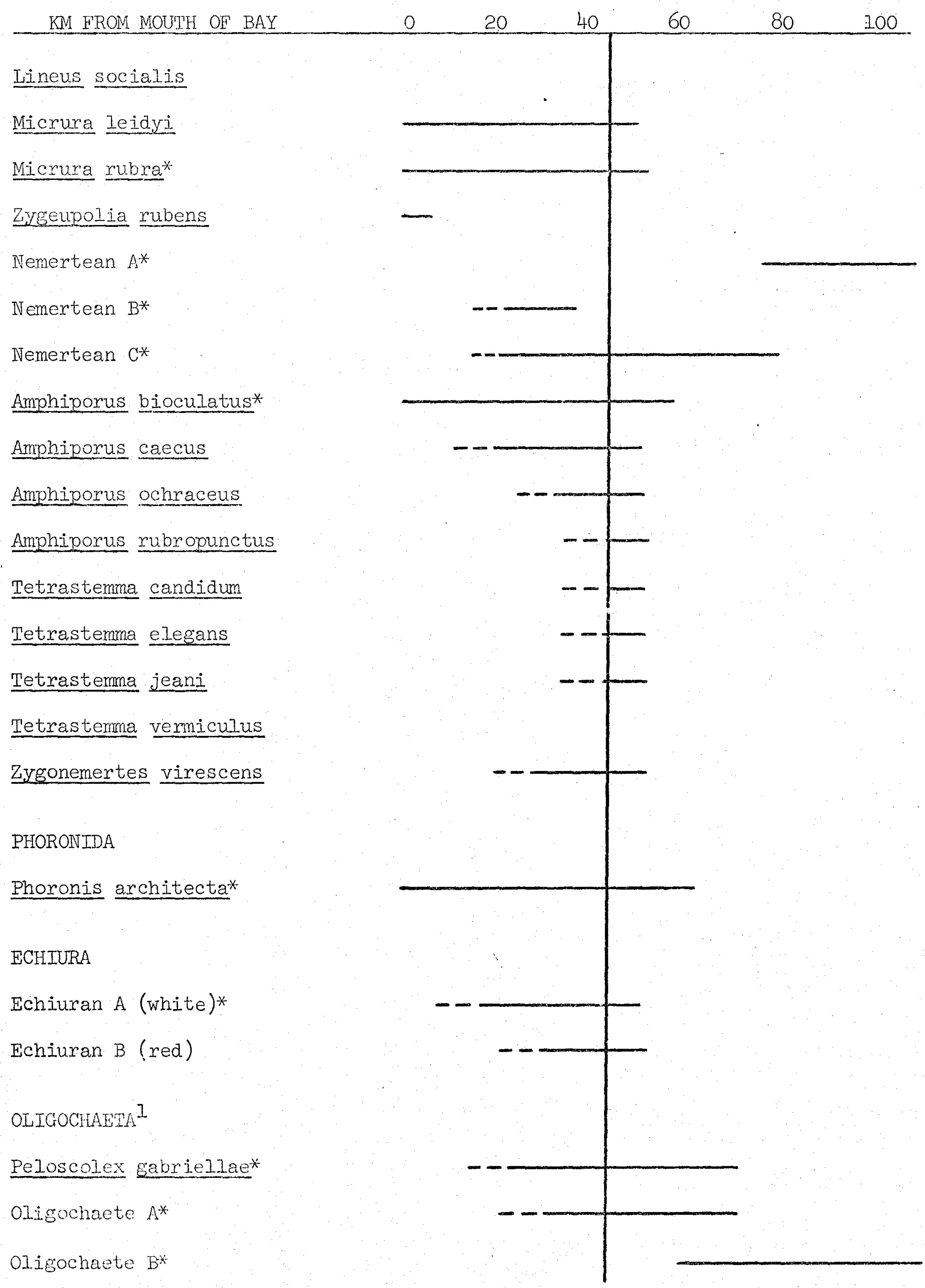
Dominant species in the lower York as determined by ranking according to the method of McNaughton (1967), were Tharyx setigera, Heteromastus filiformis, Nephtys incisa, Harmothoe sp. A, Amphiodia atra, Pseudeurythoe paucibranchiata and Cirratulus grandis.

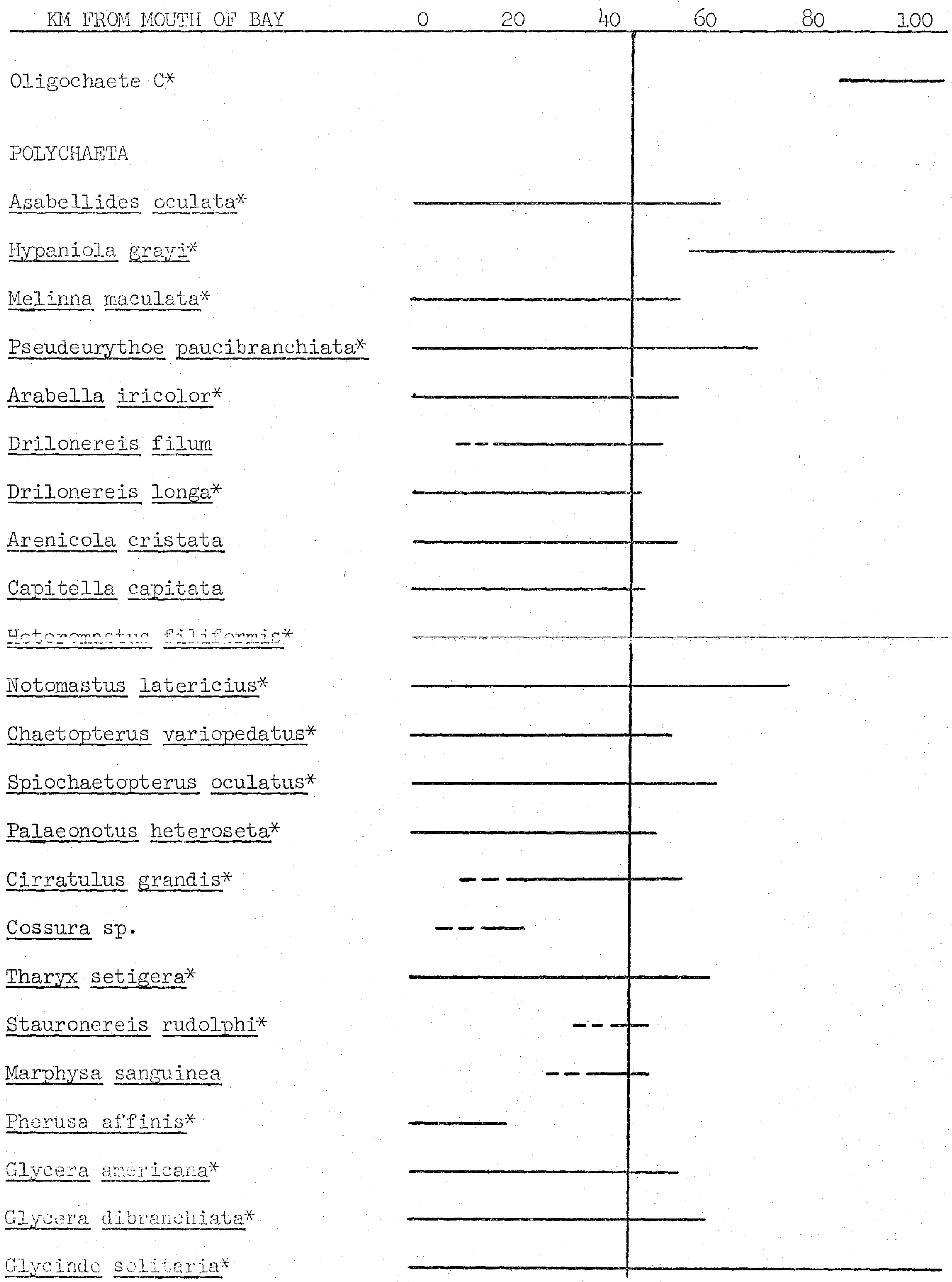
Species abundance plotted as a function of distance was presented for 48 species. No seasonal trends in

Table 1
(from Boesch, 1971)

Distribution of noncolonial macrobenthic species known from the Chesapeake-York-Pamunkey estuary. Dashed lines indicate an implied distribution to the mouth of Chesapeake Bay. Asterisks indicate species taken in this study.




KM FROM MOUTH OF BAY
0
20
40
60
80
100
Lineus socialis
Micrura leidyi
Micrura rubra*
Zygeupolia rubens
Nemertean A*
Nemertean B*
Nemertean C*
Amphiporus bioculatus*
Amphiporus caecus
Amphiporus ochraceus
Amphiporus rubropunctus
Tetrastemma candidum
Tetrastemma elegans
Tetrastemma jeani
Tetrastemma vermiculus
Zygonemertes virescens
PHORONIDA
Phoronis architecta*
ECHIURA
Echiuran A (white)*
Echiuran B (red)
OLIGOCHAETA[1]
Peloscolex gabriellae*
Oligochaete A*
Oligochaete B*


KM FROM MOUTH OF BAY
0
20
40
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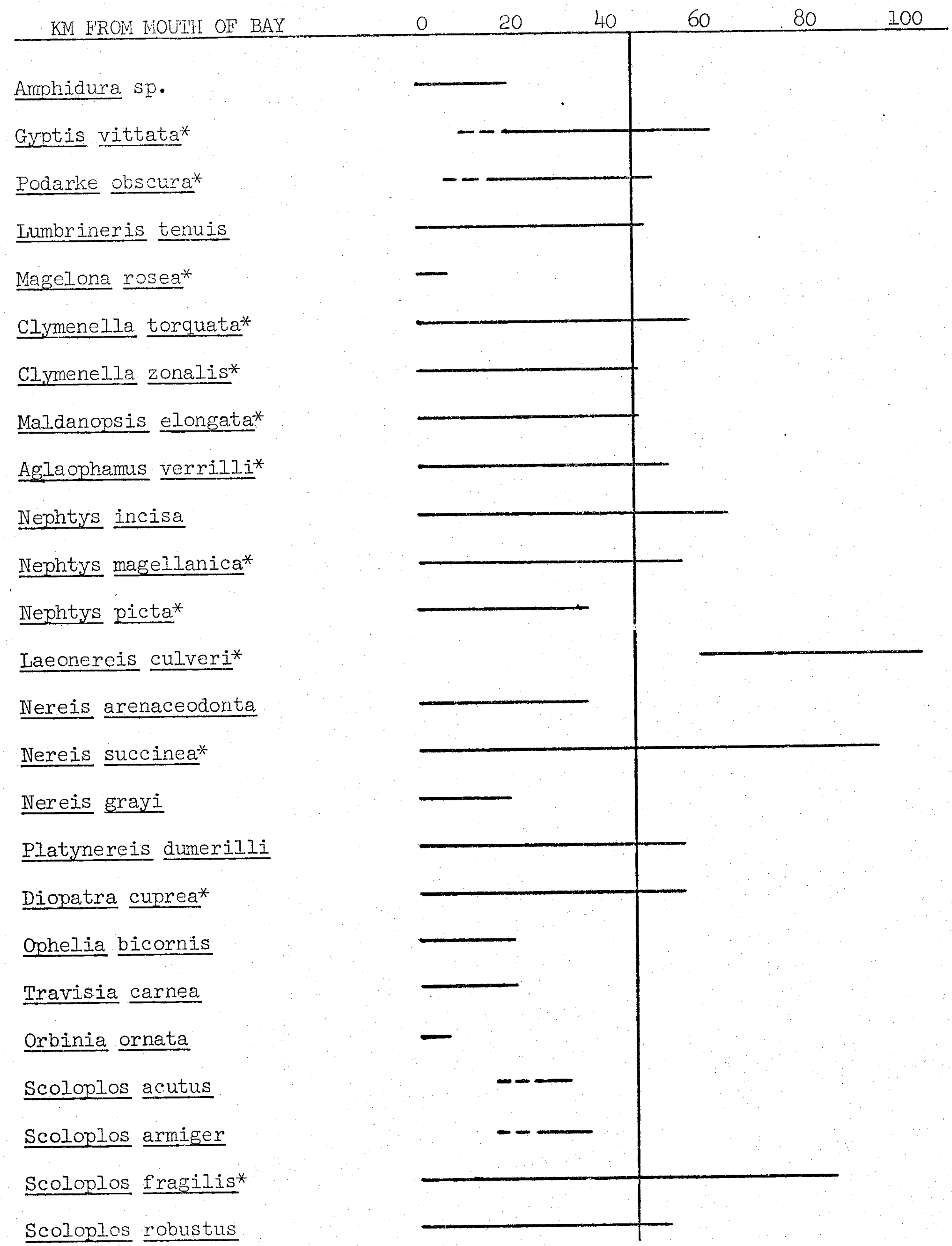
80
100
Oligochaete C*
POLYCHAETA
Asabellides oculata*
Hypaniola grayi*
Melinna maculata*
Pseudeurythoe paucibranchiata*
Arabella iricolor*
Drilonereis filum
Drilonereis longa*
Arenicola cristata
Capitella capitata
Heteromastus filiformis*
Notomastus latericius*
Chaetopterus variopedatus*
Spiochaetopterus oculatus*
Palaeonotus heteroseta*
Cirratulus grandis*
Cossura sp.
Tharyx setigera*
Stauronereis rudolphi*
Marphysa sanguinea
Pherusa affinis*
Glycera americana*
Glycera dibranchiata*
Glycinde solitaria*


KM FROM MOUTH OF BAY
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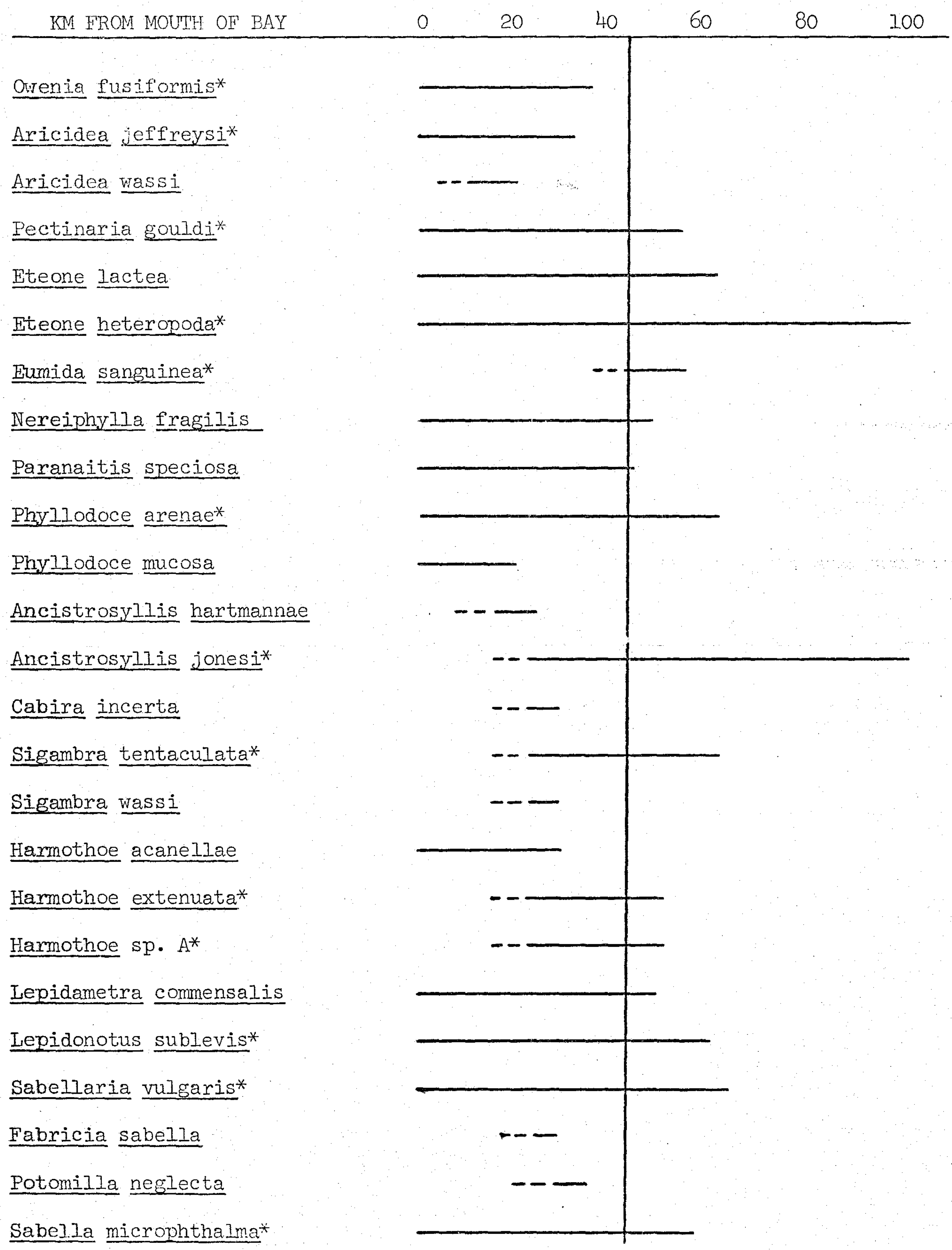
100
Amphidura sp.
Gyptis vittata*
Podarke obscura*
Lumbrineris tenuis
Magelona rosea*
Clymenella torquata*
Clymenella zonalis*
Maldanopsis elongata*
Aglaophamus verrilli*
Nephtys incisa
Nephtys magellanica*
Nephtys picta*
Laeonereis culveri*
Nereis arenaceodonta
Nereis succinea*
Nereis grayi
Platynereis dumerilli
Diopatra cuprea*
Ophelia bicornis
Travisia carnea
Orbinia ornata
Scoloplos acutus
Scoloplos armiger
Scoloplos fragilis*
Scoloplos robustus


KM FROM MOUTH OF BAY
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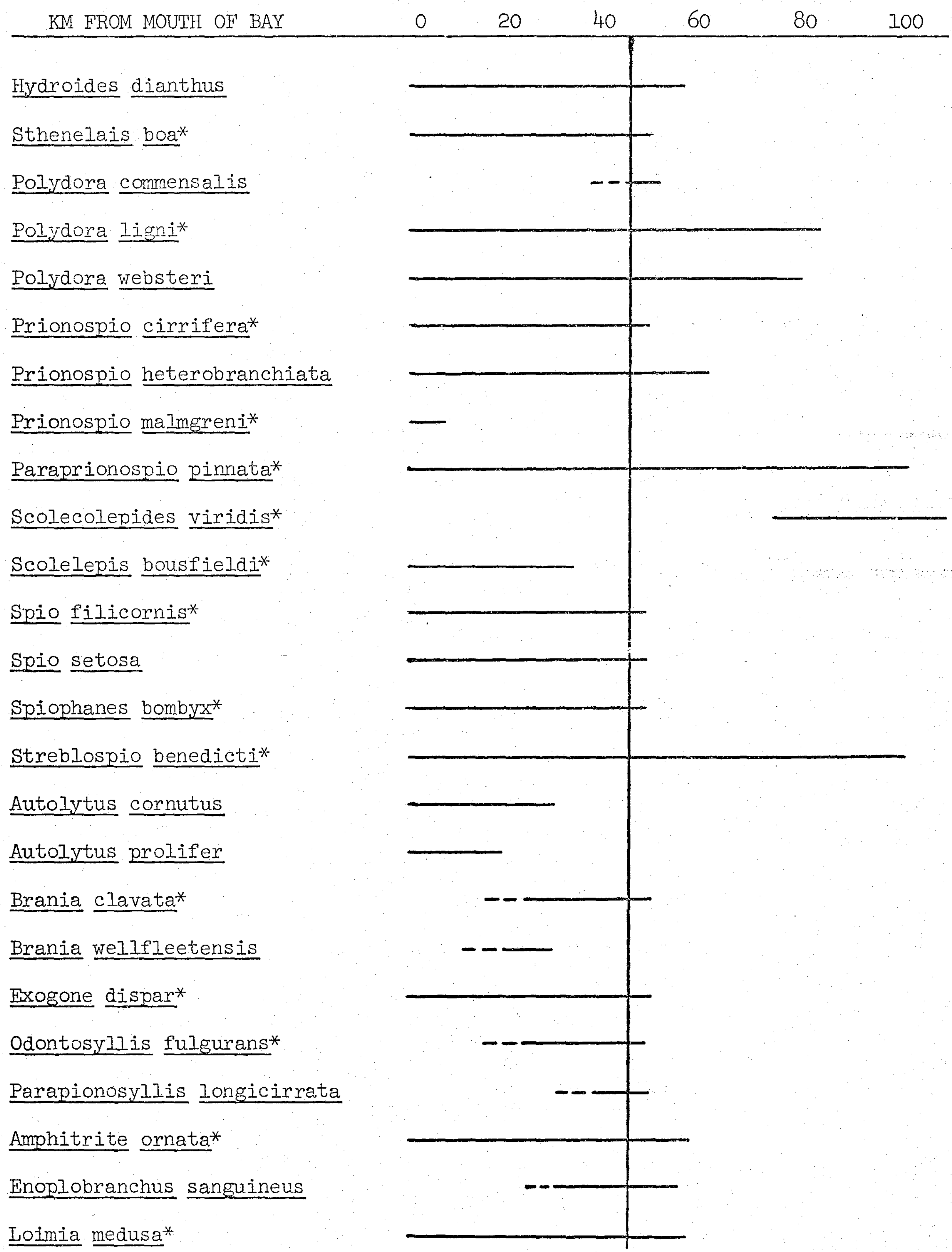
80
100
Owenia fusiformis*
Aricidea jeffreysi*
Aricidea wassi
Pectinaria gouldi*
Eteone lactea
Eteone heteropoda*
Eumida sanguinea*
Nereiphylla fragilis
Paranaitis speciosa
Phyllodoce arenae*
Phyllodoce mucosa
Ancistrosyllis hartmannae
Ancistrosyllis jonesi*
Cabira incerta
Sigambra tentaculata*
Sigambra wassi
Harmothoe acanellae
Harmothoe extenuata*
Harmothoe sp. A*
Lepidametra commensalis
Lepidonotus sublevis*
Sabellaria vulgaris*
Fabricia sabella
Potomilla neglecta
Sabella microphthalma*


KM FROM MOUTH OF BAY
0
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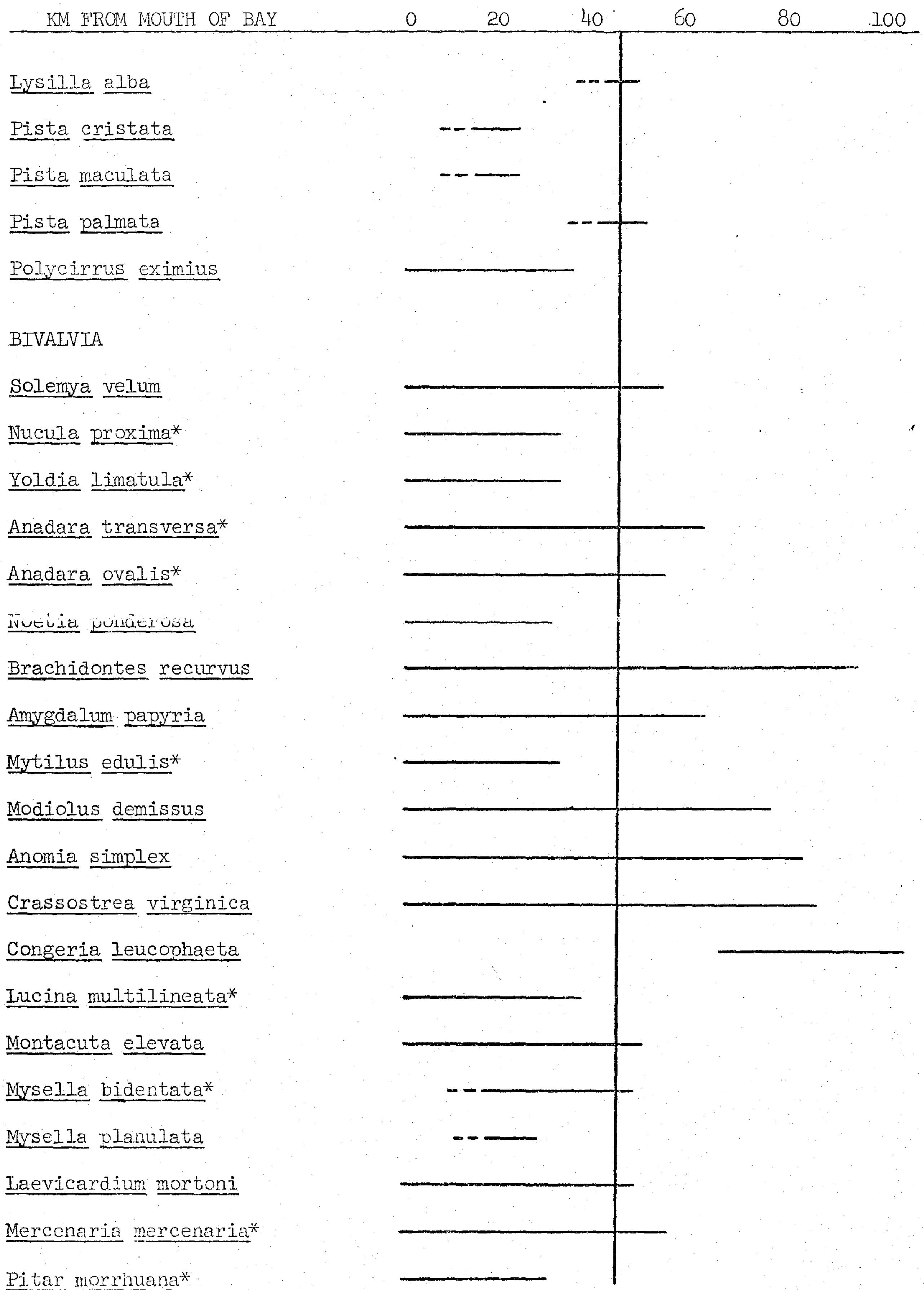
100
Hydroides dianthus
Sthenelais boa*
Polydora commensalis
Polydora ligni*
Polydora websteri
Prionospio cirrifera*
Prionospio heterobranchiata
Prionospio malmgreni*
Paraprionospio pinnata*
Scolecolepides viridis*
Scolelepis bousfieldi*
Spio filicornis*
Spio setosa
Spiophanes bombyx*
Streblospio benedicti*
Autolytus cornutus
Autolytus prolifer
Brania clavata*
Brania wellfleetensis
Exogone dispar*
Odontosyllis fulgurans*
Parapionosyllis longicirrata
Amphitrite ornata*
Enoplobranchus sanguineus
Loimia medusa*


KM FROM MOUTH OF BAY
0
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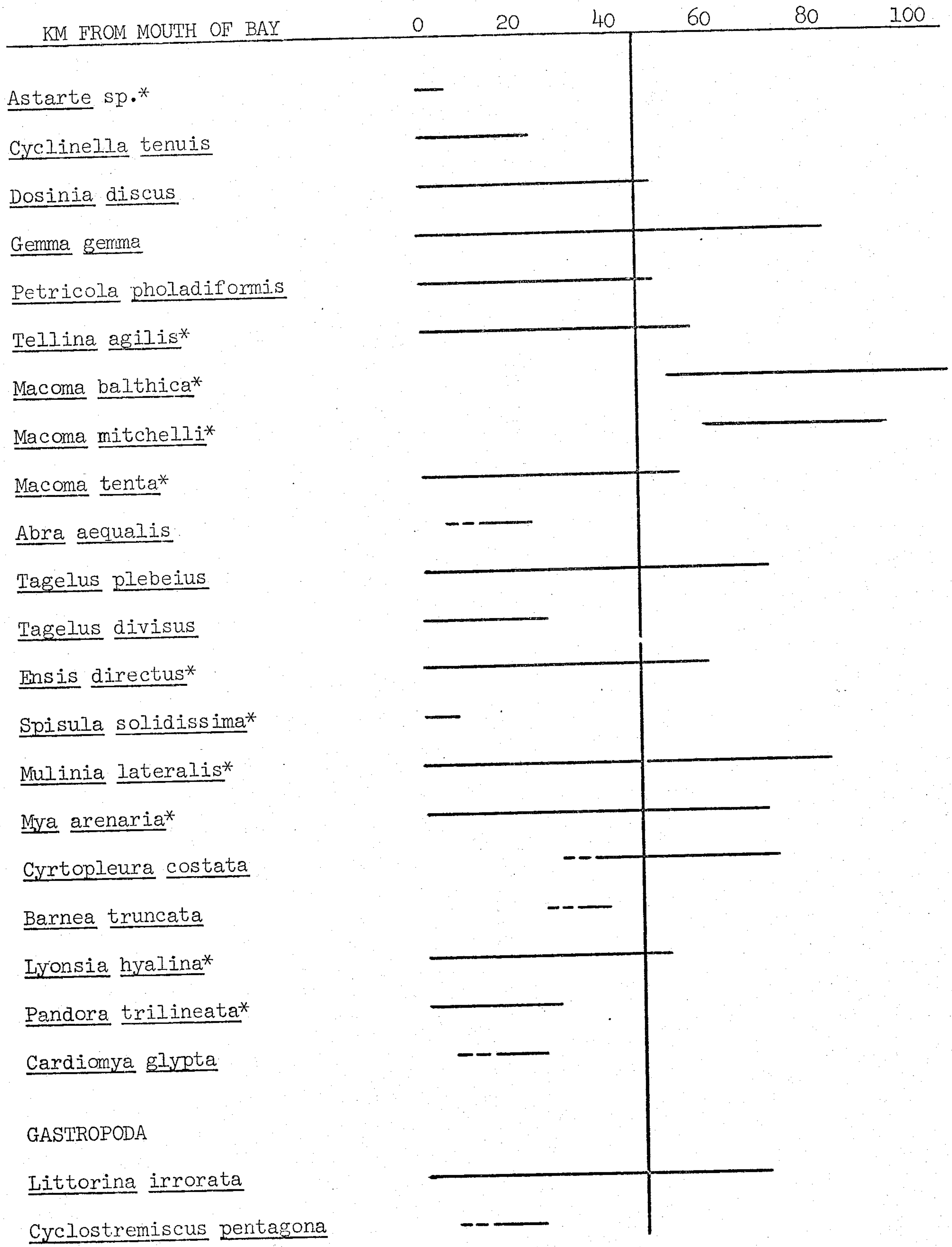
100
Lysilla alba
Pista cristata
Pista maculata
Pista palmata
Polycirrus eximius
BIVALVIA
Solemya velum
Nucula proxima*
Yoldia limatula*
Anadara transversa*
Anadara ovalis*
Noetia ponderosa
Brachidontes recurvus
Amygdalum papyria
Mytilus edulis*
Modiolus demissus
Anomia simplex
Crassostrea virginica
Congeria leucophaeta
Lucina multilineata*
Montacuta elevata
Mysella bidentata*
Mysella planulata
Laevicardium mortoni
Mercenaria mercenaria*
Pitar morrhuana*


KM FROM MOUTH OF BAY
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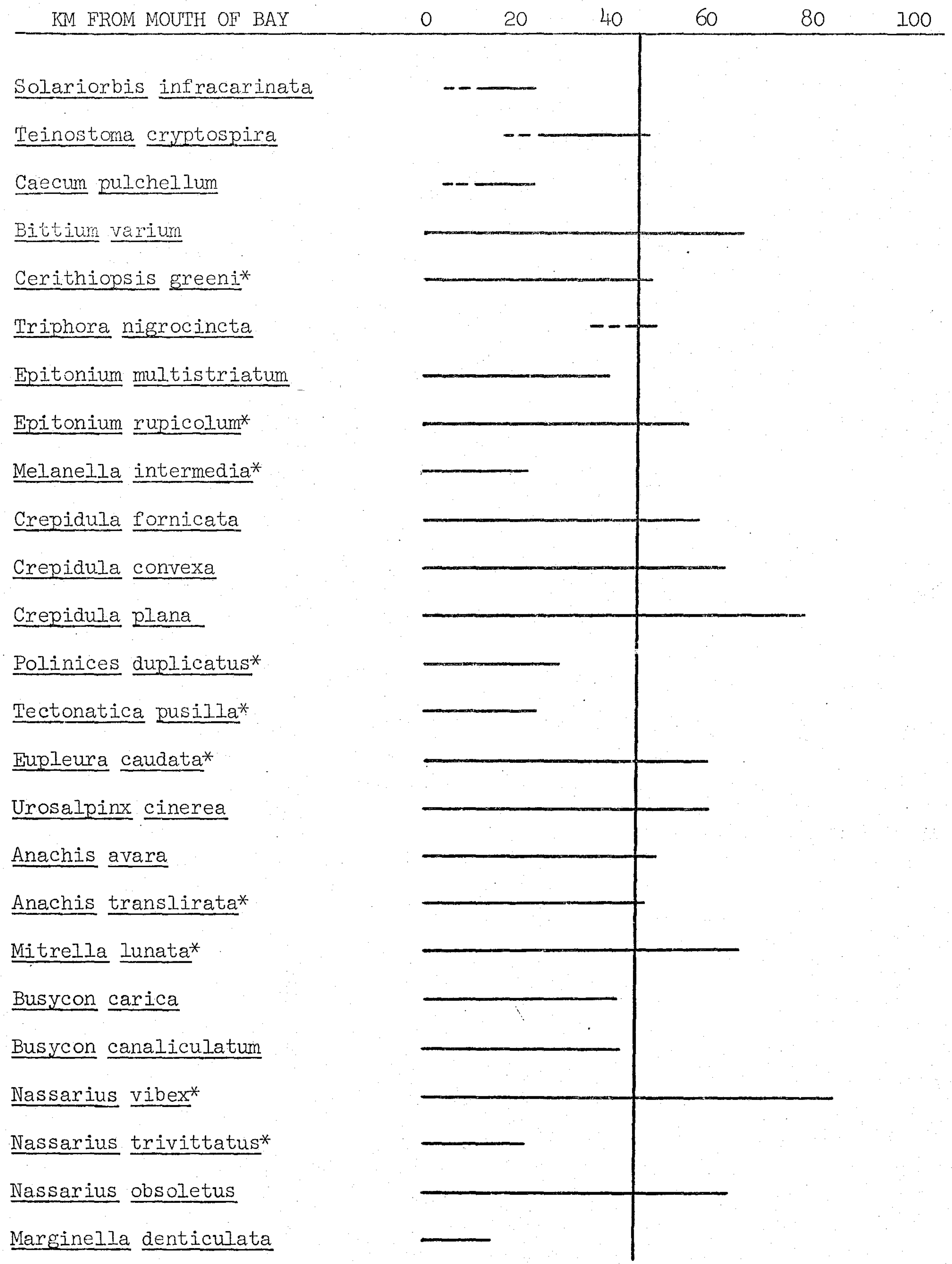
Astarte sp.*
Cyclinella tenuis
Dosinia discus
Gemma gemma
Petricola pholadiformis
Tellina agilis*
Macoma balthica*
Macoma mitchelli*
Macoma tenta*
Abra aequalis
Tagelus plebeius
Tagelus divisus
Ensis directus*
Spisula solidissima*
Mulinia lateralis*
Mya arenaria*
Cyrtopleura costata
Barnea truncata
Lyonsia hyalina*
Pandora trilineata*
Cardiomya glypta
GASTROPODA
Littorina irrorata
Cyclostremiscus pentagona


KM FROM MOUTH OF BAY
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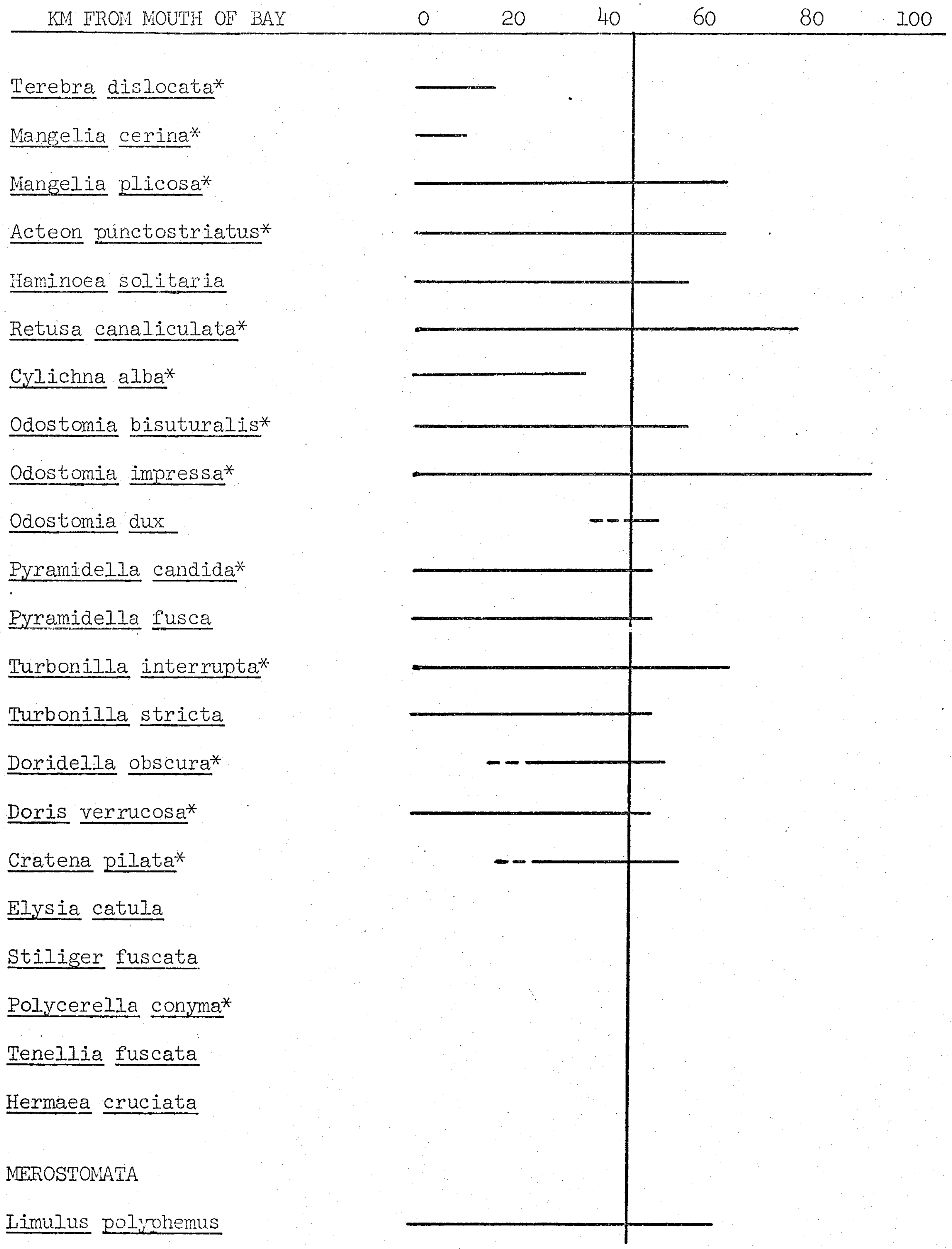
100
Solariorbis infracarinata
Teinostoma cryptospira
Caecum pulchellum
Bittium varium
Cerithiopsis greeni*
Triphora nigrocincta
Epitonium multistriatum
Epitonium rupicolum*
Melanella intermedia*
Crepidula fornicata
Crepidula convexa
Crepidula plana
Polinices duplicatus*
Tectonatica pusilla*
Eupleura caudata*
Urosalpinx cinerea
Anachis avara
Anachis translirata*
Mitrella lunata*
Busycon carica
Busycon canaliculatum
Nassarius vibex*
Nassarius trivittatus*
Nassarius obsoletus
Marginella denticulata


KM FROM MOUTH OF BAY
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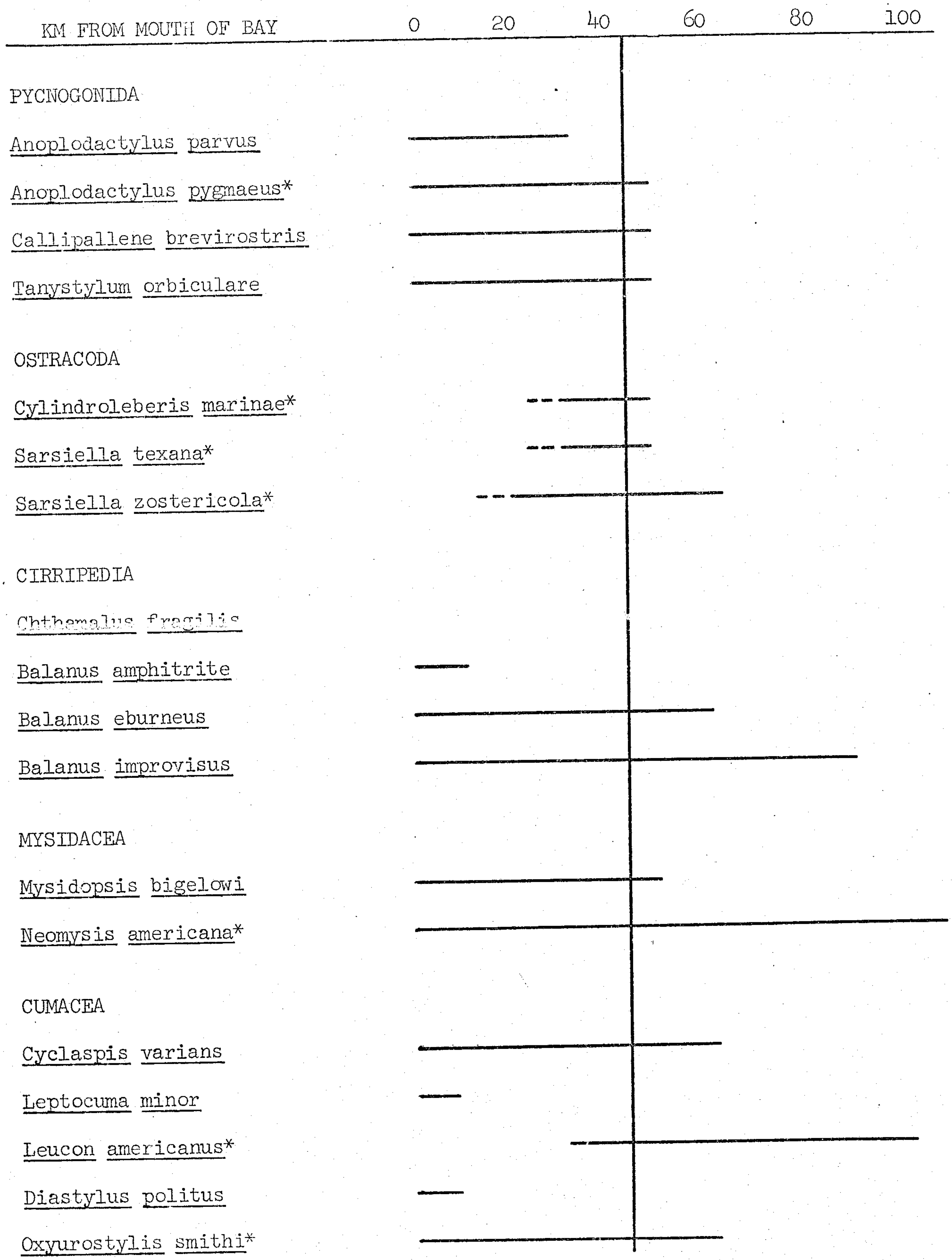
Terebra dislocata*
Mangelia cerina*
Mangelia plicosa*
Acteon punctostriatus*
Haminoea solitaria
Retusa canaliculata*
Cylichna alba*
Odostomia bisuturalis*
Odostomia impressa*
Odostomia dux
Pyramidella candida*
Pyramidella fusca
Turbonilla interrupta*
Turbonilla stricta
Doridella obscura*
Doris verrucosa*
Cratena pilata*
Elysia catula
Stiliger fuscata
Polycerella conyma*
Tenellia fuscata
Hermaea cruciata
MEROSTOMATA
Limulus polyphemus


KM FROM MOUTH OF BAY
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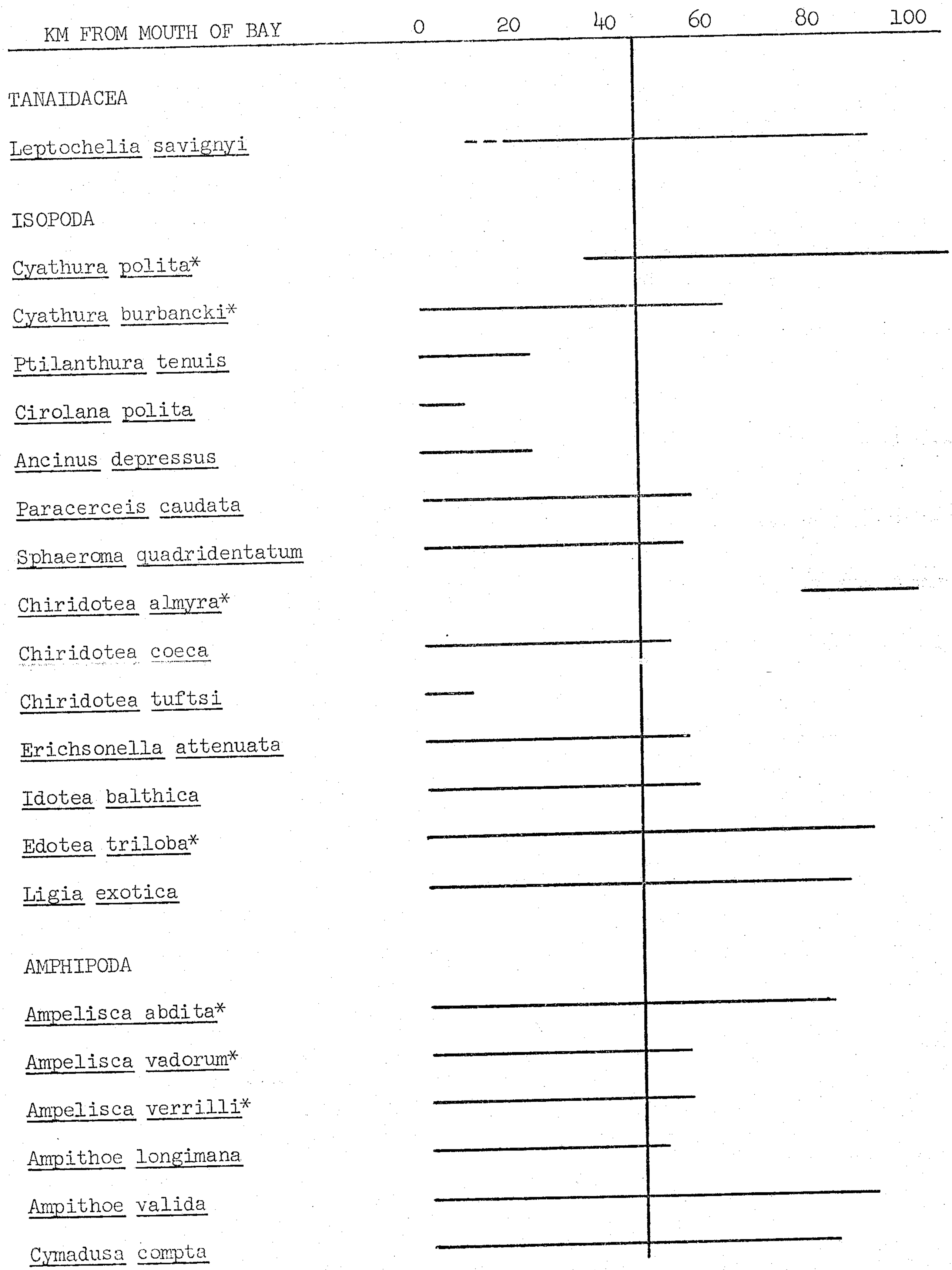
PYCNOGONIDA
Anoplodactylus parvus
Anoplodactylus pygmaeus*
Callipallene brevirostris
Tanystylum orbiculare
OSTRACODA
Cylindroleberis marinae*
Sarsiella texana*
Sarsiella zostericola*
CIRRIPEDIA
Chthamalus fragilis
Balanus amphitrite
Balanus eburneus
Balanus improvisus
MYSIDACEA
Mysidopsis bigelowi
Neomysis americana*
CUMACEA
Cyclaspis varians
Leptocuma minor
Leucon americanus*
Diastylus politus
Oxyurostylis smithi*


KM FROM MOUTH OF BAY
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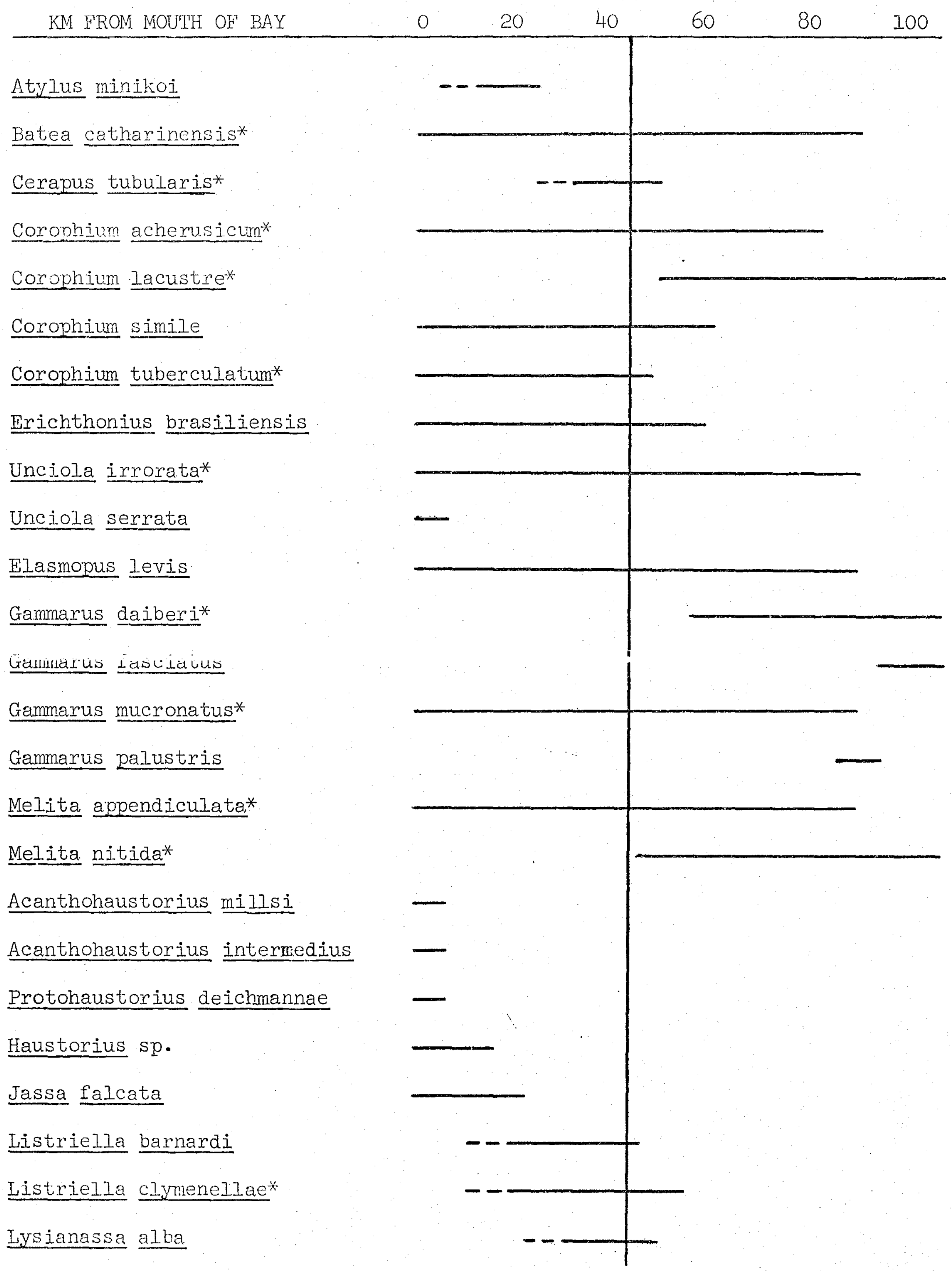
TANAIDACEA
Leptochelia savignyi
ISOPODA
Cyathura polita*
Cyathura burbancki*
Ptilanthura tenuis
Cirolana polita
Ancinus depressus
Paracerceis caudata
Sphaeroma quadridentatum
Chiridotea almyra*
Chiridotea coeca
Chiridotea tuftsi
Erichsonella attenuata
Idotea balthica
Edotea triloba*
Ligia exotica
AMPHIPODA
Ampelisca abdita*
Ampelisca vadorum*
Ampelisca verrilli*
Ampithoe longimana
Ampithoe valida
Cymadusa compta


KM FROM MOUTH OF BAY
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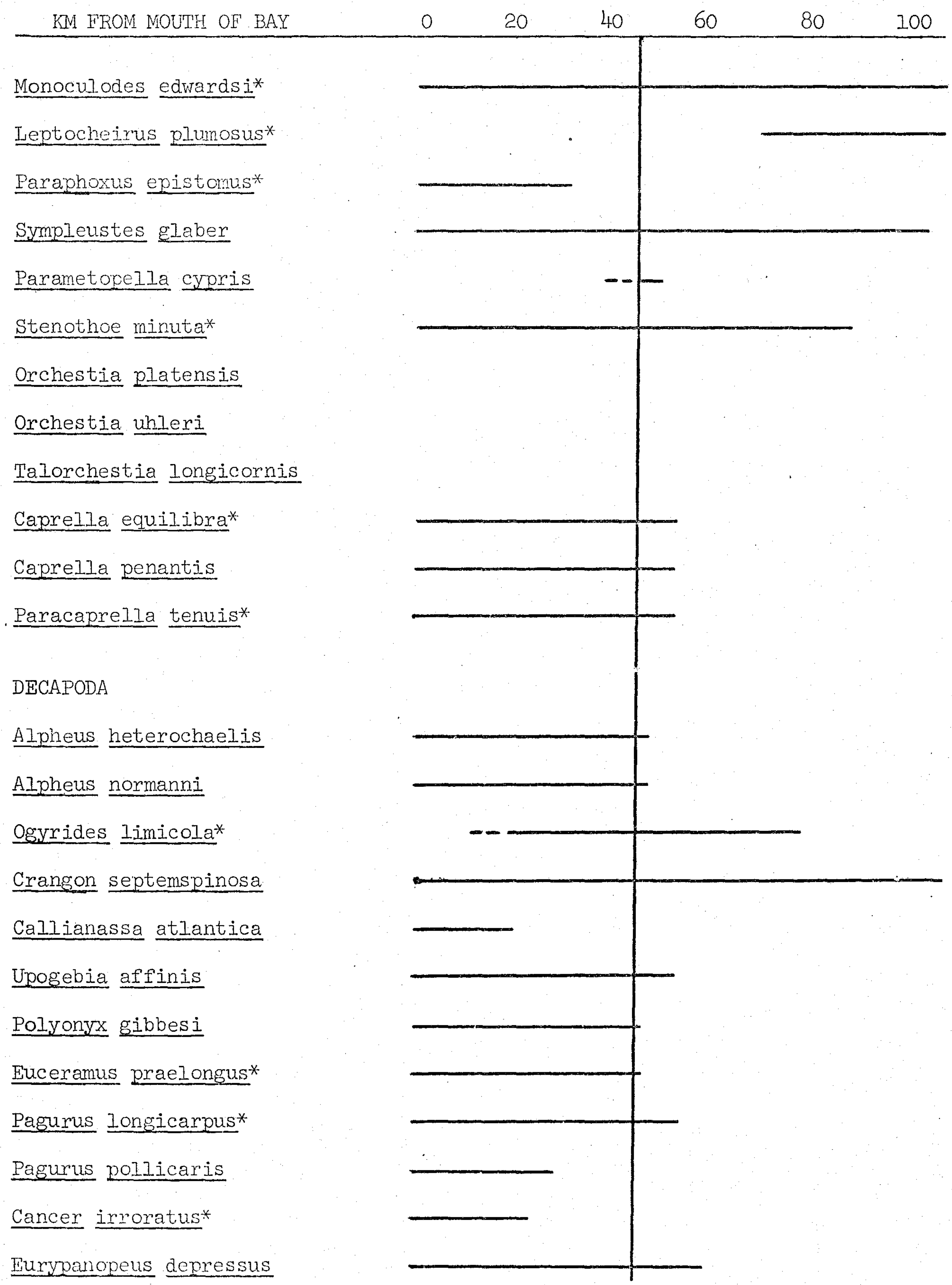
Atylus minikoi
Batea catharinensis*
Cerapus tubularis*
Corophium acherusicum*
Corophium lacustre*
Corophium simile
Corophium tuberculatum*
Erichthonius brasiliensis
Unciola irrorata*
Unciola serrata
Elasmopus levis
Gammarus daiberi*
Gammarus fasciatus
Gammarus mucronatus*
Gammarus palustris
Melita appendiculata*
Melita nitida*
Acanthohaustorius millsi
Acanthohaustorius intermedius
Protohaustorius deichmannae
Haustorius sp.
Jassa falcata
Listriella barnardi
Listriella clymenellae*
Lysianassa alba


KM FROM MOUTH OF BAY
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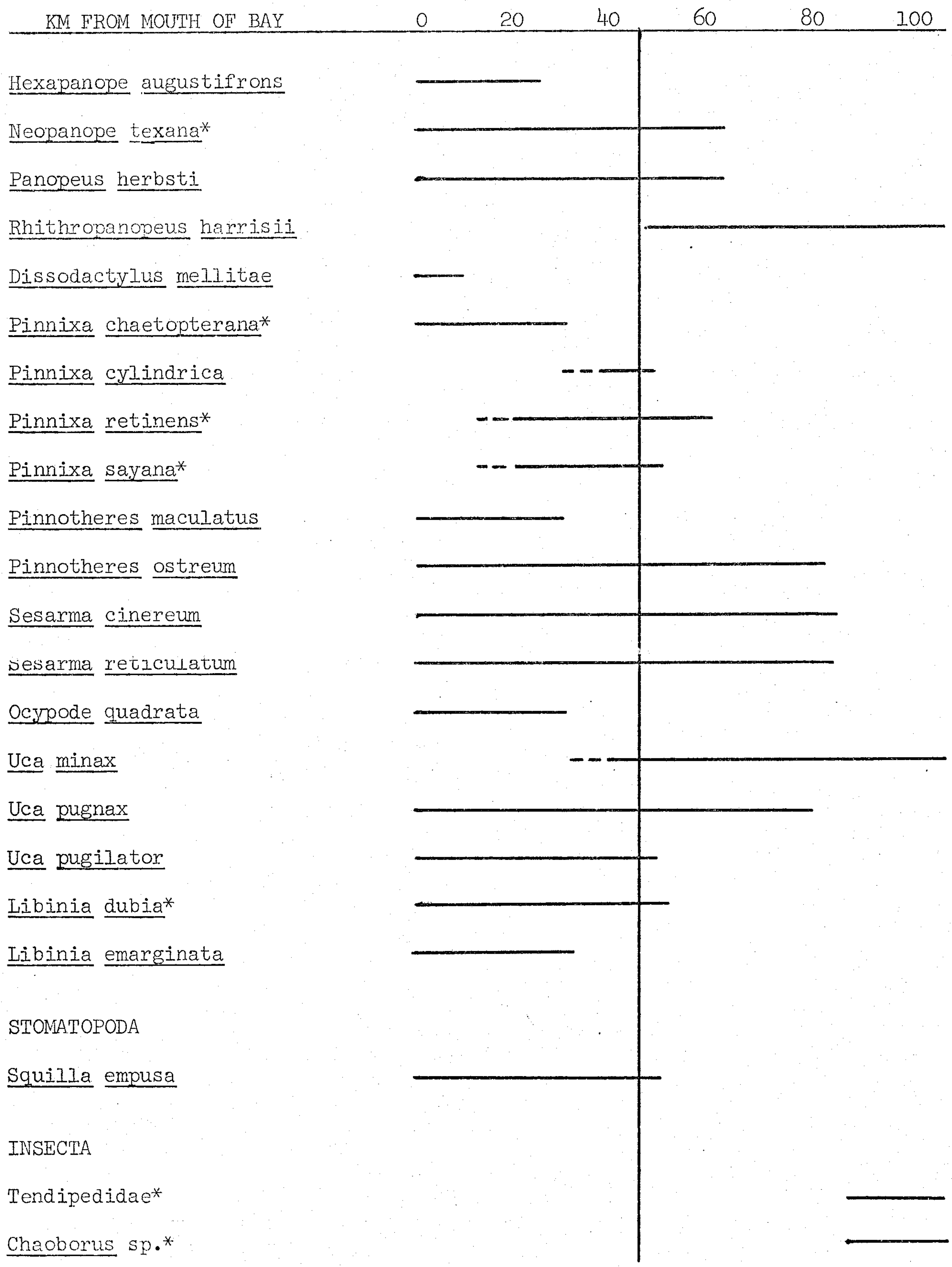
100
Monoculodes edwardsi*
Leptocheirus plumosus*
Paraphoxus epistomus*
Sympleustes glaber
Parametopella cypris
Stenothoe minuta*
Orchestia platensis
Orchestia uhleri
Talorchestia longicornis
Caprella equilibra*
Caprella penantis
Paracaprella tenuis*
DECAPODA
Alpheus heterochaelis
Alpheus normanni
Ogyrides limicola*
Crangon septemspinosa
Callianassa atlantica
Upogebia affinis
Polyonyx gibbesi
Euceramus praelongus*
Pagurus longicarpus*
Pagurus pollicaris
Cancer irroratus*
Eurypanopeus depressus


KM FROM MOUTH OF BAY
0
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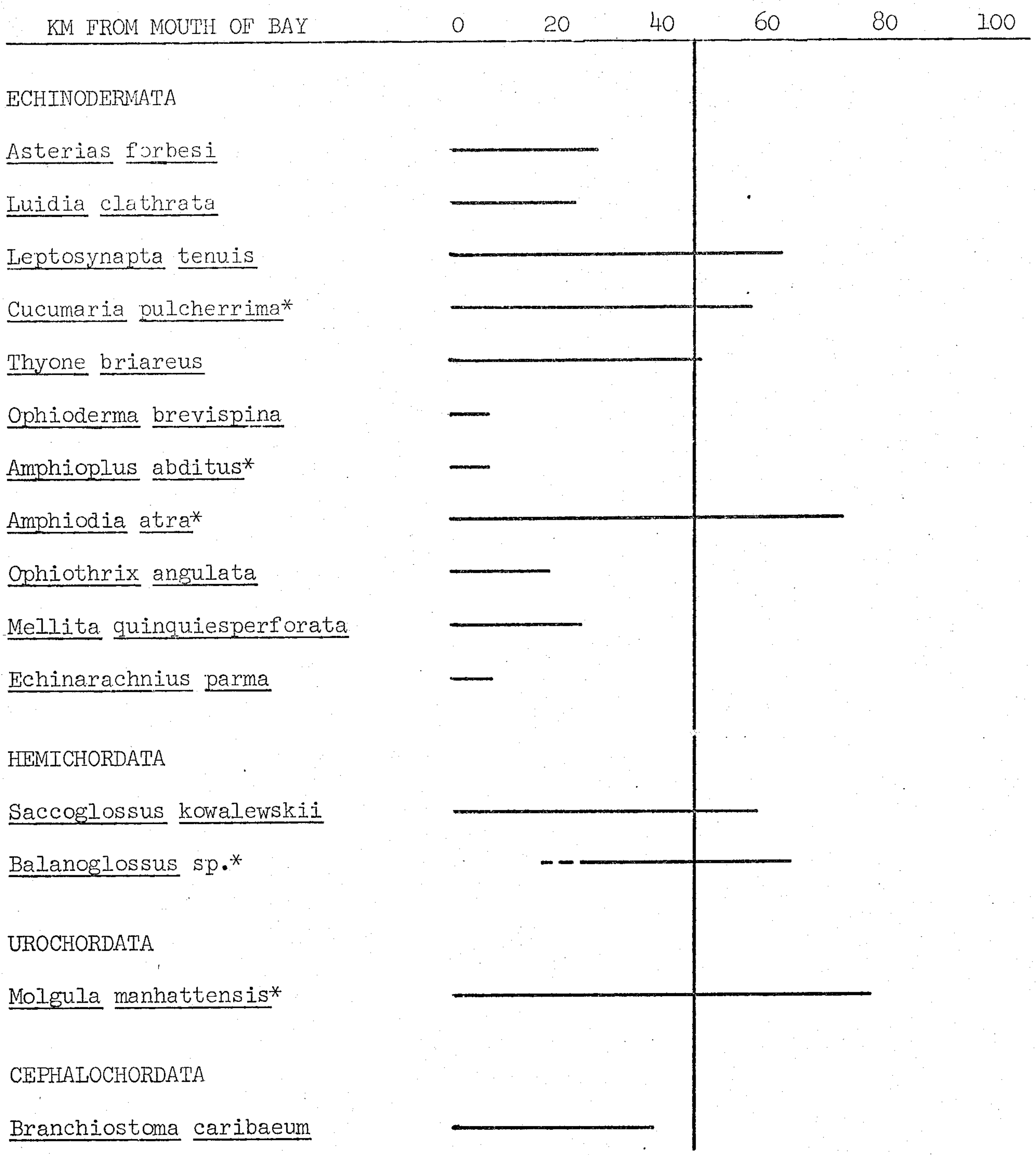
Hexapanope augustifrons
Neopanope texana*
Panopeus herbsti
Rhithropanopeus harrisii
Dissodactylus mellitae
Pinnixa chaetopterana*
Pinnixa cylindrica
Pinnixa retinens*
Pinnixa sayana*
Pinnotheres maculatus
Pinnotheres ostreum
Sesarma cinereum
Sesarma reticulatum
Ocypode quadrata
Uca minax
Uca pugnax
Uca pugilator
Libinia dubia*
Libinia emarginata
STOMATOPODA
Squilla empusa
INSECTA
Tendipedidae*
Chaoborus sp.*



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[1] Oligochaetes have been identified by Dr. D. G. Cook:

Oligochaete A - mainly immature Peloscolex gabriellae
Oligochaete B - Peloscolex heterochaetus Michaelson, 1926
Oligochaete C - P. gabriellae-like (may be distinct species, subspecies, or ecotype).

diversity were observed and the absolute value for various measures remained fairly constant until the station located about 60 km up from the Bay mouth was reached.

Feeley (1967) studied the occurrence of benthic amphipods of the Suborder Gammaridea in the lower Chesapeake Bay region. Figure 3 (reproduced from Feeley) shows the salinity ranges for 24 species found in the York-Pamunkey system during his study. He found that epifaunal species moved up or down the river with changes in salinity resulting from the seasonal oscillation of river discharge. Limiting factors most likely to affect local distribution were found to be: salinity, substrate, water temperature, dissolved oxygen concentration, and pollution.

The eelgrass or *Zostera* beds of the Chesapeake Bay play an important role in the ecology of many Bay species. They serve as a microhabitat for animals, a substrate for epibiota, provide protection for small fishes and are utilized directly as a food by waterfowl. Two studies have been conducted which characterize this community in the York River. The one concerned with benthic infauna, Orth (1971) will be reviewed first.

Orth sampled five stations located in various salinity regimes during March and July of 1970. At each station he determined community composition, sediment type and salinity. During the study a total of 117 macroinvertebrate taxa were

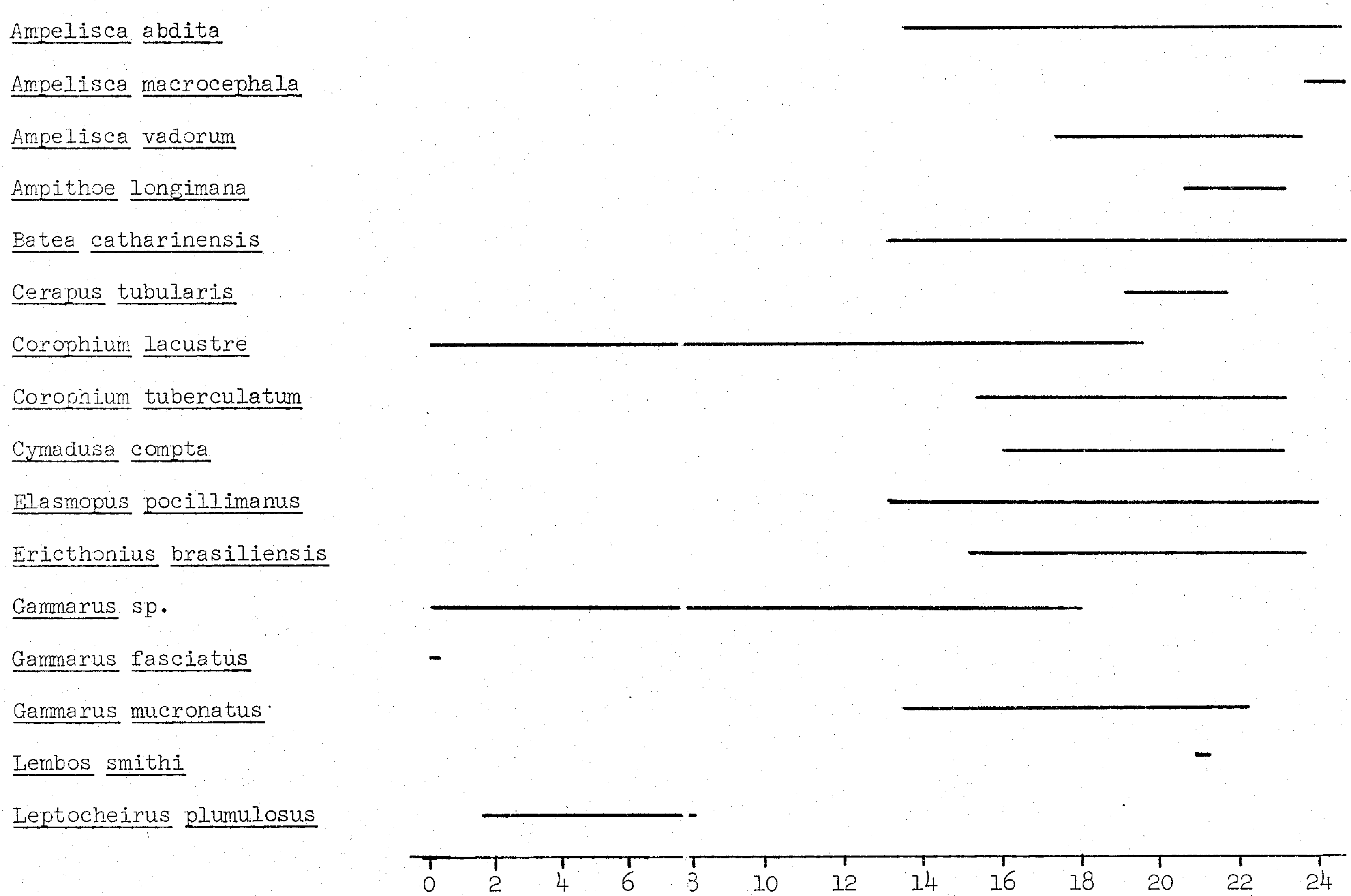


Figure 3. Salinity ranges for 24 species found in the York-Pamunkey system as determined from bottom salinities taken at time of sampling.

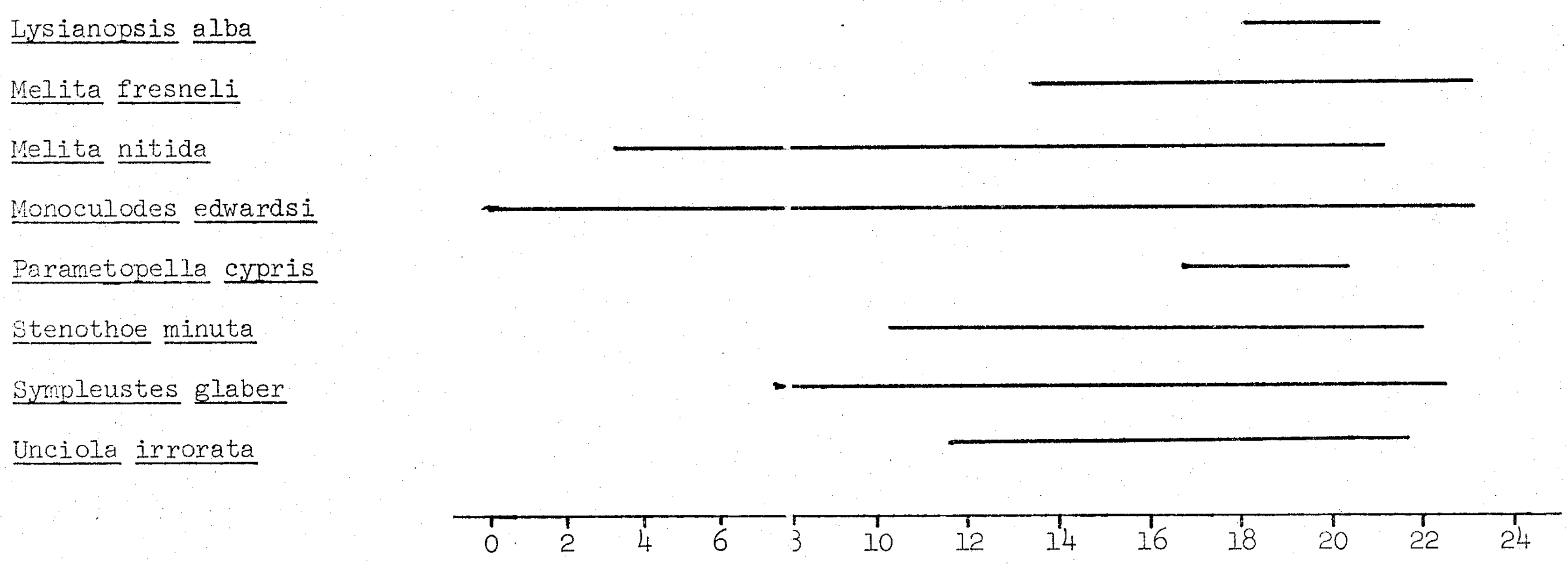


Figure 3 continued. Salinity ranges for 24 species found in the York-Pamunkey system as determined from bottom salinities taken at time of sampling.

collected. Species abundance decreased up the estuary and interactions in the number of species between stations and seasons were demonstrated.

Dominant species at station C, located nearest the site of interest were, Ampelisca abdita, Streblospio benedicti, Polydora ligni, Spiochaetopterus oculatus, oligochaetes, Nereis succinea, Ampelisca vodorum, Exogone dispar, and Heteromastus filiformis.

Greatest seasonal change in species composition at all stations occurred with the spionid polychaetes and oligochaetes. However, no significant differences were noted either between stations or seasons in diversity or equitability.

Animal densities were very high, with a mean of 15,143 individuals/m^2.

Marsh (1970) conducted an investigation of the epibiota of Zostera beds located off Mumfort Island from November 1967 to December 1968. Stations were established at three different depths within the eelgrass bed and samples were taken for 14 consecutive months.

Seasonal patterns of abundance were described for 24 species of macroinvertebrates. Three general abundance patterns were observed---peak populations occurred in summer, winter or both, with highest density between June and September being the most common.

The most abundant non-colonial invertebrates were Bittium varium, Paracerceis caudata, Crepidula convexa, Ampithoe logimana and Erichsonella attenuata. These five species accounted for nearly 60% of the total fauna collected. Although no seasonal patterns in diversity were recorded, the number of species increased from winter to summer reaching a peak at most stations in late summer.

Twenty-nine species of epiphytic algae were identified, and distinct summer and winter floras were described. Seasonal abundance patterns for eleven species are documented.

Besides studying the epibiota, he investigated the growth patterns of the eelgrass finding that the plants attained maximum biomass in June and that the biomass of the beds then declined reaching a low in February.

Warinner and Brehmer (1966) studied the effects of the present Yorktown-VEPCO thermal outfall upon the benthic community. We have calculated several new diversity indices on this data and these are presented in Table 2. Benthic communities were monitored at various distances from the thermal discharge from April 1963 through May 1964. Community composition and abundance of marine invertebrates were affected by the discharge over a distance of 300-400 m from the discharge. Species richness and diversity were lower at stations within 300 m of the discharge during the summer months. During the winter, however, the opposite was true even though the number of species was lower.

Table 2

Diversity indices calculated for the benthos data of Warinner and Brehmer (1966)

Station Number	No. of Individuals	No. of Species	Shannon Formula H-Prime	Shannon Formula Evenness-JPR	Brillouin Formula H	Brillouin Formula Evenness-J	Redundancy	Richness S-1/LN N
(1963)								
04D1	92	14	1.8123	0.4760	1.5751	0.4575	0.7367	2.8749
04D2	49	12	2.3704	0.6612	1.9822	0.6422	0.5930	2.8264
04D3	31	14	3.1887	0.8375	2.5284	0.8346	0.4600	3.7856
04C4	22	7	2.5884	0.9220	2.0852	0.9205	0.1639	1.9410
04D4	41	18	3.6492	0.8751	2.9707	0.8788	0.3161	4.5778
04D5	49	19	3.9176	0.9222	3.2587	0.9276	0.1633	4.6250
04A4	41	13	3.2509	0.8785	2.7086	0.8750	0.2432	3.2313
04B4	46	6	1.3231	0.5118	1.1381	0.4938	0.6816	1.3059
06D1	29	10	2.8623	0.8616	2.3282	0.8597	0.2993	2.6727
06D2	20	9	2.6841	0.8467	2.0596	0.8422	0.4628	2.6704
06D3	58	21	3.6667	0.8348	3.0817	0.8352	0.3448	4.9255
06D4	41	12	3.1839	0.8881	2.6813	0.8901	0.2033	2.9621
06D5	69	21	3.5674	0.8122	3.0506	0.8094	0.3482	4.7235
06C4	41	14	3.5164	0.9236	2.9283	0.9241	0.1554	3.5006
06B4	4	4	2.0000	1.0000	1.1462	1.0000	0.0000	2.1640
06A4	98	17	2.9009	0.7097	2.5874	0.7034	0.4167	3.4896
07B4	42	15	3.3943	0.8688	2.8156	0.8702	0.2758	3.7456
07D2	58	7	1.6420	0.5849	1.4417	0.5691	0.5643	1.4776
07D4	64	18	3.5841	0.8595	3.0908	0.8620	0.2419	4.0876
07A4	33	13	3.3363	0.9016	2.7070	0.9058	0.2243	3.4319
07C4	42	14	3.3940	0.8914	2.8292	0.8886	0.2235	3.4781
07D3	19	11	2.9633	0.8566	2.2037	0.8588	0.6575	3.3962
07D1	36	5	0.8482	0.3653	0.6786	0.3319	0.9247	1.1162
07D5	64	22	3.6590	0.8205	3.0880	0.8156	0.3671	5.0494
08A4	43	10	2.6870	0.8088	2.2850	0.8019	0.3235	2.3928
08B4	21	8	2.5468	0.8489	2.0000	0.8477	0.3694	2.2992
08C4	28	11	2.7134	0.7843	2.1500	0.7774	0.5385	3.0010
08D1	34	2	0.3227	0.3227	0.2685	0.2934	0.8446	0.2835
08D2	15	3	0.6998	0.4415	0.5142	0.3950	1.0000	0.7385
08D3	8	5	2.1556	0.9283	1.4642	0.9524	0.3690	1.9235
08D4	19	6	2.1406	0.8280	1.6903	0.8183	0.3785	1.6981

Table 2 (continued)

Station Number	No. of Individuals	No. of Species	Shannon Formula H-Prime	Shannon Formula Evenness-JPR	Brillouin Formula H	Brillouin Formula Evenness-J	Redundancy	Richness S-1/LN N
08D5	18	8	2.7052	0.9017	2.0794	0.9054	0.2774	2.4218
09A4	210	25	2.1846	0.4704	1.9676	0.4550	0.6826	4.4884
09B4	43	18	3.5094	0.8416	2.8584	0.8405	0.3934	4.5198
09D2	49	12	2.1948	0.6122	1.8237	0.5909	0.6782	2.8264
09C4	72	15	2.1217	0.5430	1.7989	0.5219	0.7245	3.2735
09D1	31	7	2.3096	0.8227	1.9401	0.8171	0.3016	1.7472
09D3	16	4	1.5919	0.7959	1.2622	0.7794	0.4025	1.0820
09D4	58	20	3.6078	0.8347	3.0352	0.8311	0.3396	4.6792
09D5	19	5	1.6282	0.7012	1.2807	0.6791	0.5948	1.3584
10A4	182	33	4.0408	0.8010	3.6816	0.8004	0.2778	6.1491
10B4	203	21	2.4685	0.5620	2.2681	0.5520	0.5476	3.7642
10D1	64	6	1.5157	0.5863	1.3516	0.5713	0.5336	1.2022
10D2	52	14	3.2268	0.8475	2.7538	0.8453	0.2682	3.2901
10D3	31	16	3.7166	0.9291	2.9355	0.9317	0.2277	4.3681
10D4	95	15	2.1769	0.5572	1.9101	0.5412	0.6284	3.0743
10D5	280	13	1.1008	0.2974	1.0109	0.2844	0.7930	2.1296
11B4	686	38	2.6038	0.4961	2.4886	0.4911	0.5653	5.6653
11C4	405	20	2.1699	0.5020	2.0643	0.4959	0.5583	3.1646
11D2	99	17	2.8620	0.7002	2.5514	0.6929	0.4299	3.4819
11A4	222	21	2.1126	0.4809	1.9294	0.4675	0.6405	3.7018
11D1	24	11	3.0902	0.8932	2.4189	0.8949	0.3072	2.1465
11D3	62	24	4.1432	0.9036	3.4905	0.9099	0.1989	5.5728
11D4	85	20	3.8772	0.8971	3.4166	0.8980	0.1610	4.2767
11D5	62	21	3.7582	0.8556	3.1849	0.8536	0.2888	4.8459
12A4	372	38	3.5102	0.6688	3.2900	0.6637	0.4050	6.2511
12B4	588	34	2.4426	0.4801	2.3206	0.4735	0.5881	5.1750
12C4	300	33	2.3010	0.4561	2.0991	0.4429	0.6822	5.6103
12D1	20	10	2.6954	0.8114	2.0304	0.7950	0.6864	3.0042
12D2	56	12	2.8191	0.7863	2.4507	0.7839	0.3355	2.7326
12D3	75	20	3.7289	0.8627	3.2499	0.8652	0.2273	4.4007
12D4	157	22	2.7907	0.6258	2.5195	0.6141	0.5042	4.1532
(1964)								
01A4	222	39	4.4480	0.8415	4.0818	0.8420	0.2165	7.0335

Table 2 (continued)

Station Number	No. of Individuals	No. of Species	Shannon Formula H-Prime	Shannon Formula Evenness-JPR	Brillouin Formula H	Brillouin Formula Evenness-J	Redundancy	Richness S-1/LN N
01B4	870	38	2.6372	0.5025	2.5369	0.4976	0.5467	5.4665
01C4	526	32	2.2494	0.4498	2.1192	0.4409	0.6283	4.9478
01D1	37	15	3.4185	0.8749	2.7824	0.8783	0.2948	3.8771
01D2	94	21	2.9988	0.6827	2.6326	0.6768	0.4970	4.4020
01D3	100	16	2.6722	0.6680	2.3816	0.6585	0.4684	3.2572
01D4	325	27	2.6433	0.5559	2.4739	0.5483	0.5294	4.4952
01D5	1044	48	2.9849	0.5344	2.8789	0.5304	0.5119	6.7617
02A4	422	53	4.6008	0.8032	4.3267	0.8035	0.2447	8.6021
02B4	491	35	3.3521	0.6535	3.1908	0.6498	0.4003	5.4870
02C4	404	42	3.0014	0.5566	2.7912	0.5477	0.5454	6.8317
02D1	33	17	3.7785	0.9244	2.9962	0.9266	0.2421	4.5759
02D2	24	14	3.5697	0.9375	2.7310	0.9494	0.2289	4.0905
02D3	151	25	3.6078	0.7769	3.2755	0.7728	0.3099	4.7834
02D4	737	41	3.2400	0.6047	3.1100	0.6009	0.4431	6.0582
02D5	687	37	2.2205	0.4262	2.1075	0.4188	0.6441	5.5110
03A4	126	29	4.0648	0.8367	3.6277	0.8371	0.2501	5.7895
03B4	440	27	2.1426	0.4506	2.0137	0.4414	0.6298	4.2715
03C4	165	33	3.3301	0.6601	2.9677	0.6490	0.5059	6.2672
03D1	24	6	2.1887	0.8467	1.8028	0.8397	0.2823	1.5732
03D2	113	17	2.5574	0.6256	2.2818	0.6137	0.5191	3.3845
03D3	135	28	3.8896	0.8091	3.4951	0.8083	0.2819	5.5042
03D4	144	29	3.2724	0.6736	2.9028	0.6617	0.4911	5.6340
03D5	334	30	2.1358	0.4352	1.9717	0.4243	0.6816	4.9904
04A4	233	38	3.5522	0.6768	3.2514	0.6723	0.4394	6.7876
04B4	408	29	2.2664	0.4665	2.1202	0.4568	0.6225	4.6579
04C4	158	22	2.6010	0.5832	2.3466	0.5717	0.5586	4.1480
04D1	129	22	3.2602	0.7310	2.9247	0.7226	0.3837	4.3211
04D2	75	19	3.4841	0.8202	3.0324	0.8172	0.3002	4.1690
04D3	103	29	3.7128	0.7642	3.2427	0.7628	0.4048	6.0413
04D4	339	40	2.9008	0.5450	2.6689	0.5342	0.5761	6.6941

Table 2 (continued)

Station Number	No. of Individuals	No. of Species	Shannon Formula H-Prime	Shannon Formula Evenness-JPR	Brillouin Formula H	Brillouin Formula Evenness-J	Redundancy	Richness S-1/LN N
04D5	194	27	2.8615	0.6018	2.5937	0.5902	0.5313	4.9355
05A4	82	25	3.1149	0.6707	2.6390	0.6579	0.6190	5.4462
05B4	247	27	2.3741	0.4992	2.1751	0.4883	0.6286	4.7192
05C4	449	38	2.0245	0.3857	1.8664	0.3735	0.7320	6.0586
05D1	99	22	2.8765	0.6450	2.5052	0.6331	0.5617	4.5700
05D2	46	10	2.3865	0.7184	2.0241	0.7052	0.4659	2.3507
05D3	105	26	3.9104	0.8319	3.4524	0.8301	0.2713	5.3717
05D4	200	22	2.0003	0.4485	1.8043	0.4335	0.7001	3.9635
05D5	365	41	2.7064	0.5051	2.4890	0.4934	0.6201	6.7797

Literature Cited

Boesch, D. F. 1971. Benthic communities in a gradient estuary. Ph.D. Thesis, The College of William and Mary in Virginia, Williamsburg, Va. 120 p.

Feeley, J. B. 1967. The distribution and ecology of the Gammaridea (Crustacea: Amphipoda) of the lower Chesapeake estuaries. M. A. Thesis, The College of William and Mary in Virginia, Williamsburg, Va. 76 p.

Haven, D. S., Kraeuter, J., Swartz, R. and M. Wass. 1966. An animal-sediment study in the Lower York River, Virginia. Final contract report, U.S.A.E.C. Contract No. AT-(40-1) 2789.

Marsh, G. A. 1970. A seasonal study of _Zostera_ epibiota in the York River, Virginia. Ph.D. Thesis, The College of William and Mary in Virginia, Williamsburg, Va. 155 p.

McNaughton, S. J. 1967. Relationships among functional properties of California grassland. Nature 216: 168-169.

Orth, R. J. 1971. Benthic infauna of eelgrass, _Zostera marina_ beds. M. S. Thesis, University of Virginia, Charlottesville, Va. 79 p.

Warinner, J. E. and M. L. Brehmer. 1966. The effects of thermal effluents on marine organisms. _Air and Water Pollut. Int. J._ 10: 272-289.

Wass, M. L., Kerwin, J. A. and J. C. McCain. 1967. A York River infaunal community in soft bottom. Manuscript.

Oyster Populations of the York River

by

Dexter Haven

The York River receives considerable freshwater inflow and in this respect it is similar to the Rappahannock and James rivers. Oysters occur over the length of the system but are extremely scarce in the lower half of the river today, due to MSX which is most destructive, Andrews (1967). Drills are abundant in the lower third of the river and extend up-river as far as Greens and Pages Rock. For this reason few spat setting on natural cultch survive in the zone from Gloucester Point to the mouth of the river. Oyster culture today is restricted to the upper third of the river from Capahosic to Bell Rock. Prior to MSX in 1960, however, the lower river was extensively used by private growers for growing James River seed to market size.

The York River has had a history of poor set and low oyster production. The magnitude of set is comparable to that which occurs in the lower Rappahannock. Setting was first studied in the York River in 1936 using wire shell bags, Galtsoff _et al._ (1947). Their study showed that setting decreased from the mouth to the head of the river. They commented that mortality of spat on the bottom material was greatest down-river, and that by the end of the setting season there was no material difference between numbers of surviving spat in the two parts of the river. Data extracted from the Galtsoff paper showed that setting began in the lower river in mid-July and lasted through mid-October, with a peak in mid-September. In the upper river near West Point setting occurred over a shorter period during August and September. Calculations based on these data show maximum weekly set in the upper river at about 0.1 spat per shell per week. In the lower river it was about 0.5 spat per shell per week. Spat on naturally occurring bottom cultch at nine stations when sampled in 1936 averaged about 100 spat per bushel and showed no difference in numbers in an up or down-river direction.

Data on bottom material from the York from 1947 to 1971 are tabulated in Table 3.

Spat on Natural Cultch

Numbers of spat surviving on natural cultch for the years from 1946 to 1960 fluctuated erratically with five year averages ranging from 6 to 154 spat per bushel. From 1960 to 1971, however, there seemed to be a decline in the quantity of set surviving at all stations. There is a question however, of whether or not there was an actual decline at Aberdeen Rock, Page's Rock and Green Rock, from 1961 to 1971 since pre-1961 averages are so heavily weighted by the heavy set of 1956.

Table 3

Live Oysters Per Bushel of Unculled Bottom Sample from the York River[1]

Calendar Year	LARGE OYSTERS			
	Green Rock	Page's Rock	Aberdeen Rock	Bell Rock
1946	N/A	72	N/A	92
7	N/A	71	60	64
8	N/A	N/A	N/A	N/A
9	N/A	61	37	92
1950	N/A	164	27	124
Average	N/A	92	41	93
1951	N/A	40	23	54
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	41	N/A	N/A
5	N/A	37	56	90
Average	N/A	39	40	72
1956	N/A	21	61	56
7	N/A	84	92	118
8	32	42	46	72
9	31	27	25	60
1960	10	15	27	12
Average	24	38	50	63
1961	3	16	30	24
2	5	16	19	32
3	N/A	50	52	39
4	15	27	91	78
5	9	57	57	50
Average	8	33	50	45
1966	9	50	35	20
7	N/A	39	28	11
8	N/A	24	36	47
9	6	6	20	67
1970	7	19	30	56
Average	5	28	30	40
1971	0	1	14	8

Table 3 (continued)

Live Oysters Per Bushel of Unculled Bottom Sample from the York River

Calendar Year	SMALL OYSTERS AND YEARLINGS			
	Green Rock	Page's Rock	Aberdeen Rock	Bell Rock
1946	N/A	156	2	100
7	N/A	116	104	107
8	N/A	N/A	N/A	N/A
9	N/A	40	23	76
1950	N/A	52	12	90
Average	N/A	91	35	93
1951	N/A	10	64	276
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	43	N/A	N/A
5	17	7	2	2
Average	17	20	33	139
1956	N/A	175	141	222
7	N/A	159	380	246
8	46	124	316	148
9	7	32	269	82
1960	9	6	50	65
Average	20	99	231	152
1961	0	41	81	106
2	0	15	22	139
3	2	47	24	75
4	1	5	91	85
5	6	360	109	374
Average	3	94	65	156
1966	1	13	36	114
7	N/A	66	71	443
8	N/A	25	99	178
9	3	7	34	203
1970	2	15	65	118
Average	2	25	61	211
1971	4	14	8	128

Table 3 (continued)

Live Oysters Per Bushel of Unculled Bottom Sample from the York River

	SPAT			
Calendar Year	Green Rock	Page's Rock	Aberdeen Rock	Bell Rock
1946	N/A	0	2	4
7	N/A	0	4	381
8	N/A	N/A	N/A	N/A
9	N/A	101	45	64
1950	N/A	8	13	170
Average	N/A	27	16	154
1951	N/A	4	67	54
2	N/A	N/A	N/A	N/A
3	N/A	N/A	N/A	N/A
4	N/A	0	N/A	N/A
5	90	113	2	2
Average	90	38	34	28
1956	N/A	210	230	326
7	N/A	21	95	294
8	1	40	1	1
9	11	1	3	12
1960	N/A	3	0	13
Average	6	55	65	129
1961	0	2	0	1
2	6	16	11	9
3	N/A	36	18	1
4	21	53	166	93
5	0	2	21	11
Average	7	22	43	23
1966	16	17	11	34
7	N/A	11	3	0
8	N/A	2	1	0
9	7	22	40	2
1970	16	12	1	0
Average	13	13	11	7
1971	6	64	4	10

1. Andrews, J.D., unpublished data 1947-1967; Haven, D.S., in Marine Resource Information Bulletin, VIMS, 1968-1971.

2. N/A .... Data were not available.

There was no consistent pattern to the up or down-river pattern in numbers of surviving spat at stations in the York. In this respect, the presence of the oyster drill _U. cinerea_ must be considered. Drills are present and cause considerable damage at Green and Page's Rock. Of course therefore, they may possibly have grazed the spat from bars in the lower river before they could be counted.

Numbers of Small, Yearling and Market Oysters on Natural Cultch

There seems to be a well-defined gradient for small oysters and yearlings and market oysters with numbers increasing up-river. This distribution probably reflects survival and is not related to the initial set. Harvest by commercial tongers has been light especially in recent years so it is probable that this factor has not naturally influenced the observed distribution. As previously outlined, drills, _Dermocystidium_ and MSX are probably responsible for the small numbers of survivors on bars in the lower river.

For all groupings and at all stations a decline in numbers was indicated after 1960 when MSX affected the lower reaches of the river.

Shell Bag Studies

Spat surviving on shell bags show no well-developed spatial survival pattern from 1947 to 1971. That is, there was no tendency for survival to be higher up or down-river (Table 4). This is somewhat similar to the results noted

Table 4

Seasonal Spatfall on Shelltags in the York River[1]

Spat Per Shell

LOCATION

Calendar Year	Ellen Island	Wormley Rock	Gloucester Point	Green Rock	Page's Rock	Aberdeen Rock	Clay Bank	Purtan Bay	Bell's Rock
1947			1.9						
8					.3			.1	0
9		1.1			1.3			.7	.2
1950		.3			.5	1.4			1.6
Average		.7	1.9		.8	1.4		.4	.6
1958			1.7						
9	.9		.1		.1				
1960					.4				
Average	.9		.9		.2				
1961			.5						
2				.2	.1		1.1		
3	.5		3.8	.5	.4		.2		
4	.3	.1	2.6	3.8					
5			.4		.4				
6	.4		.2	1.2	.4		2.4		
7	.1		.1		.1		.1		
8									
9									
1970			2.3	.1			.4		0
1971			22.0	1.9	1.3		1.4	.1	.1
Average	.3	.1	4.0	1.3	.4		.9	.1	1

1. Andrews, J.D., unpublished data for 1947 through 1967; data not available for 1951 through 1957. Haven, D.S., in Marine Resource Information Bulletin. VIMS. 1970. Blanks indicate that data were not available.

for spat on natural cultch. Data for the upper river are lacking, but results suggest that survival on shell bags in the lower York has not changed materially from 1947 to 1971. In the last eleven years the numbers of spat surviving on shell bags have averaged from about .3 to 4.0 spat per shell (stations with inadequate data not included). This gives a calculated theoretical yield of from 150 to 2,000 spat per bushel.

A remarkable aspect of these shell bag studies is that stations still receive a strike in regions of high salinity such as Gloucester Point, where public rocks are almost completely devoid of oysters.

Weekly Setting Pattern

Limited shell string data has been collected in the lower York (Table 5). From 1947 to 1955 data were collected from strings exposed off the Yorktown Pier at Yorktown; from 1963 to 1971 data were obtained from strings suspended from the VIMS pier at Gloucester Point. Data consequently are not strictly comparable. The data suggest, however, that the lower York is still receiving strikes but that intensity has decreased in the last ten years. The average recorded for 1963 to 1971 (44.1) may be misleading, since it is heavily weighted by the heavy 1964 strike. Many years during the 1963 and 1971 period have about half the number of spat as in the 1947 to 1955 periods. When data

Table 5

Weekly Spatfall on Shell Strings in the York River near Gloucester Point;[1] Sum, Maximum and Week of Occurrence

Spat Per Smooth Shellface

Calendar Year	Duration of Setting	Sum of Weekly Spatfall	Max. Wkly Spatfall and Wk. of Occurrence[2]	
1947	7/ 7 - 10/7	28.5	5.8	A 5
8	6/28 - 9/27	11.0	2.7	S 2
9				
1950	7/12 - 9/27	36.8	13.8	S 2
1	6/27 - 10/10	44.8	11.8	A 4
2	6/23 - 11/17	51.0	21.4	S 2
3	6/12 - 10/ 7	56.7	19.5	A 4
4	6/28 - 11/ 8	28.5	14.2*	S 3
5	7/ 7 - 8/27!	34.7	11.1	J 3
Average		36.5		
1963	7/12 - 9/23	19.5	6.5	S 3
4	8/17 - 10/ 5	224.5	156.7	S 1
5	7/12 - 10/28	5.4	1.9	A 4
6	7/ 5 - 10/17	26.8	7.7	S 1
7	7/17 - 10/14	1.0	.8	S 2
8	6/26 - 9/ 1!	.4	.1	J 4
9	7/ 2 - 10/13	12.2	.7	S 3
1970	8/ 5 - 10/15	19.7	5.1	S 3
1	7/20 - 10/19	87.2	53.2	S 2
Average		44.1		

1. Andrews, J.D., unpublished data for 1947 through 1968; data not available for 1949 and 1956 - 1962. Haven, D.S., 1969-1971, Marine Resource Information Bulletin, VIMS. Data were taken at the Yorktown fish pier in 1947-48 and at VIMS' pier, Gloucester Point, in the remaining years.

2. Letters indicate the month of occurrence (J = July, A = August, and S = September). The digits immediately following the letters indicate the week of the month.

* Shell string stayed in water about 4 weeks.

! Observations stopped on this date.

for 1964 are eliminated, set on shell strings for 1963 to 1971 was 21.5 which is less than that of the preceding period.

From 1947 to 1971 maximum strike in the York River generally occurred in August, or September. In recent years, September has been the period of maximum set (Table 5).

A summary of all data pertinent to setting and bottom cultch in the York is shown in Tables 6 and 7. These data suggest:

1. Since 1946, surviving spat, small oysters, yearlings, and market oysters have been most abundant in the upper river at Bell's and Aberdeen rocks, as contrasted to numbers in the lower river at Page's and Green rocks.
2. There has been a drastic decline in numbers of market, small oysters and yearlings and spat in the lower two-thirds of the York at Aberdeen, Pages and Green rocks, since 1960. At the upper stations, at Bell's Rock there has not been a well-defined decline in market, small and yearlings, but here there was almost a 90% reduction in spat. The decline in numbers of oysters in the lower half of the York is probably due to MSX. Commercial harvest is light in the river and probably contributed little to the decline.

Table 6

Comparison of Average Number of Oysters in Bushel Samples of Natural Cultch in Pre and Post-MSX Years in York River
1947 - 1971

Area	MARKET		SMALL & YEARLING		SPAT	
	1946-60	1961-71	1946-60	1961-71	1946-60	1961-71
Bell's Rock	76	45	140	178	124	15
Aberdeen Rock	46	37	139	58	73	25
Page's Rock	55	28	77	55	42	22
Green Rock	21	7	20	2	34	9
Average	50	29	94	73	68	18

Table 7

Comparison of Average Numbers of Spat per Shell on Natural Cultch, Shellbags and Shellstrings in Pre and Post-MSX Periods in the York River, Virginia

Area	NATURAL CULTCH[1]		SHELLBAGS		SUM OF WEEKLY SET SHELLSTRINGS[2]	
	1946-60	1961-71	1946-60	1961-71	1946-60	1961-71
Bell's Rock	.25	.03	.6	0		
Aberdeen Rock	.08	.05	1.4			
Page's Rock	.07	.04	.9	.4		
Green Rock	.07	.02		1.3		
Gloucester Pt.			1.2	4.0	36.5	88.2

1. Assuming 500 shells per bushel.

2. Total spatfall per shell for entire season; number per shellface doubled.

3. Spat on shell bags shows no evidence of a change in survival in the lower river. Data are not adequate to allow a formation of an opinion for the upper river.
4. Intensity of set at Gloucester Point as deduced from shell strings seems to have declined from 1960 to 1971 over the previous period.

Literature Cited

Andrews, J. D. 1967. Oyster mortality studies in Virginia. II. History and distribution of *Minchinia nelsoni*, a pathogen of oysters in Virginia. *Chesapeake Sci.* 8: 1-13.

Galtsoff, P. S. *et al*. 1947. Ecological and physiological studies of the effects of sulphate pulp mill wastes on oysters in the York River, Virginia. U. S. Fish and Wildlife Serv. Bull. 43, Vol. 51: 59-186.

Distribution of Hard Clams in the Lower York
from Haven and Loesch, 1971

The distribution and abundance of hard clams was studied between 1968-70 with a standard Maryland hydraulic escalator dredge. Sixty-four stations in the lower Bay region were established (Figure 4) with 18 of these located near the mouth of the York. Table 8 summarizes the catch information collected during the study.

Relatively heavy concentration of hard clams was found on the north side of the York River from the mouth to just above the George P. Coleman Memorial Bridge. Catches from the experimental plots at Ellen Island and from worked out plots at Gains Point indicate an abundance of about 50 to 80 bushels per acre. Two worked out plots at Yorktown produced 15 to 24 bushels per half acre, while one at Gloucester Point yielded 17 bushels from the experimental half-acre plot. On the lower south side of the York River clams were less abundant. Two completely escalated sites at Goodwin Island indicate a density of about 18 to 25 bushels per acre. Between the Yorktown and Goodwin Island areas, hard clam density decreased dramatically at two sample stations (Nos. 49 and 50) immediately below the AMOCO oil refinery plant. Distribution was spotty and abundance sparse at sampled sites above the Coleman Bridge. One notable exception occurred at Green Point (No. 57) where

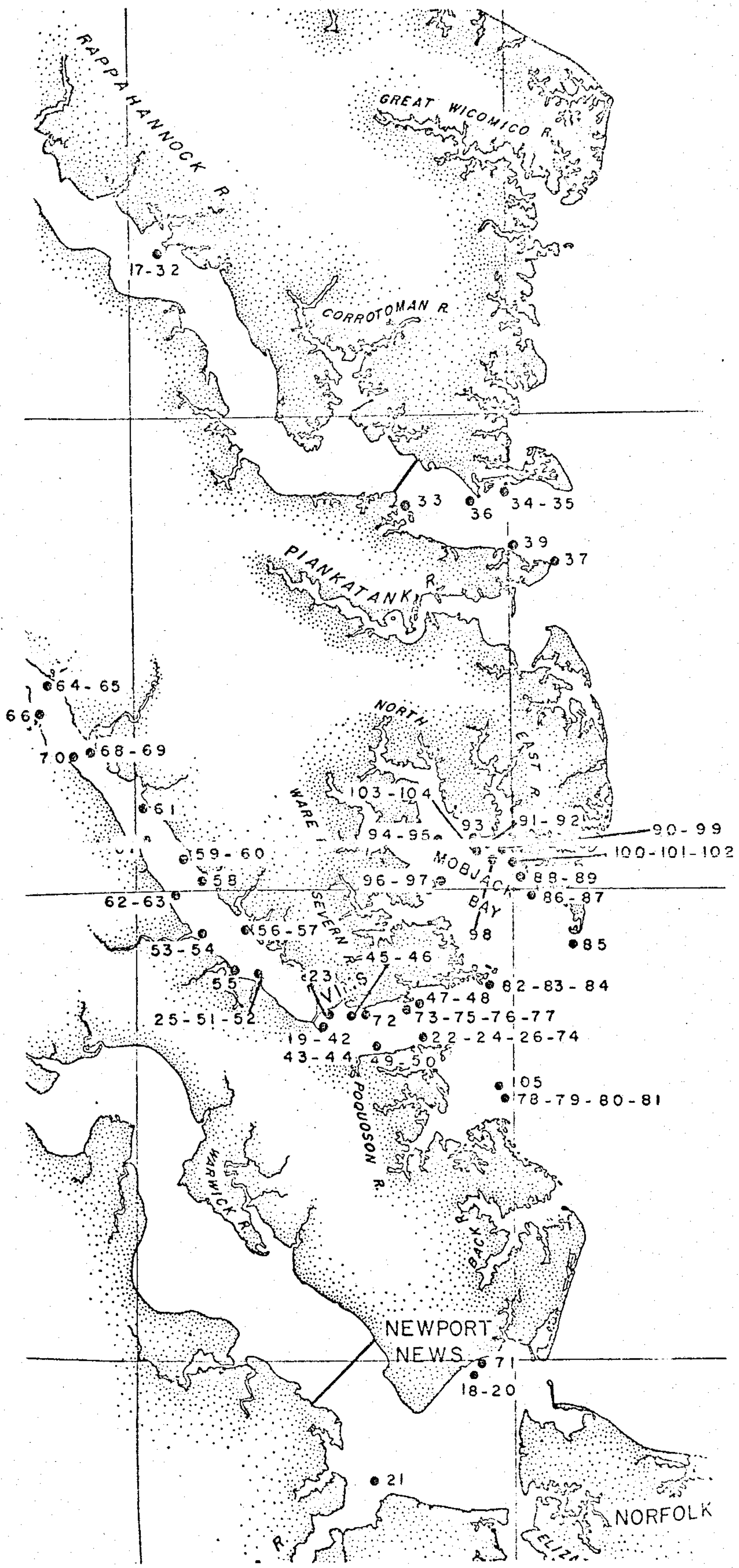


Figure 4. Locations sampled for hard clams in 1968, 1969 and 1970 with a hydraulic escalator dredge.

Table 8

Catch per Unit of Effort of *Venus mercenaria* Captured with an Escalator Harvester in 1968, 1969 and 1970 in Various Locations

Coll. No.	River and Location	Month and Year	MLW Depth (ft.)	Effort (hrs)	Total Catch (bu)	Catch/bu/hr Over-all	Catch/bu/hr First 2 hrs.	$\bar{x}$ no. bu.	$\bar{x}$ wt. bu. (lbs)
	Y-Yorktown No. 1	6-68	6-8	12.0	15		1.5		
17	R-Morattico No. 1	9-68	7	7.8	0				
18	J-Hampton Bar No. 1	1-69	9	16.8	78.5	4.7	8.0	285	83.1
19	Y-Yorktown No. 5	7-68	6	6.0	14.5	2.4	2.5	223	75.6
20	J-Hampton Bar No. 2	7-68	8	4.5	43.8	9.7	9.5	265	82.0
21	J-Nansemond Ridge	2-69	8	6.0	21.5	3.6	6.0	354	83.1
22	Y-Goodwin Island No. 1	3-69	4-6	7.5	12.5	1.7	2.0	224	83.6
23	Y-Gloucester Point	3-69	6	9.0	17.0	1.9	3.0	218	82.7
24	Y-Goodwin Island No. 2	3-69	4-6	2.0	3.7	1.8	1.8	223	84.2
25	Y-Sandy Point	4-69	4-6	1.0	0.7	0.7	0.9	255	86.0
26	Y-Goodwin Island	4-69		3.5	3.4	0.9	0.9	255	86.0
27	ES-Cobb Island No. 1	5-69	4-6	1.3	1.0	0.8	1.0	612	97.8
28	ES-Cobb Island No. 2	5-69	4	2.0	2.0	1.0	1.0	330	83.1
29	ES-Terry's Ground	5-69	4	0.3	0.2	0.6			
30	ES			0.8	0.5	0.7		304	86.9
	Y-Yorktown No. 1 (rework)	6-69	6-8	2.8	0.8		0.3		
17	R-Morattico No. 1	7-69	7	6.3	0				
32	R-Morattico No. 2	9-69	10	12.8	0				
33	R-Parrotts Island	8-69	6-8	12.7	0				
34	R-Deep Hole Point	8-69	4-8	4.0	0				
35	R-Deep Hole Point	8-69	4-8	2.3	22 clams				
36	R-Mosquito Point	8-69	4-8	2.5	101 clams				
37	R-Deltaville	9-69	4-8	1.0	46 clams				
38	R-Broad Creek	9-69	4-8	1.0	9 clams				
42	Y-Yorktown, adjacent	10-69	4	2.0	1.2	0.6	0.6	236	90.0
43	Y-Yorktown, adjacent	10-69	6	2.0	2.3	1.2	1.2	206	85.5
44	Y-Yorktown No. 3	10-69	9	24.5	24.1	1.0	2.5	232	87.5

Procedure of sampling changed. Clams sampled in 12-foot circular path inside half-acre.

Table 8 (continued)

Catch per Unit of Effort of *Venus mercenaria* Captured with an Escalator Harvester in 1968, 1969 and 1970 in Various Locations

Coll. No.	River and Location	Month and Year	MLW Depth (ft.)	Effort (hrs)	Total Catch (bu)	Catch/bu/hr Over-all	Catch/bu/hr First 2 hrs	$\bar{x}$ no. bu	$\bar{x}$ wt. bu (lbs)
45	Y-Gains Point	1-70	4	2.5	7.0	2.8	3.1	275	89.0
46	Y-Gains Point	1-70	9	2.5	4.7	1.9	2.0	306	86.5
47	Y-Ellen Island	2-70	4	5.0	10.0	2.0	1.8	320	85.0
48	Y-Ellen Island	2-70	9	6.4	17.6	2.8	3.5	298	91.9
49	Y-Below AMOCO	2-70	4	2.0	0.5	0.3	0.3		
50	Y-Below AMOCO	2-70	9	5.5	3.4	0.6	0.4	205	
51	Y-Sandy Point	2-70	4	6.0	2.4	0.4	0.6	221	86.2
52	Y-Sandy Point	2-70	9	0.8	8 clams				
53	Y-Queens Creek	2-70	4	1.5	199 clams				
54	Y-Queens Creek	3-70	9	3.5	134 clams				
55	Y-Indian Field Creek	3-70	4	2.5	104 clams				
56	Y-Green Point	3-70	4	2.0	332 clams				
57	Y-Green Point	3-70	9	3.0	12.5	4.2	5.2	300	88.3
58	Y-Aberdeen Cr.(Leigh's)	3-70	14	2.0	144 clams				
59	Y-Camp Peary (Walker's)	3-70	4	2.5	1.7	0.7	0.8	335	90.6
60	Y-Camp Peary (Walker's)	3-70	6	1.0	2 clams				
61	Y-Allmondsville Whalf	4-70		2.6	0				
62	Y-Camp Peary (Leigh's)	4-70	4	0.5	0				
63	Y-Camp Peary (Leigh's)	4-70	6	0.5	0				
64	Y-Bell Rock (inshore)	5-70	4	0.5	0				
65	Y-Bell Rock (offshore)	5-70	4	0.5	0				
66	Y-Ware Creek	5-70	4	0.5	0				
67	Y-Skimino Creek	5-70	4	0.5	0				
68	Y-Poropotank (inshore)	5-70	4	1.0	0				
69	Y-Poropotank (offshore)	5-70	4	1.0	0				
70	Y-Mt. Folly	5-70	4	0.5	0				
19	Y-Yorktown No. 5 (rework)	5-70	6	1.0	0.8 (205 clams)				
23	Y-Gloucester Pt. (rework)	5-70	6	1.5	0.5 (88 clams)				
	Y-Yorktown No. 1 (rework)	5-70	6-8	1.0	0.2 (47 clams)		0.2		

Table 8 (continued)

Catch per Unit of Effort of *Venus mercenaria* Captured with an Escalator Harvester in 1968, 1969 and 1970 in Various Locations

Coll. No.	River and Location	Month and Year	MLW Depth (ft.)	Effort (hrs)	Total Catch (bu)	Catch/bu/hr Over-all	Catch/bu/hr First 2 hrs	$\bar{x}$ no. bu.	$\bar{x}$ wt. bu.(lbs)
71	J-Hampton Roads	6-70	8-0	22.1	60.4	2.7	5.4	278	87.0
72	Y-Gains Point	7-70	6-5	20.0	45.8	2.3	4.9	301	89.9
73	Y-Ellen Island	8-70	9-0	15.4	26.4	1.7	7.7	357	88.7
74	Y-Goodwin Island	8-70	6-0	6.4	9.2	1.4	4.2	234	88.8
99	Mobjack Bay	9-70	9-0	6.0	10.9	1.5	5.1	241	91.1
103	Mobjack Bay	10-70	9-0	6.1	14.0	2.3	6.2	270	88.4
104	Mobjack Bay	10-70	6-0	5.5	14.8	2.7	7.4	274	94.4
105	Poquoson Flat	12-70	7-0	6.0	15.2	3.6	8.2	310	89.15

12.5 bushels were harvested in 3 hours from an old oyster rock. An adjacent station (No. 56), however, lacking a heavy shell content in the mud-sand substrate produced about 1 bushel in 2 hours of escalation. No hard clams were found above the Camp Peary-Clay Bank area.

Literature Cited

Haven, D. S. and J. Loesch. 1971. A study of the hard and soft clam resources of Virginia. Final contract report, U. S. Dept. Interior, Fish and Wildlife Service, Bureau of Commercial Fisheries Contract Nos. 3-77-R-1, 3-77-R-2, 3-77-R-3.

Distribution of the Blue Crab, *Callinectes sapidus*, in the York River

from

Mark Chittenden

Blue crabs were collected at stations Y00, Y10, Y20, Y25, P30, P35, P40 and P50 in the York and Pamunkey rivers from April through November in the years 1958, 59 and 1965 through 1970. Samples were taken in the channel using a 9.1 m semiballoon otter trawl having 1 1/4 inch stretch mesh in the cod end.

The geometric mean catch was 6.79 crabs/tow in the York River. Table 9 summarizes analysis of variance for differences using a logarithmic transformation. There were significant differences in catch between stations, between months and between years.

Tables 10, 11 and 12 present geometric mean catches for each station, month and year respectively, along with a summary of Student-Newman-Keuls' multiple range tests based upon unequal sample sizes to determine which differences are significant at the 5% level.

Blue crab catches varied from 0.6/tow at P50 to 19.2/tow at Y25. The chief nursery, where catches varied from 10.0

Table 9

Summary of analysis of variance for differences in blue crab distribution, York River. Rounded to two places.

Source of Variation	Degrees of[1] Freedom	Sum of Squares	Mean Square	F
Total	549	278.39	--	
Years	7	30.50	4.36	15.35
Months	7	24.67	3.52	12.41
Stations	8	77.83	9.73	34.27
Y X M	49	46.68	.95	--
Y X S	56	19.17	.34	--
M X S	56	11.67	.21	<1
Y X M X S	392	67.87	.17	--
Pooled Error	471	133.72	.28	

1. 26 degrees of freedom subtracted from total and pooled error because of missing values.

Table 10

Summary of multiple range tests for differences in blue crab catch between York River stations.

Station	Geometric Mean	Significance
Y25	19.2	a
Y20	16.9	a b
Y15	16.9	a b c
P30	11.3	a b c d
Y10	10.0	b c d e
Y00	4.1	f
P35	4.1	f g
P40	1.9	h
P50	.6	i

Similar letters mean no significant difference at $\alpha = .05$

Table 11

Summary of multiple range tests for differences in monthly blue crab catches in the York River

Month	Geometric Mean	Significance
July	14.1	a
August	12.2	a b
May	10.2	a b c
June	8.6	a b c d
April	5.1	d
September	5.1	d e
October	3.6	e
November	2.8	e

Similar letters mean no significant difference at α = .05

Table 12

Summary of annual mean blue crab catches
in the York River

Year	Geometric Mean	Mean
1969	17.9	1.27739
1970	9.9	1.03631
1965	9.3	1.01113
1966	9.2	1.00757
1958	6.2	.85910
1967	5.7	.82212
1959	2.8	.57996
1968	2.5	.54080

to 19.2 blue crabs/tow, extends from Y10 to P30. Catch magnitude progressively decreased upstream from P30 and downstream of Y10.

Highest blue crab catches were made in July (14.1/tow) and smallest in November (2.8/tow). Trawl surveys in the period January through March caught few, if any, crabs.

Discussions with the author have indicated that caution must be applied in interpretation of the data, i.e. the data represent only channel stations and may not reflect the crab populations in other depths or substrate types.

Section V

Finfish

by Douglas Markle

Life Histories of Commercially and Ecologically Important Fishes of the Lower York River

The fishes of the lower York River can be conveniently grouped into four categories: 1) resident species, those which spawn and remain in the York River system; 2) anadromous species, those which use the upper York River as a spawning and nursery area and migrate as juveniles or young adults; 3) catadromous species, those which spawn outside of the York River and spend some or most of their life in the York River system; and 4) strays, those species which occasionally wander into the York River (Tables 1-4). No life histories are given for species in this last group. In the remaining three groups, there is inadequate information on temperature or salinity requirements for spawning, egg, larval, juvenile or adult stages and even less information on synergistic effects of temperature and salinity.

Resident Species

Anchoa mitchilli, Bay anchovy

Hildebrand and Schroeder (1928) and Hildebrand (1943), Mansueti and Hardy (1967)

The spawning season is from May to August with a peak in July. Spawning occurs at about 8 P.M. The eggs are buoyant and transparent until a few hours before hatching, when they sink. The young feed primarily on copepods, and the adults feed on mysids. *Anchoa mitchilli* occurs in schools, is very abundant, and is an important prey species for many commercially important species. It remains in the study area throughout its life.

Opsanus tau, Oyster toadfish

Hildebrand and Schroeder (1928)

The spawning season is from April to November with a peak in spawning during the summer months. The eggs are large and are guarded in nests by the male. Incubation lasts about three weeks and the young remain near the bottom. It remains in the study area throughout its life.

Fundulus heteroclitus, Mummichog

Breder and Rosen (1966) and Garside and Jordan (1968)

The spawning season is from April to August. The eggs are demersal and incredibly hardy as are the other life stages. It is an abundant species and important as a prey species for larger carnivorous species. It remains in the study area throughout its life.

Menidia menidia, Atlantic silverside

Hildebrand and Schroeder (1928)

The spawning season is from March to August with a peak in April and May. The eggs attach to underwater objects.

It is very abundant, schools, and is an important prey species for larger carnivorous species. It remains in the study area throughout its life.

Paralichthys dentatus, Summer flounder

Hildebrand and Schroeder (1928)

Spawning occurs in winter, possibly in deeper parts of the river or Bay. The young appear in the lower York at least by July and all life stages remain in the study area most of the year with some movement into deeper water during winter.

Pseudopleuronectes americanus, Winter flounder

Hildebrand and Schroeder (1928)

The reported spawning season is winter and early spring. The eggs are demersal and are deposited along sandy shores. Incubation time is 15 to 18 days at 37 F. The species remains in the study area throughout its life, but is most abundant from November to April.

Trinectes maculatus, Hogchoker

Hildebrand and Schroeder (1928), Dovel, Mihursky, and McErlean (1969)

Spawning takes place in summer. It is an extremely abundant species. The eggs and all other life stages remain in the study area all year.

Anadromous species

Alosa aestivalis, Blueback herring

Alosa mediocris, Hickory shad

Alosa pseudoharengus, Alewife

Alosa sapidissima, American shad

Hildebrand and Schroeder (1928), Svetovidou (1952), Mansueti and Hardy (1967), and Chittenden (pers. comm.)

All four species enter the study area in the spring on their way to freshwater spawning grounds. The upstream migration is initiated by gonad development but they avoid temperatures below about 10 C so that this temperature sets a limit on when migration begins. Adults return to sea around June or at temperatures around 18 to 20 C. Juveniles stay in fresh water until December when they too migrate to sea. Adults may be expected in the study area from March to the end of May and juveniles, depending on the severity of the winter, can be expected year round.

No reliable thermal tolerance data are available on these important commercial species, but investigations by VIMS personnel should provide this information in the near future.

Morone americana, White perch

Hildebrand and Schroeder (1928) and Mansueti (1961)

Spawning is from April to May in fresh or slightly brackish water at temperatures of 10 to 15 C. The adults migrate downstream and remain in the river after spawning.

The young spend their first year in the upper reaches of the river and migrate downstream as winter approaches. Some young, juveniles and adults can be expected in the study area year round.

Morone saxatilis, Striped bass

Massmann and Pacheo (1961), Talbot (1966), Massmann *et al*. (1952), Krouse (1968)

Spawning occurs from late April to June in fresh water at temperatures of 15 to 20 C. Adults undertake coastal migrations after spawning. The juveniles remain in the Pamunkey River in May and June but some enter the study area as small as 34 mm as early as the middle of June. The young remain in the study area at least two years and the older fish pass through the study area from April to June on their spawning migration. The striped bass is subject to year class fluctuations in abundance.

"Fingerlings" reportedly tolerate a maximum temperature of 35 C, but "survival" is best at a range of 13 to 25 C and 5 to 25‰ salinity. Adults attempting to ascend a fish ladder were subjected to a "large stress" when the ambient temperature was raised 7 to 10 C in the Neuse River, North Carolina.

Catadromous Species

Brevoortia tyrannus, Atlantic menhaden

Hildebrand and Schroeder (1928), Lewis and Hettler (1968), and Reintjes and Pacheo (1966), and Mansueti and Hardy (1967).

The adults spawn in oceanic water in March and April and possibly again in September and October. The larvae enter the study area from October to June. Generally only the young can be found in the study area although schools of adults occasionally may be found near the mouth of the York River. Temperatures greater than 33 C are usually lethal.

Urophycis regius, Spotted hake

Hildebrand and Schroeder (1928), and Barans (1972).

The spawning season is during the winter in oceanic water. The young enter the study area around January and remain until June. During the spring it is one of the more abundant of fishes in the study area.

Cynoscion regalis, Weakfish

Massmann (1963) and Thomas (1971)

Spawning takes place offshore in the summer. Young and older fish move into the study area around April and leave around October. It is a fairly abundant commercially important food fish during the summer.

<u>Leiostomus xanthurus</u>, Spot

Pacheco (1962), Thomas (1971) and Parker (1971)

Spawning takes place offshore in late autumn and winter. Juveniles and adults move into study area in April and May and return to the ocean in the fall. The spot is subject to year class fluctuations in abundance.

<u>Micropogon undulatus</u>, Atlantic croaker

Haven (1959), Thomas (1971) and Parker (1971)

Spawning takes place offshore at least from August to March and possibly all year. Post-larvae and juveniles move into the study area and remain about a year. Adults move into the study area in spring and return to the ocean in the fall. The croaker is subject to large year-class fluctuations in abundance.

<u>Prionotus carolinus</u>, Northern searobin

Hildebrand and Schroeder (1928) and Wong (1968)

Spawning takes places from July to September in offshore waters. The young and adults undertake inshore migrations in the spring and offshore migrations in the summer and fall. The species is not of commercial value, but the young are extremely abundant in the study area in spring and summer.

Table 1. A List of the Resident Fishes of the Lower York River

Family	Species	Common Name
Clupeidae	*Dorosoma cepedianum*	Gizzard shad
Engraulidae	*Anchoa hepsetus*	Striped anchovy
	Anchoa mitchilli	Bay anchovy
Batrachoididae	*Opsanus tau*	Oyster toadfish
Gobiesocidae	*Gobiesox strumosus*	Skilletfish
Exocoetidae	*Hyporhamphus unifasciatus*	Halfbeak
Belonidae	*Strongylura marina*	Atlantic needlefish
Cyprinodontidae	*Cyprinodon variegatus*	Sheepshead minnow
	Fundulus diaphanus	Banded killifish
	Fundulus heteroclitus	Mummichog
	Fundulus majalis	Striped killifish
	Lucania parva	Rainwater killifish
Poeciliidae	*Gambusia affinis*	Mosquitofish
Atherinidae	*Membras martinica*	Rough silverside
	Menidia beryllina	Tidewater silverside
	Menidia menidia	Atlantic silverside
Gasterosteidae	*Apeltes quadracus*	Fourspine stickleback
Syngnathidae	*Syngnathus floridae*	Dusky pipefish
	Syngnathus fuscus	Northern pipefish
Blenniidae	*Chasmodes bosquianus*	Striped blenny
	Hypsoblennius hentzi	Feather blenny
Gobiidae	*Gobiosoma bosci*	Naked goby
	Microgobius thalassinus	Green goby
Bothidae	*Paralichthys dentatus*	Summer flounder
Pleuronectidae	*Pseudopleuronectes americanus*	Winter flounder
Soleidae	*Trinectes maculatus*	Hogchoker

Table 2. A List of the Anadromous Fishes of the Lower York River

Family	Species	Common Name
Petromyzontidae	*Petromyzon marinus*	Sea lamprey
Clupeidae	*Alosa aestivalis*	Blueback herring
	Alosa mediocris	Hickory shad
	Alosa pseudoharengus	Alewife
	Alosa sapidissima	American shad
Perichthyidae	*Morone americana*	White perch
	Morone saxatilis	Striped bass

Table 3. A List of the Catadromous Fishes of the Lower York River

Family	Species	Common Name
Anguillidae	Anguilla rostrata	American eel
Clupeidae	Brevoortia tyrannus	Atlantic menhaden
Gadidae	Urophycis regius	Spotted hake
Serranidae	Centropristis striatus	Black sea bass
Sciaenidae	Bairdiella chrysura	Silver perch
	Cynoscion nebulosus	Spotted seatrout
	Cynoscion regalis	Weakfish
	Leiostomus xanthurus	Spot
	Micropogon undulatus	Atlantic croaker
	Menticirrhus americanus	Southern kingfish
	Menticirrhus saxatilis	Northern kingfish
Triglidae	Prionotus carolinus	Northern searobin
Tetraodontidae	Sphoeroides maculatus	Northern puffer

Table 4. A List of the Stray Fishes from the Lower York River

Family	Species	Common Name
Carcharhinidae	*Carcharinus milberti*	Sandbar shark
	Mustelus canis	Smooth dogfish
Squalidae	*Squalus acanthios*	Spiny dogfish
Rajidae	*Raja eglanteria*	Clearnose skate
Dasyatidae	*Dasyatis centroura*	Roughtail stingray
	Dasyatis sayi	Bluntnose stingray
Myliobatidae	*Rhinoptera bonasus*	Cownose ray
Congridae	*Conger oceanicus*	Conger eel
Clupeidae	*Clupea harengus*	Atlantic herring
	Opisthonema oglinum	Atlantic thread herring
Synodontidae	*Synodus foetens*	Inshore lizardfish
Gadidae	*Merluccius bilinearis*	Silver hake
	Urophycis chuss	Red hake
Ophidiidae	*Rissola marginata*	Striped cusk-eel
Belonidae	*Ablennes hians*	Flat needlefish
Syngnathidae	*Hippocampus erectus*	Lined seahorse
Serranidae	*Mycteroperca microlepis*	Gag
Pomatomidae	*Pomatomus saltatrix*	Bluefish
Echeneidae	*Remora australis*	Whalesucker
Carangidae	*Caranx crysos*	Blue runner
	Caranx hippos	Crevalle jack
	Trachurus lathami	Rough scad
	Vomer setapinis	Atlantic moonfish
Coryphaenidae	*Coryphaena hippurus*	Dolphin
Pomadasyidae	*Orthopristis chrysoptera*	Pigfish
Sparidae	*Lagodon rhomboides*	Pinfish
	Stenotomus chrysops	Scup
Sciaenidae	*Pogonias cromis*	Black drum
	Sciaenops ocellata	Red drum
Ephippidae	*Chaetodipterus faber*	Atlantic spadefish
Chaetodontidae	*Chaetodon ocellatus*	Spotfin butterflyfish
Labridae	*Tautoga onitis*	Tautog
Mugilidae	*Mugil cephalus*	Striped mullet
	Mugil curema	White mullet
Uranoscopidae	*Astroscopus guttatus*	Northern stargazer
Gobiidae	*Gobiosoma ginsburgi*	Seaboard goby
Trichiuridae	*Trichiurus lepturus*	Atlantic cutlassfish
Scombridae	*Euthynnus alletteratus*	Little tuna
	Scomberomorus maculatus	Spanish mackerel
Stromateidae	*Peprilus alepidotus*	Harvestfish
	Peprilus triacanthus	Butterfish
Triglidae	*Prionotus evolans*	Striped searobin

Table 4. (continued)

Family	Species	Common Name
Bothidae	*Etropus microstomus*	Smallmouth flounder
Scophthalmidae	*Scophthalmus aquosus*	Windowpane
Cynoglossidae	*Symphurus plagiusa*	Blackcheek tonguefish
Balistidae	*Aluterus schoepfi*	Orange filefish
Diodontidae	*Chilomycterus schoepfi*	Striped burrfish

Literature Cited

Barans, C. A., 1972. Spotted hake, Urophycis regius, of the York River and lower Chesapeake Bay. Ches. Sci. 13 (1): 59-62.

Breder, C. M. and D. E. Rosen, 1966. Modes of reproduction in fishes. The Natural History Press, Garden City, N. Y., 941 pp.

Dovel, W. L., J. A. Mihursky, and A. J. McErlean, 1969. Life history aspects of the hogchoker, Trinectes maculatus, in the Patuxent River estuary, Maryland. Ches. Sci. 10 (2): 104-119.

Garside, E. T. and C. M. Jordan, 1968. Upper lethal temperatures at various levels of salinity in the euryhaline cyprinodontids Fundulus heteroclitus and F. diaphanus after isosmotic acclimation. J. Fish. Research Bd. Canada. 25 (12): 2717-2720.

Haven, D. S., 1959. Migration of the Croaker, Micropogon undulatus. Copeia (1): 25-30.

Hildebrand, S. F., 1943. A review of the American anchovies. Bull. Bingham Oceano. Coll. 8 (2): 165 pp.

Hildebrand, S. F. and W. C. Schroeder, 1928. Fishes of Chesapeake Bay. Bull. U. S. Bur. Fish. 43 (1): 1-366.

Krouse, J. S., 1968. Effects of dissolved oxygen, temperature, and salinity on survival of young striped bass, Roccus saxatilis (Walbaun). M. S. thesis, University of Maine, Orono, 61 pp. (unpublished).

Lewis, R. M. and W. F. Hettler, 1968. Effect of temperature and salinity on the survival of young Atlantic menhaden, Brevoortia tyrannus. Trans. Am. Fish. Soc. 97 (4): 344-349.

Mansueti, R. J., 1961. Movements, reproduction, and mortality of the white perch, Roccus americanus, in the Patuxent estuary, Maryland. Ches. Sci. (3-4): 142-205.

Mansueti, A. J. and J. D. Hardy, 1967. Development of fishes of the Chesapeake Bay region, an atlas of egg, larval, and juvenile stages, Part I. Natural Resources Institute, University of Maryland, 202 pp.

Massmann, W. H., 1963. Age and size composition of weakfish, Cynoscion regalis, from pound nets in Chesapeake Bay, Virginia. 1954-1958. Ches. Sci. 4 (1): 43-51.

Massmann, W. H., E. C. Ladd and H. N. McCutcheon, 1952. A biological survey of the Rappahannock River, Virginia. Va. Fish. Lab., 2 vol., 221 pp.

Massmann, W. H. and A. L. Pacheo, 1961. Movements of striped bass in Virginia waters of Chesapeake Bay. Ches. Sci. (1-2): 37-44.

Pacheco, A. L., 1962. Age and growth of spot in lower Chesapeake Bay, with notes on distribution and abundance of juveniles in the York River system. Ches. Sci. 3 (1): 18-28.

Parker, J. C., 1971. The biology of the spot, _Leiostomus xanthurus_ Lacepede, and Atlantic croaker, _Micropogon undulatus_ (Linnaeus), in two Gulf of Mexico nursery areas. Texas A&M University, Sea Grant Pub. No. TAMU-SG-71-210.

Reintjes, J. W. and A. L. Pacheo, 1966. The relation of menhaden to estuaries. IN _A symposium on estuarine fisheries_. Amer. Fish. Soc. Spec. Pub. No. 3: 50-58.

Svetovidov, A. N., 1952. Fauna of the U.S.S.R. - Fishes, Clupeidae 2 (1): 1-428. NSF, Washington, D. C. (English translation).

Talbot, G. B., 1966. Estuarine environmental requirements and limiting factors for striped bass. IN _A symposium on estuarine fisheries_. Amer. Fish. Soc. Spec. Pub. No. 3: 37-49.

Thomas, D. L., 1971. The early life history and ecology of six species of drum (Sciaenidae) in the lower Delaware River, a brackish tidal estuary. _Ichthyological Associates, Bull_. No. 3, 247 pp.

Wong, R.S.P., 1968. Age and growth of the northern searobin, _Prionotus carolinus_ (Finnaeus). M. A. Thesis, College of William and Mary, Williamsburg, 49 pp. (unpublished).

Thermal Tolerances of Fishes

A paper by Gift and Westman (1971), dealing with thermal tolerances of estuarine fishes, has been included as Appendix 3.

Commercial Fishing in the York River

Two types of commercial gear are generally used in the York River--pound nets and gill nets. Counts of pound nets in the York River are made bimonthly by VIMS personnel throughout the season (about 1 March to 30 November). The range and mean number of pound nets per month for the years 1959 to 1971 are given in Figure 1. The decline in mean number of nets fished is primarily due to deaths of fishermen rather than a decline in the fishery. The species composition of the pound net catch is usually withheld or distorted by the fishermen so that no catch data are available.

Counts of gill nets in the York River are also made by VIMS personnel throughout the season (about 1 January to 30 April). The total number of gill nets fished in the York River for the years 1967 to 1971 is given in Table 5. The gill net catch composition for the York, Pamunkey, and Mattaponi rivers is given in Table 6. The data in Table 6 are based on one wholesale-retail market and represent approximately 60% of the York River system's gill net fishery. These figures do not reflect fish retailed by the store, nor do they reflect true abundance since market conditions, especially for buck shad but also for roe shad and roe jacks, have been so depressed over the last few years that prices determined which fish the wholesaler would buy.

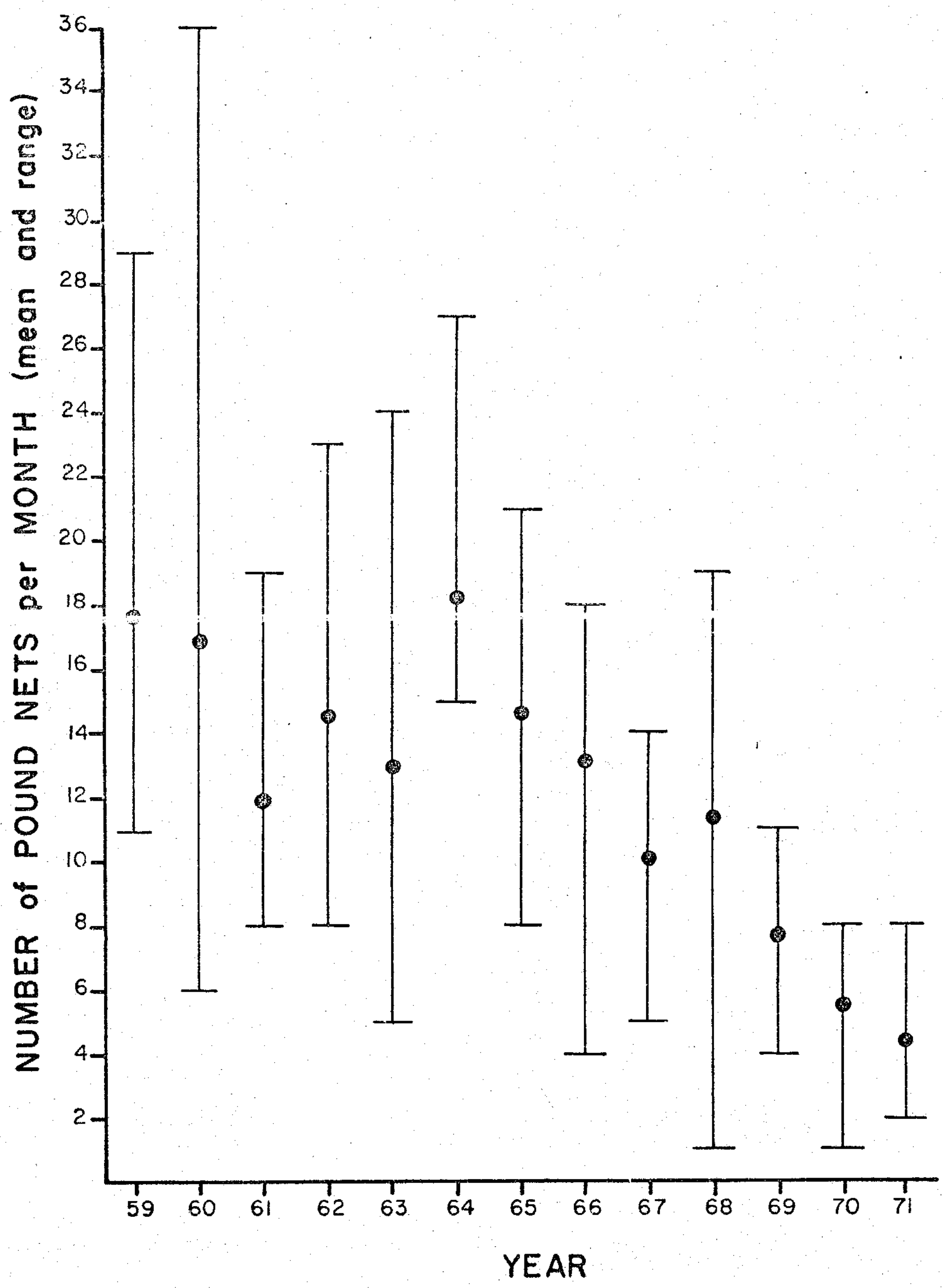


Figure 1. Pound Nets in the York River

Table 5. Total Number of Gill Nets Fished in the York River

Year	1967	1968	1969	1970	1971
Total Number	90	86	94	71	109

Table 6. Gill Net Catch Composition from the York, Pamunkey and Mattaponi Rivers (see text for explanation)

	Pounds per year			
	1968	1969	1970	1971
Rock *Morone saxatilis*	15,594	16,382	13,949	14,026
Roe shad *Alosa sapidissima*	152,598	126,619	116,829	97,285
Roe jacks *Alosa mediocris*	2,454	1,100	2,412	-
Buck shad *Alosa sapidissima*	5,065	4,159	9,200	11,941
Perch *Morone americanus*	9,239	12,704	2,219	24,579

Sport Fishing in the Lower York River (R. Jordan)

During the period 1955 through 1960 a survey of the sport fishery of the Virginia portion of Chesapeake Bay and its tributaries was conducted by the Virginia Fisheries Laboratory (Richards, 1962). The area studied the most intensively during this survey was the York River, from its mouth upstream to Pages Rock Light.

Estimates of fishing effort during the fishing season (May - September) were based on counts of boats recorded at two hour intervals by drawbridge tenders at the George P. Coleman Memorial Bridge. Interviews of fishermen and examinations of log books were conducted to provide estimates of the average durations of fishing trips by private boats (4 hours) and charter boats (5 hours) and average numbers of fisherman per boat (2.6 for private boats, 7 for charter boats). With this information numbers of boats could be converted to fishing effort in man-hours.

Results showed that maximum fishing effort on an average day occurred between 1000 and 1400 hours. Effort on weekend days was about three times that on week days, while the greatest effort was recorded on holidays. In the long run the peak of private boat activity was in June and July, while the greatest party boat business occurred in July and August. Levels of effort were fairly constant from year to year in the period

1955-58, but then declined, probably because of an unexplained drop in availability of croakers. It is believed by the author (C. E. Richards, personal communication) that future fishing effort in the lower York River will be strongly influenced by fluctuations in croaker populations.

Estimates of catch were obtained mostly from interviews with fishermen on the fishing grounds and near landings. Catch data and effort data were combined to yield catch per man-hour for each of six species (Table 7). Catch rate for croakers reached a maximum in June and July, and gradually droppped to zero in October. The croaker catch was good in 1955 and 1956, then declined steadily.

For spot the maximum catch rate occurred in September. The availability of spot and its importance in the catch increased as the croaker catch declined in late summer and early fall, and also as the croaker catch declined from year to year.

The catch rate of weakfish reached a maximum in August and early fall, and was fairly consistent year to year. For flounder the rate was fairly constant with season, but exhibited a definite spring maximum. Spring and fall maxima were found for the striped bass catch rate, while for puffers the peak was in the fall. Rates for the last three species increased in the later years of the study.

A few boat counts in the York River were compiled by Richards in 1961, observing from VIMS roof, and by other

Table 7

Angling catch per man-hour by months, areas, and years of private boats, 1955-60, Tidewater Virginia (taken from Table 6 of Richards, 1962)

Catch Rates by Months (Averaged over five study areas)

Species	Apr	May	Jun	Jul	Aug	Sep	Oct
Croaker	.53	1.32	2.05	1.68	.96	.30	.02
Spot	.00	.05	.43	1.42	1.75	1.83	1.41
Weakfish	.00	.03	.11	.12	.19	.24	.22
Flounder	.04	.22	.17	.07	.07	.05	.07
Striped Bass	.14	.12	.03	.07	.05	.13	.36
Puffer	.01	.02	.00	.03	.04	.05	.05

Catch Rates by Area

Species	York River
Croaker	1.46
Spot	.34
Weakfish	.08
Flounder	.05
Striped Bass	.02
Puffer	.08

Catch Rates by Year (Averaged over five study areas)

Species	1955	1956	1957	1958	1959	1960
Croaker	2.15	1.97	1.67	1.10	.32	.21
Spot	.72	.53	1.16	.99	2.14	1.41
Weakfish	.16	.16	.15	.17	.14	.10
Flounder	.02	.03	.03	.30	.11	.07
Striped Bass	.03	.02	.04	.11	.17	.17
Puffer	.00	.00	.01	.01	.07	.11

observers in 1966, 1968, 1971, and 1972 operating from aircraft or VIMS vessels. Since these data are meager and have not been interpreted, they will not be included here.

LITERATURE CITED

Richards, C. E. 1962. A survey of salt-water sport fishing in Virginia, 1955-1960. Chesapeake Science 3:223-35.

Quantitative Aspects of the York River Ichthyofauna

Introduction and Methods

Biologically, the Chesapeake-York-Pamunkey estuary is a relatively well-known, undisturbed coastal estuary (Boesch, 1971). Reports on the fishes (Massmann, 1962; McHugh, 1967) have essentially been lists of species or species ranges in the system. Both of these reports, the present report, and most other reports on estuarine fishes (Bechtel and Copeland, 1970; Dahlberg and Odum, 1970) are based on data obtained from fixed sampling sites, usually located in the channel or mid-stream. Assuming fishes are evenly distributed from shore to shore and throughout the sampling area, this sampling design is sufficient to accurately characterize the community present. However, such an even distribution is seldom the case, and the interpretability of data from fixed sampling sites is consequently limited. In the present study, reference to the Chesapeake-York-Pamunkey system applies to fixed stations in the channel, and although generalizations are made which imply spatial interpolation between stations, these should be viewed as a pragmatic means of discussing results rather than as accurate statements of the situation in the entire river.

The data discussed in this report were obtained from monthly trawl surveys conducted by VIMS personnel. These data have been stored in a computer card file at VIMS, and selected portions have been published in various VIMS contributions.

The stations were located at five or ten mile intervals from the mouth of Chesapeake Bay to a point 50 miles upstream from the mouth of the York River (Table 8 and Fig. 2). Stations were generally sampled around the second or third week of each month. During the period from 1967 to 1971, fishing effort was relatively consistent (Table 9) and only data from this five-year period were used in this report.

A 9.1 meter, unlined, semi-balloon otter trawl with a 38 mm stretch mesh cod-end was towed at 2.5 knots by the R. V. Pathfinder and, occasionally, the R. V. Langley. Bottom salinity and temperature were recorded at each station. The duration of each tow was 15 minutes in the Bay and York River, and 7.5 minutes in the Pamunkey. The effect of tow duration on catch size and composition is unknown, although Chittenden (in press) presents evidence that it may have little effect. All samples are, therefore, treated equally in this report.

Two final limitations apply to these data. First, fish are mobile; they can avoid nets, some species better than others, and some age classes of a species better than others. Second, some estuarine fishes are subject to large year-class fluctuations in abundance. These fluctuations can distort "normal" dominance relationships and community structure.

Because of the above limitations and the quantity of the data, the following approach is taken in the data analyses. Each year that a station was sampled in a given month is considered a replicate of that station for that month, even

Table 8

VIMS monthly river trawl stations in Chesapeake Bay (C00-C10), York (Y00-Y25) and Pamunkey Rivers (P30-P50)

Station Number	Latitude	Longitude	Depth (m)
C00	37°03.3'N	76°04.9'W	17
C10	37°11.0'N	76°14.9'W	12
Y00	37°14.6'N	76°23.2'W	17
Y10	37°19.2'N	76°35.8'W	9
Y15	37°23.0'N	76°39.2'W	10
Y20	37°26.3'N	76°42.9'W	7
Y25	37°29.1'N	76°45.3'W	9
P30	37°32.7'N	76°49.8'W	10
P35	37°32.9'N	76°51.9'W	6
P40	37°32.8'N	76°53.4'W	7
P50	37°35.2'N	76°58.6'W	7

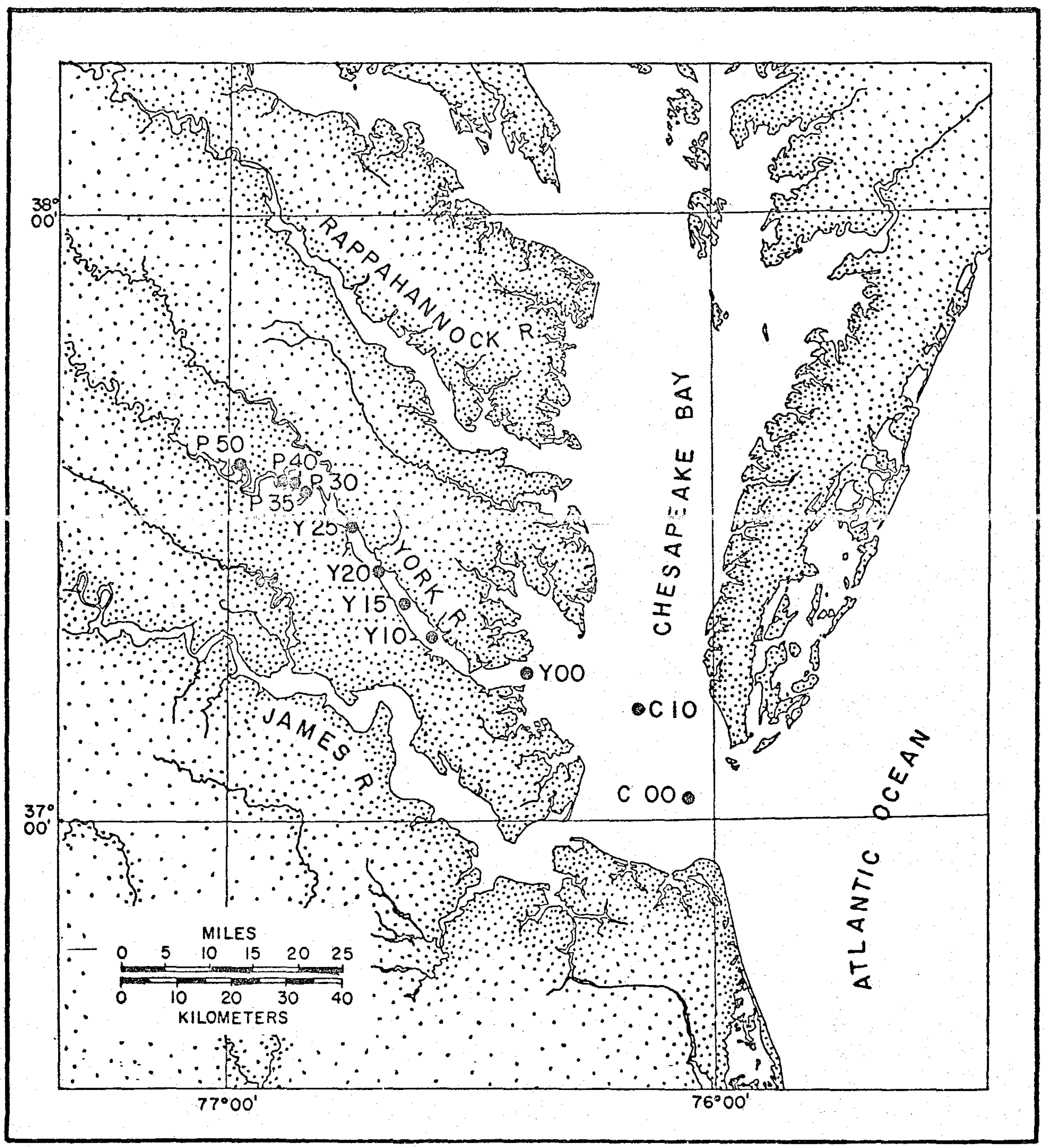


Figure 2. VIMS monthly trawl stations.

Table 9

Total number of years a station was sampled during each month from 1967 to 1971

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
	Station Number										
12	4	5	5	5	5	5	5	5	5	5	5
11	5	5	5	5	5	5	5	5	5	5	5
10	5	5	5	5	5	5	5	5	5	5	5
9	5	5	5	5	5	5	5	5	5	5	5
8	5	5	5	5	5	5	5	5	5	5	5
7	5	5	5	5	5	5	5	5	5	5	5
6	5	5	5	5	5	4	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5
4	5	5	5	5	5	5	5	5	5	5	5
3	4	5	5	5	5	5	5	5	5	4	5
2	4	5	5	5	5	5	5	5	5	4	5
1	3	3	3	4	4	5	5	5	4	4	4

when no fish were caught. When a station was not sampled it is not considered. The total number of species and individuals and the mean bottom temperature and salinity were calculated for all 132 combinations of stations and months. Diversity (H') was calculated in bits per individual by pooling all years at each station each month (Pielou, 1966). Sanders' (1960) biological index was calculated by ranking the five dominant species in each replicate (year), summing, and thereby producing a dominance rank for each station each month.

The spatial and temporal distributions of most of the dominant species were determined by calculating the antilog of the transformed (ln(x+1)) mean number at each station each month. Transformation was used to help eliminate skewed distributions caused by year-class fluctuations and contagion (see Taylor, 1953).

In order to show general trends the data at each station were analyzed using running means of three, calculating chronological differences in running means, and taking running means of three of the differences. For example, the monthly trend for November was obtained as follows:

Month	Datum Value	Running Mean	Difference	Monthly Trend
January	A			
December	B	$\frac{A+B+C}{3}$		
			$\frac{A-D}{3}$	
November	C	$\frac{B+C+D}{3}$		$\frac{A-D+B-E+C-F}{9}$
			$\frac{B-E}{3}$	
October	D	$\frac{C+D+E}{3}$		
			$\frac{C-F}{3}$	
September	E	$\frac{D+E+F}{3}$		
			$\frac{D-G}{3}$	
August	F	$\frac{E+F+G}{3}$		
July	G			

The result $\frac{A+B+C-D-E-F}{9}$ will either be positive or negative, depending on whether the data were tending to increase or decrease in November, and further, will show the rate of change. Since much random variation is eliminated, this method does not permit confidence intervals or tests of significance to be placed on the results.

This report attempts to show general trends in the spatial and temporal distributions of the fishes in the channel of the Chesapeake-York-Pamunkey system. Annual differences in the abundance of the major species is also shown. However, both the general trends and the annual differences must be interpreted with caution since, as stated initially, distribution and abundance at fixed channel locations does not necessarily reflect the distribution and abundance of populations in shoal water or the river as a whole.

Results and Discussion

Temperature and Salinity

Mean monthly bottom temperature and monthly trends in changes of bottom temperature are shown in Tables 10 and 11, respectively. In the Pamunkey River temperatures tend to increase from February to July. In Chesapeake Bay and the York River proper the increase lasts through August, although in the Bay it does not begin until March. The stations in the York River proper (Y25-Y10) have seven months of generally increasing temperature while the Pamunkey and Bay stations have six.

Mean monthly bottom salinity is shown in Table 12. At any one station, salinity is generally lower in the spring and higher in the fall due to differential seasonal runoff. Mean monthly salinity (‰) ranges from zero to 10.2 in the Pamunkey River, 8.6 to 21.3 in the York River proper and 16.4 to 29.2 at the Bay stations. A classification of the stations based on salinity regimes (Carriker, 1967) shows that P50 is fresh, P40 and P35 are oligohaline (0.5 to 5‰ salinity), P30 to Y15 are mesohaline (5 to 18‰), and Y10 to C00 are polyhaline (18 to 30‰).

Table 10

Mean monthly bottom temperature at each station-month combination
1967 to 1971

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
	Station Number										
12	6.6	7.2	7.2	7.6	7.0	7.4	7.3	7.4	8.2	8.0	8.8
11	12.6	13.2	13.2	13.0	13.2	13.6	13.2	13.4	13.6	13.8	14.0
10	20.2	20.4	20.4	20.6	20.0	20.0	20.0	20.0	20.0	20.0	19.8
9	24.8	24.8	24.8	25.2	24.8	24.6	25.0	24.8	24.4	23.6	22.8
8	27.6	27.4	27.2	27.4	26.8	27.0	26.6	26.6	25.4	25.2	23.6
7	28.2	27.6	27.8	27.4	27.2	26.8	26.4	25.6	25.0	24.2	24.0
6	26.0	25.4	25.2	25.0	24.8	24.3	24.0	23.6	22.2	21.4	20.8
5	21.4	20.8	20.6	20.6	19.6	18.8	18.0	18.0	17.0	15.2	15.0
4	16.6	15.2	14.8	14.4	14.8	16.0	15.4	14.6	12.4	10.6	10.6
3	9.0	8.6	8.0	8.4	7.8	7.2	6.4	6.2	7.6	6.3	7.4
2	4.3	4.3	4.0	3.8	3.6	3.8	3.6	4.2	3.0	3.3	3.2
1	2.7	3.3	3.3	2.3	3.0	2.8	2.6	2.8	3.3	4.7	4.3

Table 11

Monthly trends in changes of bottom temperature at each station
1967 to 1971

Month	Station Number										
	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
12	-4.89	-4.84	-4.88	-5.01	-4.93	-4.91	-4.97	-4.87	-4.83	-4.60	-4.48
11	-5.63	-5.43	-5.41	-5.59	-5.38	-5.31	-5.39	-5.31	-4.97	-4.70	-4.34
10	-4.58	-4.33	-4.33	-4.31	-4.29	-4.16	-4.17	-4.02	-3.67	-3.47	-3.09
9	-2.69	-2.44	-2.42	-2.33	-2.31	-2.21	-2.09	-1.96	-1.62	-1.49	-1.31
8	- .33	- .13	- .13	+ .02	0.00	+ .19	+ .36	+ .47	+ .62	+ .89	+ .71
7	+1.84	+2.04	+2.13	+2.22	+2.18	+2.14	+2.29	+2.31	+2.58	+2.87	+2.67
6	+3.87	+3.98	+4.09	+4.04	+4.07	+4.01	+4.13	+4.11	+3.96	+4.30	+3.93
5	+5.08	+5.08	+5.20	+5.16	+5.04	+4.77	+4.78	+4.69	+4.58	+4.51	+4.29
4	+5.33	+5.02	+5.03	+5.06	+4.98	+5.03	+4.98	+4.78	+4.19	+3.66	+3.50
3	+3.71	+3.31	+3.21	+3.30	+3.18	+3.11	+2.92	+2.71	+2.50	+1.79	+1.86
2	+ .89	+ .49	+ .34	+ .41	+ .33	+ .36	+ .26	+ .16	- .23	- .70	- .66
1	-2.60	-2.73	-2.83	-2.97	-2.87	-3.02	-3.10	-3.07	-3.10	-3.06	-3.08

Table 12

Mean monthly bottom salinity (‰)

Month	Station Number										
	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
12	0	2.4	5.2	9.8	13.6	15.6	19.5	21.3	23.0	23.5	28.7
11	0.6	2.8	5.4	9.8	15.8	17.2	18.8	20.0	22.8	25.0	28.0
10	0.5	2.4	5.4	10.0	14.4	16.0	18.2	20.0	22.4	24.8	28.4
9	0.5	2.2	5.0	10.2	15.0	16.6	19.2	20.2	22.6	25.8	29.2
8	0	1.0	3.3	7.0	12.3	15.0	18.3	20.3	22.5	24.0	27.8
7	0	1.0	3.6	8.6	13.2	15.0	17.8	19.4	22.8	24.0	27.0
6	0	0.6	2.8	6.8	10.8	12.8	16.0	18.0	22.2	24.4	27.5
5	0	0	2.0	6.8	11.6	14.2	17.4	20.3	21.0	23.3	26.6
4	0	0	0.2	3.0	8.6	11.2	14.2	16.4	20.6	24.6	28.5
3	0	0.6	2.8	6.4	12.8	14.2	16.2	19.0	19.8	22.5	28.0
2	1.0	1.0	3.4	7.6	12.0	15.0	17.4	19.2	21.7	27.3	28.2
1	0	0	1.7	7.3	13.0	15.6	17.6	19.0	21.7	25.0	26.5

Numbers of Species and Individuals

In total, 98 species were captured during the five-year period. The total number caught at any station-month combination over this period ranged from 4 to 28 (Table 13). The monthly trends in changes in total number of species showed an increase from about March through October, with the York River proper and station Y00 showing a summer decrease (Table 14). A decline in the bottom dissolved oxygen concentration (Brehmer, 1970) appears to account for part of this decrease in total number of species (personal observation). The five-year mean total number of species per month decreased going upstream from the Bay stations (17.8) to the York (15.2) to the Pamunkey (11.8).

The total number of individuals captured during the five-year period was 226,240. The total number caught at any station-month combination over this period ranged from 110 to 10,468 (Table 15). The monthly trends in changes in total number of individuals showed three general patterns: at station C00 there was an increase from May to August, and from November to January; at stations C10 through Y10 there was a long period of general increase in numbers from about March to October; and at stations Y15 through P50 there was an increase from March to April, and again from August through November (Table 16). The five-year mean total number of individuals per month was 995 for the Bay stations, 2,607 for

Table 13

Total number of species per station per month
1967 to 1971

Month	Station Number										
	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
12	12	8	10	12	15	17	11	17	18	14	20
11	18	15	16	14	15	17	15	17	15	19	20
10	16	12	15	14	15	22	21	16	19	25	22
9	16	11	17	15	14	16	16	11	12	21	22
8	10	10	11	11	15	16	12	12	15	22	28
7	13	13	14	14	12	17	15	15	18	19	15
6	13	14	14	14	17	18	18	20	15	20	25
5	10	10	10	12	12	23	17	17	18	15	27
4	12	11	11	8	14	17	15	15	22	14	16
3	12	10	10	10	14	15	16	14	15	13	15
2	12	9	11	8	12	14	14	14	13	13	14
1	11	5	4	10	10	12	9	14	13	12	17

Table 14

Monthly trends in changes of total number of species at each station

Month	Station Number										
	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
12	-1.67	-.178	-2.56	-1.44	- .78	-1.33	-.200	+ .11	- .22	-2.89	-1.44
11	- .11	- .56	-1.44	- .44	- .44	- .89	-1.56	+1.00	0	-2.56	-1.67
10	+ .78	+ .11	- .11	0	+ .44	+ .78	+ .44	+1.33	+ .78	- .44	- .33
9	+1.56	+ .11	+1.00	+ .44	0	+ .44	+ .78	- .33	- .22	+ .44	- .44
8	+ .67	- .44	+ .56	0	+ .33	- .44	- .11	-1.44	- .56	+1.56	+ .56
7	+ .44	- .11	+ .78	+ .67	- .22	-1.00	- .78	-1.56	-1.11	+1.44	- .33
6	+ .22	+ .67	+ .89	+1.00	+ .44	- .44	- .33	+ .11	- .78	+2.11	+1.11
5	0	+ .78	+ .67	+1.56	+ .11	+1.33	+ .56	+1.00	+ .11	+1.56	+2.44
4	0	+1.22	+1.10	+ .67	+ .78	+1.89	+1.22	+1.11	+1.56	+1.22	+2.44
3	- .11	+1.00	+ .67	0	+ .33	+1.33	+1.56	+ .11	+1.22	+ .33	+ .78
2	- .56	+ .22	+ .22	-1.11	0	0	+1.11	- .56	+ .44	- .56	-1.33
1	-1.22	-1.22	-1.78	-1.33	-1.00	-1.67	- .89	- .89	-1.22	-2.22	-1.78

saxatilis (Walbaun). M. S. thesis, University of Maine, Orono, 61 pp. (unpublished).

Lewis, R. M. and W. F. Hettler, 1968. Effect of temperature and salinity on the survival of young Atlantic menhaden, *Brevoortia tyrannus*. *Trans. Am. Fish. Soc.* 97 (4): 344-349.

Mansueti, R. J., 1961. Movements, reproduction, and mortality of the white perch, *Roccus americanus*, in the Patuxent estuary, Maryland. *Ches. Sci.* (3-4): 142-205.

Mansueti, A. J. and J. D. Hardy, 1967. Development of fishes of the Chesapeake Bay region, an atlas of egg, larval, and juvenile stages, Part I. Natural Resources Institute, University of Maryland, 202 pp.

Massmann, W. H., 1963. Age and size composition of weakfish, *Cynoscion regalis*, from pound nets in Chesapeake Bay, Virginia. 1954-1958. *Ches. Sci.* 4 (1): 43-51.

Massmann, W. H., E. C. Ladd and H. N. McCutcheon, 1952. A biological survey of the Rappahannock River, Virginia. Va. Fish. Lab., 2 vol., 221 pp.

Massmann, W. H. and A. L. Pacheo, 1961. Movements of striped bass in Virginia waters of Chesapeake Bay. *Ches. Sci.* (1-2): 37-44.

Pacheco, A. L., 1962. Age and growth of spot in lower Chesapeake Bay, with notes on distribution and abundance of juveniles in the York River system. *Ches. Sci.* 3 (1): 18-28.

Parker, J. C., 1971. The biology of the spot, Leiostomus xanthurus Lacepede, and Atlantic croaker, Micropogon undulatus (Linnaeus), in two Gulf of Mexico nursery areas. Texas A&M University, Sea Grant Pub. No. TAMU-SG-71-210.

Reintjes, J. W. and A. L. Pacheo, 1966. The relation of menhaden to estuaries. IN A symposium on estuarine fisheries. Amer. Fish. Soc. Spec. Pub. No. 3: 50-58.

Svetovidov, A. N., 1952. Fauna of the U.S.S.R. - Fishes, Clupeidae 2 (1): 1-428. NSF, Washington, D. C. (English translation).

Talbot, G. B., 1966. Estuarine environmental requirements and limiting factors for striped bass. IN A symposium on estuarine fisheries. Amer. Fish. Soc. Spec. Pub. No. 3: 37-49.

Thomas, D. L., 1971. The early life history and ecology of six species of drum (Sciaenidae) in the lower Delaware River, a brackish tidal estuary. Ichthyological Associates, Bull. No. 3, 247 pp.

Wong, R.S.P., 1968. Age and growth of the northern searobin, Prionotus carolinus (Finnaeus). M. A. Thesis, College of William and Mary, Williamsburg, 49 pp. (unpublished).

Thermal Tolerances of Fishes

A paper by Gift and Westman (1971), dealing with thermal tolerances of estuarine fishes, has been included as Appendix 3.

Commercial Fishing in the York River

Two types of commercial gear are generally used in the York River--pound nets and gill nets. Counts of pound nets in the York River are made bimonthly by VIMS personnel throughout the season (about 1 March to 30 November). The range and mean number of pound nets per month for the years 1959 to 1971 are given in Figure 1. The decline in mean number of nets fished is primarily due to deaths of fishermen rather than a decline in the fishery. The species composition of the pound net catch is usually withheld or distorted by the fishermen so that no catch data are available.

Counts of gill nets in the York River are also made by VIMS personnel throughout the season (about 1 January to 30 April). The total number of gill nets fished in the York River for the years 1967 to 1971 is given in Table 5. The gill net catch composition for the York, Pamunkey, and Mattaponi rivers is given in Table 6. The data in Table 6 are based on one wholesale-retail market and represent approximately 60% of the York River system's gill net fishery. These figures do not reflect fish retailed by the store, nor do they reflect true abundance since market conditions, especially for buck shad but also for roe shad and roe jacks, have been so depressed over the last few years that prices determined which fish the wholesaler would buy.

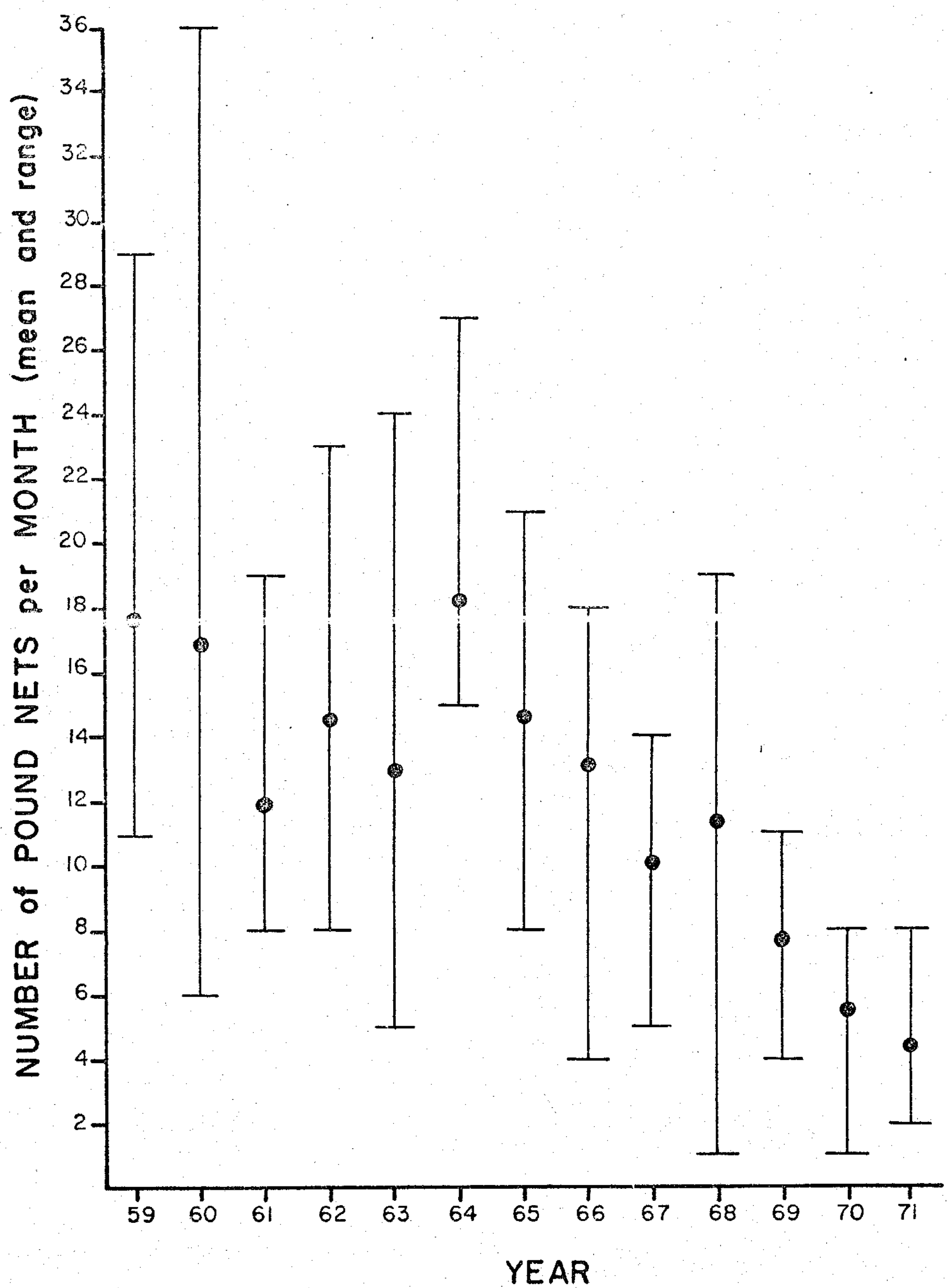


Figure 1. Pound Nets in the York River

Table 5. Total Number of Gill Nets Fished in the York River

Year	1967	1968	1969	1970	1971
Total Number	90	86	94	71	109

Table 6. Gill Net Catch Composition from the York, Pamunkey and Mattaponi Rivers (see text for explanation)

	Pounds per year			
	1968	1969	1970	1971
Rock Morone saxatilis	15,594	16,382	13,949	14,026
Roe shad Alosa sapidissima	152,598	126,619	116,829	97,285
Roe jacks Alosa mediocris	2,454	1,100	2,412	-
Buck shad Alosa sapidissima	5,065	4,159	9,200	11,941
Perch Morone americanus	9,239	12,704	2,219	24,579

Sport Fishing in the Lower York River (R. Jordan)

During the period 1955 through 1960 a survey of the sport fishery of the Virginia portion of Chesapeake Bay and its tributaries was conducted by the Virginia Fisheries Laboratory (Richards, 1962). The area studied the most intensively during this survey was the York River, from its mouth upstream to Pages Rock Light.

Estimates of fishing effort during the fishing season (May - September) were based on counts of boats recorded at two hour intervals by drawbridge tenders at the George P. Coleman Memorial Bridge. Interviews of fishermen and examinations of log books were conducted to provide estimates of the average durations of fishing trips by private boats (4 hours) and charter boats (5 hours) and average numbers of fisherman per boat (2.6 for private boats, 7 for charter boats). With this information numbers of boats could be converted to fishing effort in man-hours.

Results showed that maximum fishing effort on an average day occurred between 1000 and 1400 hours. Effort on weekend days was about three times that on week days, while the greatest effort was recorded on holidays. In the long run the peak of private boat activity was in June and July, while the greatest party boat business occurred in July and August. Levels of effort were fairly constant from year to year in the period

1955-58, but then declined, probably because of an unexplained drop in availability of croakers. It is believed by the author (C. E. Richards, personal communication) that future fishing effort in the lower York River will be strongly influenced by fluctuations in croaker populations.

Estimates of catch were obtained mostly from interviews with fishermen on the fishing grounds and near landings. Catch data and effort data were combined to yield catch per man-hour for each of six species (Table 7). Catch rate for croakers reached a maximum in June and July, and gradually droppped to zero in October. The croaker catch was good in 1955 and 1956, then declined steadily.

For spot the maximum catch rate occurred in September. The availability of spot and its importance in the catch increased as the croaker catch declined in late summer and early fall, and also as the croaker catch declined from year to year.

The catch rate of weakfish reached a maximum in August and early fall, and was fairly consistent year to year. For flounder the rate was fairly constant with season, but exhibited a definite spring maximum. Spring and fall maxima were found for the striped bass catch rate, while for puffers the peak was in the fall. Rates for the last three species increased in the later years of the study.

A few boat counts in the York River were compiled by Richards in 1961, observing from VIMS roof, and by other

Table 7

Angling catch per man-hour by months, areas, and years of private boats, 1955-60, Tidewater Virginia (taken from Table 6 of Richards, 1962)

Catch Rates by Months (Averaged over five study areas)

Species	Apr	May	Jun	Jul	Aug	Sep	Oct
Croaker	.53	1.32	2.05	1.68	.96	.30	.02
Spot	.00	.05	.43	1.42	1.75	1.83	1.41
Weakfish	.00	.03	.11	.12	.19	.24	.22
Flounder	.04	.22	.17	.07	.07	.05	.07
Striped Bass	.14	.12	.03	.07	.05	.13	.36
Puffer	.01	.02	.00	.03	.04	.05	.05

Catch Rates by Area

Species	York River
Croaker	1.46
Spot	.34
Weakfish	.08
Flounder	.05
Striped Bass	.02
Puffer	.08

Catch Rates by Year (Averaged over five study areas)

Species	1955	1956	1957	1958	1959	1960
Croaker	2.15	1.97	1.67	1.10	.32	.21
Spot	.72	.53	1.16	.99	2.14	1.41
Weakfish	.16	.16	.15	.17	.14	.10
Flounder	.02	.03	.03	.30	.11	.07
Striped Bass	.03	.02	.04	.11	.17	.17
Puffer	.00	.00	.01	.01	.07	.11

observers in 1966, 1968, 1971, and 1972 operating from aircraft or VIMS vessels. Since these data are meager and have not been interpreted, they will not be included here.

LITERATURE CITED

Richards, C. E. 1962. A survey of salt-water sport fishing in Virginia, 1955-1960. Chesapeake Science 3:223-35.

Quantitative Aspects of the York River Ichthyofauna

Introduction and Methods

Biologically, the Chesapeake-York-Pamunkey estuary is a relatively well-known, undisturbed coastal estuary (Boesch, 1971). Reports on the fishes (Massmann, 1962; McHugh, 1967) have essentially been lists of species or species ranges in the system. Both of these reports, the present report, and most other reports on estuarine fishes (Bechtel and Copeland, 1970; Dahlberg and Odum, 1970) are based on data obtained from fixed sampling sites, usually located in the channel or mid-stream. Assuming fishes are evenly distributed from shore to shore and throughout the sampling area, this sampling design is sufficient to accurately characterize the community present. However, such an even distribution is seldom the case, and the interpretability of data from fixed sampling sites is consequently limited. In the present study, reference to the Chesapeake-York-Pamunkey system applies to fixed stations in the channel, and although generalizations are made which imply spatial interpolation between stations, these should be viewed as a pragmatic means of discussing results rather than as accurate statements of the situation in the entire river.

The data discussed in this report were obtained from monthly trawl surveys conducted by VIMS personnel. These data have been stored in a computer card file at VIMS, and selected portions have been published in various VIMS contributions.

The stations were located at five or ten mile intervals from the mouth of Chesapeake Bay to a point 50 miles upstream from the mouth of the York River (Table 8 and Fig. 2). Stations were generally sampled around the second or third week of each month. During the period from 1967 to 1971, fishing effort was relatively consistent (Table 9) and only data from this five-year period were used in this report.

A 9.1 meter, unlined, semi-balloon otter trawl with a 38 mm stretch mesh cod-end was towed at 2.5 knots by the R. V. Pathfinder and, occasionally, the R. V. Langley. Bottom salinity and temperature were recorded at each station. The duration of each tow was 15 minutes in the Bay and York River, and 7.5 minutes in the Pamunkey. The effect of tow duration on catch size and composition is unknown, although Chittenden (in press) presents evidence that it may have little effect. All samples are, therefore, treated equally in this report.

Two final limitations apply to these data. First, fish are mobile; they can avoid nets, some species better than others, and some age classes of a species better than others. Second, some estuarine fishes are subject to large year-class fluctuations in abundance. These fluctuations can distort "normal" dominance relationships and community structure.

Because of the above limitations and the quantity of the data, the following approach is taken in the data analyses. Each year that a station was sampled in a given month is considered a replicate of that station for that month, even

Table 8

VIMS monthly river trawl stations in Chesapeake Bay (C00-C10), York (Y00-Y25) and Pamunkey Rivers (P30-P50)

Station Number	Latitude	Longitude	Depth (m)
C00	37°03.3'N	76°04.9'W	17
C10	37°11.0'N	76°14.9'W	12
Y00	37°14.6'N	76°23.2'W	17
Y10	37°19.2'N	76°35.8'W	9
Y15	37°23.0'N	76°39.2'W	10
Y20	37°26.3'N	76°42.9'W	7
Y25	37°29.1'N	76°45.3'W	9
P30	37°32.7'N	76°49.8'W	10
P35	37°32.9'N	76°51.9'W	6
P40	37°32.8'N	76°53.4'W	7
P50	37°35.2'N	76°58.6'W	7

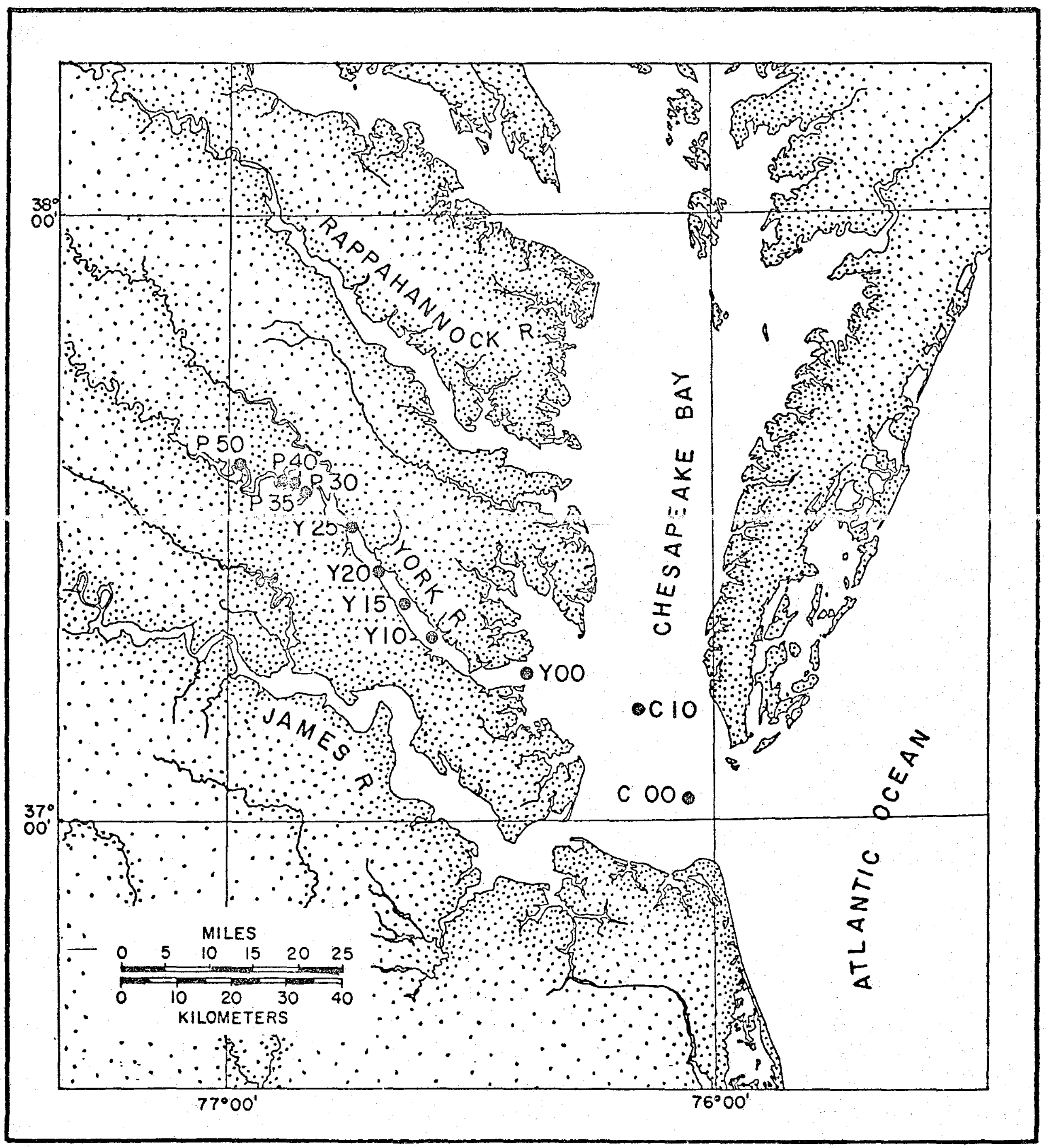


Figure 2. VIMS monthly trawl stations.

Table 9

Total number of years a station was sampled during each month from 1967 to 1971

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
	Station Number										
12	4	5	5	5	5	5	5	5	5	5	5
11	5	5	5	5	5	5	5	5	5	5	5
10	5	5	5	5	5	5	5	5	5	5	5
9	5	5	5	5	5	5	5	5	5	5	5
8	5	5	5	5	5	5	5	5	5	5	5
7	5	5	5	5	5	5	5	5	5	5	5
6	5	5	5	5	5	4	5	5	5	5	5
5	5	5	5	5	5	5	5	5	5	5	5
4	5	5	5	5	5	5	5	5	5	5	5
3	4	5	5	5	5	5	5	5	5	4	5
2	4	5	5	5	5	5	5	5	5	4	5
1	3	3	3	4	4	5	5	5	4	4	4

when no fish were caught. When a station was not sampled it is not considered. The total number of species and individuals and the mean bottom temperature and salinity were calculated for all 132 combinations of stations and months. Diversity (H') was calculated in bits per individual by pooling all years at each station each month (Pielou, 1966). Sanders' (1960) biological index was calculated by ranking the five dominant species in each replicate (year), summing, and thereby producing a dominance rank for each station each month.

The spatial and temporal distributions of most of the dominant species were determined by calculating the antilog of the transformed (ln(x+1)) mean number at each station each month. Transformation was used to help eliminate skewed distributions caused by year-class fluctuations and contagion (see Taylor, 1953).

In order to show general trends the data at each station were analyzed using running means of three, calculating chronological differences in running means, and taking running means of three of the differences. For example, the monthly trend for November was obtained as follows:

Month	Datum Value	Running Mean	Difference	Monthly Trend
January	A			
December	B	$\frac{A+B+C}{3}$		
			$\frac{A-D}{3}$	
November	C	$\frac{B+C+D}{3}$		$\frac{A-D+B-E+C-F}{9}$
			$\frac{B-E}{3}$	
October	D	$\frac{C+D+E}{3}$		
			$\frac{C-F}{3}$	
September	E	$\frac{D+E+F}{3}$		
			$\frac{D-G}{3}$	
August	F	$\frac{E+F+G}{3}$		
July	G			

The result $\frac{A+B+C-D-E-F}{9}$ will either be positive or negative, depending on whether the data were tending to increase or decrease in November, and further, will show the rate of change. Since much random variation is eliminated, this method does not permit confidence intervals or tests of significance to be placed on the results.

This report attempts to show general trends in the spatial and temporal distributions of the fishes in the channel of the Chesapeake-York-Pamunkey system. Annual differences in the abundance of the major species is also shown. However, both the general trends and the annual differences must be interpreted with caution since, as stated initially, distribution and abundance at fixed channel locations does not necessarily reflect the distribution and abundance of populations in shoal water or the river as a whole.

Results and Discussion

Temperature and Salinity

Mean monthly bottom temperature and monthly trends in changes of bottom temperature are shown in Tables 10 and 11, respectively. In the Pamunkey River temperatures tend to increase from February to July. In Chesapeake Bay and the York River proper the increase lasts through August, although in the Bay it does not begin until March. The stations in the York River proper (Y25-Y10) have seven months of generally increasing temperature while the Pamunkey and Bay stations have six.

Mean monthly bottom salinity is shown in Table 12. At any one station, salinity is generally lower in the spring and higher in the fall due to differential seasonal runoff. Mean monthly salinity (‰) ranges from zero to 10.2 in the Pamunkey River, 8.6 to 21.3 in the York River proper and 16.4 to 29.2 at the Bay stations. A classification of the stations based on salinity regimes (Carriker, 1967) shows that P50 is fresh, P40 and P35 are oligohaline (0.5 to 5‰ salinity), P30 to Y15 are mesohaline (5 to 18‰), and Y10 to C00 are polyhaline (18 to 30‰).

Table 10

Mean monthly bottom temperature at each station-month combination
1967 to 1971

Month						Station Number					
	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
12	6.6	7.2	7.2	7.6	7.0	7.4	7.3	7.4	8.2	8.0	8.8
11	12.6	13.2	13.2	13.0	13.2	13.6	13.2	13.4	13.6	13.8	14.0
10	20.2	20.4	20.4	20.6	20.0	20.0	20.0	20.0	20.0	20.0	19.8
9	24.8	24.8	24.8	25.2	24.8	24.6	25.0	24.8	24.4	23.6	22.8
8	27.6	27.4	27.2	27.4	26.8	27.0	26.6	26.6	25.4	25.2	23.6
7	28.2	27.6	27.8	27.4	27.2	26.8	26.4	25.6	25.0	24.2	24.0
6	26.0	25.4	25.2	25.0	24.8	24.3	24.0	23.6	22.2	21.4	20.8
5	21.4	20.8	20.6	20.6	19.6	18.8	18.0	18.0	17.0	15.2	15.0
4	16.6	15.2	14.8	14.4	14.8	16.0	15.4	14.6	12.4	10.6	10.6
3	9.0	8.6	8.0	8.4	7.8	7.2	6.4	6.2	7.6	6.3	7.4
2	4.3	4.3	4.0	3.8	3.6	3.8	3.6	4.2	3.0	3.3	3.2
1	2.7	3.3	3.3	2.3	3.0	2.8	2.6	2.8	3.3	4.7	4.3

Table [illegible]1

Monthly trends in changes of bottom temperature at each station
1967 to 1971

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
	Station Number										
12	-4.89	-4.84	-4.88	-5.01	-4.93	-4.91	-4.97	-4.87	-4.83	-4.60	-4.48
11	-5.63	-5.43	-5.41	-5.59	-5.38	-5.31	-5.39	-5.31	-4.97	-4.70	-4.34
10	-4.58	-4.33	-4.33	-4.31	-4.29	-4.16	-4.17	-4.02	-3.67	-3.47	-3.09
9	-2.69	-2.44	-2.42	-2.33	-2.31	-2.21	-2.09	-1.96	-1.62	-1.49	-1.31
8	- .33	- .13	- .13	+ .02	0.00	+ .19	+ .36	+ .47	+ .62	+ .89	+ .71
7	+1.84	+2.04	+2.13	+2.22	+2.18	+2.14	+2.29	+2.31	+2.58	+2.87	+2.67
6	+3.87	+3.98	+4.09	+4.04	+4.07	+4.01	+4.13	+4.11	+3.96	+4.30	+3.93
5	+5.08	+5.08	+5.20	+5.16	+5.04	+4.77	+4.78	+4.69	+4.58	+4.51	+4.29
4	+5.33	+5.02	+5.03	+5.06	+4.98	+5.03	+4.98	+4.78	+4.19	+3.66	+3.50
3	+3.71	+3.31	+3.21	+3.30	+3.18	+3.11	+2.92	+2.71	+2.50	+1.79	+1.86
2	+ .89	+ .49	+ .34	+ .41	+ .33	+ .36	+ .26	+ .16	- .23	- .70	- .66
1	-2.60	-2.73	-2.83	-2.97	-2.87	-3.02	-3.10	-3.07	-3.10	-3.06	-3.08

Table 12

Mean monthly bottom salinity (‰)

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
	Station Number										
12	0	2.4	5.2	9.8	13.6	15.6	19.5	21.3	23.0	23.5	28.7
11	0.6	2.8	5.4	9.8	15.8	17.2	18.8	20.0	22.8	25.0	28.0
10	0.5	2.4	5.4	10.0	14.4	16.0	18.2	20.0	22.4	24.8	28.4
9	0.5	2.2	5.0	10.2	15.0	16.6	19.2	20.2	22.6	25.8	29.2
8	0	1.0	3.3	7.0	12.3	15.0	18.3	20.3	22.5	24.0	27.8
7	0	1.0	3.6	8.6	13.2	15.0	17.8	19.4	22.8	24.0	27.0
6	0	0.6	2.8	6.8	10.8	12.8	16.0	18.0	22.2	24.4	27.5
5	0	0	2.0	6.8	11.6	14.2	17.4	20.3	21.0	23.3	26.6
4	0	0	0.2	3.0	8.6	11.2	14.2	16.4	20.6	24.6	28.5
3	0	0.6	2.8	6.4	12.8	14.2	16.2	19.0	19.8	22.5	28.0
2	1.0	1.0	3.4	7.6	12.0	15.0	17.4	19.2	21.7	27.3	28.2
1	0	0	1.7	7.3	13.0	15.6	17.6	19.0	21.7	25.0	26.5

Numbers of Species and Individuals

In total, 98 species were captured during the five-year period. The total number caught at any station-month combination over this period ranged from 4 to 28 (Table 13). The monthly trends in changes in total number of species showed an increase from about March through October, with the York River proper and station Y00 showing a summer decrease (Table 14). A decline in the bottom dissolved oxygen concentration (Brehmer, 1970) appears to account for part of this decrease in total number of species (personal observation). The five-year mean total number of species per month decreased going upstream from the Bay stations (17.8) to the York (15.2) to the Pamunkey (11.8).

The total number of individuals captured during the five-year period was 226,240. The total number caught at any station-month combination over this period ranged from 110 to 10,468 (Table 15). The monthly trends in changes in total number of individuals showed three general patterns: at station C00 there was an increase from May to August, and from November to January; at stations C10 through Y10 there was a long period of general increase in numbers from about March to October; and at stations Y15 through P50 there was an increase from March to April, and again from August through November (Table 16). The five-year mean total number of individuals per month was 995 for the Bay stations, 2,607 for

Table 13

Total number of species per station per month
1967 to 1971

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
	Station Number										
12	12	8	10	12	15	17	11	17	18	14	20
11	18	15	16	14	15	17	15	17	15	19	20
10	16	12	15	14	15	22	21	16	19	25	22
9	16	11	17	15	14	16	16	11	12	21	22
8	10	10	11	11	15	16	12	12	15	22	28
7	13	13	14	14	12	17	15	15	18	19	15
6	13	14	14	14	17	18	18	20	15	20	25
5	10	10	10	12	12	23	17	17	18	15	27
4	12	11	11	8	14	17	15	15	22	14	16
3	12	10	10	10	14	15	16	14	15	13	15
2	12	9	11	8	12	14	14	14	13	13	14
1	11	5	4	10	10	12	9	14	13	12	17

Table 14

Monthly trends in changes of total number of species at each station

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
	Station Number										
12	-1.67	-.178	-2.56	-1.44	- .78	-1.33	-.200	+ .11	- .22	-2.89	-1.44
11	- .11	- .56	-1.44	- .44	- .44	- .89	-1.56	+1.00	0	-2.56	-1.67
10	+ .78	+ .11	- .11	0	+ .44	+ .78	+ .44	+1.33	+ .78	- .44	- .33
9	+1.56	+ .11	+1.00	+ .44	0	+ .44	+ .78	- .33	- .22	+ .44	- .44
8	+ .67	- .44	+ .56	0	+ .33	- .44	- .11	-1.44	- .56	+1.56	+ .56
7	+ .44	- .11	+ .78	+ .67	- .22	-1.00	- .78	-1.56	-1.11	+1.44	- .33
6	+ .22	+ .67	+ .89	+1.00	+ .44	- .44	- .33	+ .11	- .78	+2.11	+1.11
5	0	+ .78	+ .67	+1.56	+ .11	+1.33	+ .56	+1.00	+ .11	+1.56	+2.44
4	0	+1.22	+1.10	+ .67	+ .78	+1.89	+1.22	+1.11	+1.56	+1.22	+2.44
3	- .11	+1.00	+ .67	0	+ .33	+1.33	+1.56	+ .11	+1.22	+ .33	+ .78
2	- .56	+ .22	+ .22	-1.11	0	0	+1.11	- .56	+ .44	- .56	-1.33
1	-1.22	-1.22	-1.78	-1.33	-1.00	-1.67	- .89	- .89	-1.22	-2.22	-1.78

Table 15

Total number of individuals per station per month
1967 to 1971

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
					Station Number						
12	498	1456	1346	2016	2221	1226	2463	653	707	456	193
11	4385	8603	2582	1502	9564	7036	7109	7480	1799	679	648
10	2455	1397	1616	1259	2721	10,468	5509	2100	4644	3223	445
9	1236	665	1108	1358	1239	902	904	1015	1545	1077	833
8	347	435	529	505	1271	1151	1663	3177	1360	940	1254
7	635	821	843	630	1593	1053	2848	1247	1999	2009	425
6	434	283	834	698	1578	1397	848	1061	734	969	454
5	913	379	611	1127	4984	2104	4854	1358	1120	1352	392
4	1137	1942	1863	3877	5499	4833	6058	2301	574	483	351
3	1007	755	1821	1073	1701	733	756	276	356	110	238
2	924	407	3001	1241	1734	1200	641	256	389	882	316
1	206	307	320	1914	1791	893	1175	437	738	167	1947

Table 15

Monthly trends in changes of total number of individuals at each station

Month	Station Number										
	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
12	-716	- 944	- 71	+117	- 864	-1682	-1027	-1028	-684	-386	+ 59
11	+117	+ 874	+111	+257	+ 927	- 368	+ 297	+ 253	-478	-438	+ 28
10	+569	+1059	+340	+254	+1156	+1742	+1074	+ 533	+250	+ 37	-136
9	+740	+1014	+344	+254	+1009	+1651	+ 907	+ 568	+433	+118	- 23
8	+228	+ 113	+107	+ 74	- 325	+ 885	- 53	+ 292	+411	+101	+140
7	- 30	- 76	- 92	-357	- 884	- 581	- 705	+ 80	+275	+136	+146
6	-182	- 171	-232	-472	- 860	- 452	- 701	+ 172	+227	+219	+128
5	-121	- 180	-489	-415	- 87	- 246	+ 122	+ 93	+282	+317	+ 41
4	+ 39	+ 126	-204	+164	+ 759	+ 612	+1021	+ 417	+105	+183	-145
3	+159	+ 101	- 41	+101	+ 715	+ 483	+ 821	+ 288	+ 24	+ 49	-164
2	-225	- 807	+271	+ 84	- 516	- 271	- 366	- 637	-214	+ 19	-209
1	-578	-1110	- 45	- 61	-1031	-1773	-1390	-1029	-630	-355	+135

the York stations, and 1,360 for the Pamunkey stations.

The patterns shown for numbers of species and numbers of individuals are due to the composite effects of the movements of juveniles and adults of many species. They move into the river channel or become available to the gear in spring and fall, leave or move randomly or move into shoaler water in the summer, and leave or move within the channel in winter.

Diversity

Values of pooled H' ranged from 0.523 to 3.775, with a mean of 1.986 (Table 17). The high values of pooled H' at station C00 are due, in part, to year to year differences in catch composition that were not evident at other stations, and that were attributable to the 173 marine species that regularly or occasionally enter the Bay during the summer (Musick, 1972).

Monthly trends in changes of pooled H' (Table 18) showed complicated patterns which either had two periods of increase (C00 through Y25) or one period of increase (P30 through P50). Within the York River proper, the summer increase in pooled H' coincided well with the summer decrease in total number of individuals (Table 15)and species(Table 13). If these changes were due to the decrease in dissolved oxygen concentration mentioned above, then its effects must generally be mild, perhaps forcing a few species out of the channel

Table 17

Mean pooled diversity (H') at each station each month

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
	Station Number										
12	2.104	0.888	1.579	1.177	1.442	2.193	1.202	2.586	2.809	2.135	3.046
11	0.893	0.523	1.985	1.979	0.971	0.730	0.818	1.107	2.343	2.422	2.689
10	2.023	2.111	2.928	1.743	1.704	0.950	1.697	2.187	2.254	2.540	2.853
9	2.176	2.490	2.622	2.162	2.282	2.812	2.410	2.334	2.432	2.942	2.853
8	2.323	1.594	1.697	2.218	2.684	2.524	1.787	1.519	1.937	2.266	2.811
7	1.925	2.247	2.488	2.490	2.995	2.713	1.607	1.907	2.077	2.554	1.868
6	2.471	2.406	2.443	2.434	2.316	1.763	1.998	2.318	2.660	2.238	3.495
5	2.265	1.947	1.985	1.830	1.030	1.755	0.755	1.916	2.832	1.662	3.775
4	1.806	1.360	0.933	0.673	1.308	0.842	0.757	0.989	2.417	2.116	3.047
3	1.966	1.859	1.318	1.466	1.568	2.044	1.871	2.700	2.449	2.864	2.503
2	1.687	1.992	0.947	1.445	1.880	2.069	1.941	2.734	2.787	1.546	2.414
1	1.705	1.659	1.337	0.904	1.569	1.554	1.048	1.693	2.246	1.762	1.727

Table 18

Monthly trends in changes of mean pooled diversity at each station

Month	P50	P40	P35	P30	Y25	Y20	Y15	Y10	Y00	C10	C00
	Station Number										
12	+.045	-.065	-.408	-.262	-.007	+.147	-.082	+.154	+.090	-.273	-.134
11	-.202	-.347	-.261	-.229	-.299	-.201	-.314	-.073	+.086	-.159	-.117
10	-.156	-.312	-.035	-.219	-.427	-.464	0.232	+.013	+.107	-.074	+.117
9	-.181	-.125	+.101	-.140	-.338	-.279	-.052	-.013	+.039	+.094	+.025
8	-.015	-.045	+.037	-.070	+.037	+.006	+.170	-.011	-.105	+.144	-.069
7	-.013	+.069	+.161	+.215	+.367	+.410	+.255	+.060	-.163	+.194	-.309
6	+.076	+.120	+.266	+.353	+.454	+.262	+.223	+.015	-.114	+.046	-.128
5	+.134	+.154	+.413	+.352	+.176	+.142	-.023	-.031	-.009	-.008	+.130
4	+.132	+.023	+.195	+.125	-.040	-.145	-.150	-.212	+.047	-.017	+.408
3	+.060	+.070	+.041	+.049	-.109	-.131	-.090	-.156	-.016	+.133	+.238
2	+.084	+.238	-.189	-.053	+.086	+.053	+.167	+.115	+.028	+.023	+.056
1	+.038	+.221	-.321	-.120	+.100	+.199	+.127	+.139	+.008	-.103	-.216

and reducing the concentrations of most other species to a more equitable structure, thus increasing the diversity.

Hypothetical Classification of Stations

Boesch (1971) found the Chesapeake-York-Pamunkey system to be an estuary with stable, mild gradients, showing no abrupt changes in the distribution of the macrobenthos. On the basis of several factors, the stations in this report can be arbitrarily divided into Bay, York and Pamunkey stations (Table 19). These groups imply no abrupt changes in the physical or biological parameters measured. In fact, the validity of these groupings breaks down seasonally for many species and renders minimal the utility of this or any type of static station classification in this situation.

Dominance

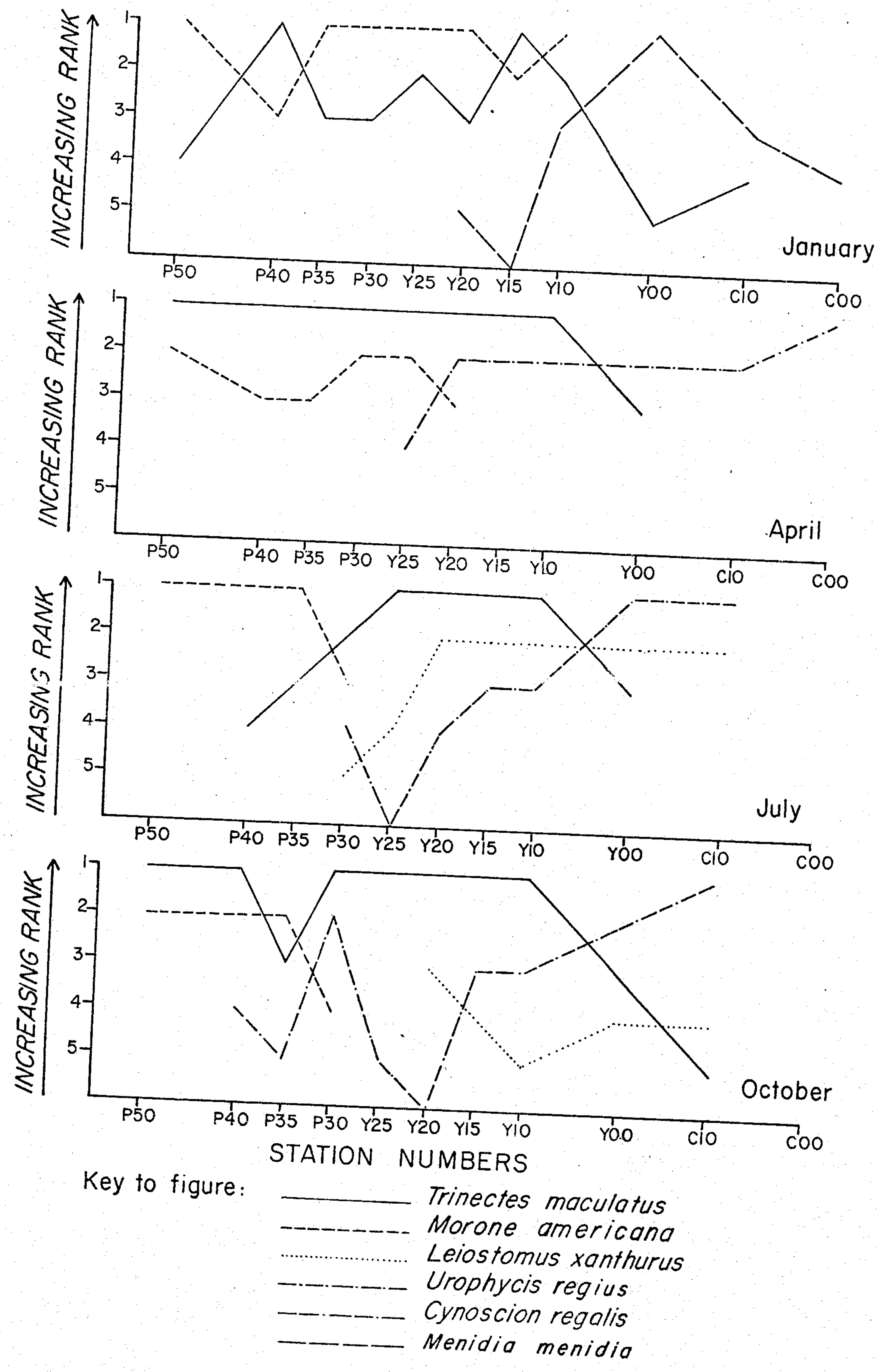
Figure 3 shows some of the more dominant species, as determined by Sanders' (1960) biological index, for each station in January, April, July and October. Within the Bay stations and station Y00, dominance is ephemeral and seldom lasts over two months for any one species. In the York River proper, *Trinectes maculatus* pre-dominates most of the year with *Morone americana*, *Leiostomus xanthurus*, and *Cynoscion regalis* periodically gaining importance. In the Pamunkey River, *M. americana* shares the dominant position with *T. maculatus*, *Ictalurus catus* and, at P50, *I. punctatus* is

Table 19

Artificial classification of stations in the Chesapeake Bay-York-Pamunkey estuary

Factor	Pamunkey	York	Bay
Stations	P50 to P30	Y25 to Y10	Y00 to C00
Salinity regime	fresh to mesohaline	mesohaline to polyhaline	polyhaline
Months with generally increasing temperature	6	7	6
Summer decrease in total number of individuals	yes	yes	no
Summer decrease in total number of species	no	yes	no
Number of separate periods of increasing diversity	1	2	2
Mean pooled diversity	1.8	1.8	2.5
Mean total number of individuals per month (5 years)	1360	2607	995
Mean total number of species per month (5 years)	11.8	15.2	17.8

Figure 3. Dominant species as determined by the bioindex (Sanders, 1960) for January, April, July, and October.



INCREASING RANK
1
2
3
4
5
January
April
July
October
P50
P40
P35
P30
Y25
Y20
Y15
Y10
Y00
C10
C00
STATION NUMBERS
Key to figure:
Trinectes maculatus
Morone americana
Leiostomus xanthurus
Urophycis regius
Cynoscion regalis
Menidia menidia

also important in the Pamunkey River.

Twelve species accounted for almost 92% of the total catch (Table 20). The spatial and temporal distributions of these major species, shown in Figures 4A to 4L, will be discussed next. Following the name of each species are the salinity and temperature ranges at which it has been captured.

Anchoa mitchilli (Bay anchovy) (Fig. 4A) (0-31‰, 1-29 C) was present throughout the year from Y20 to C00. Greatest abundance and greatest upstream movement occurred in the fall. The slightly disjunct spatial distribution in October has been reported previously for York River anchovies (Massmann, 1962). During this month stations P30 and Y25 separate the two regions of greatest abundance. Either the effluent from a pulp mill, located in this area, or the tendency of juveniles to concentrate in low salinity water (Dovel, 1971) may account for this distribution.

Cynoscion regalis (weakfish) (Fig. 4B) (1-31‰, 5-29 C) was abundant in the Bay stations from May to November and appeared to enter and leave the channel at temperatures near 15 C. From September to November, juveniles were present as far upstream as P50 and were abundant as far upstream as P35.

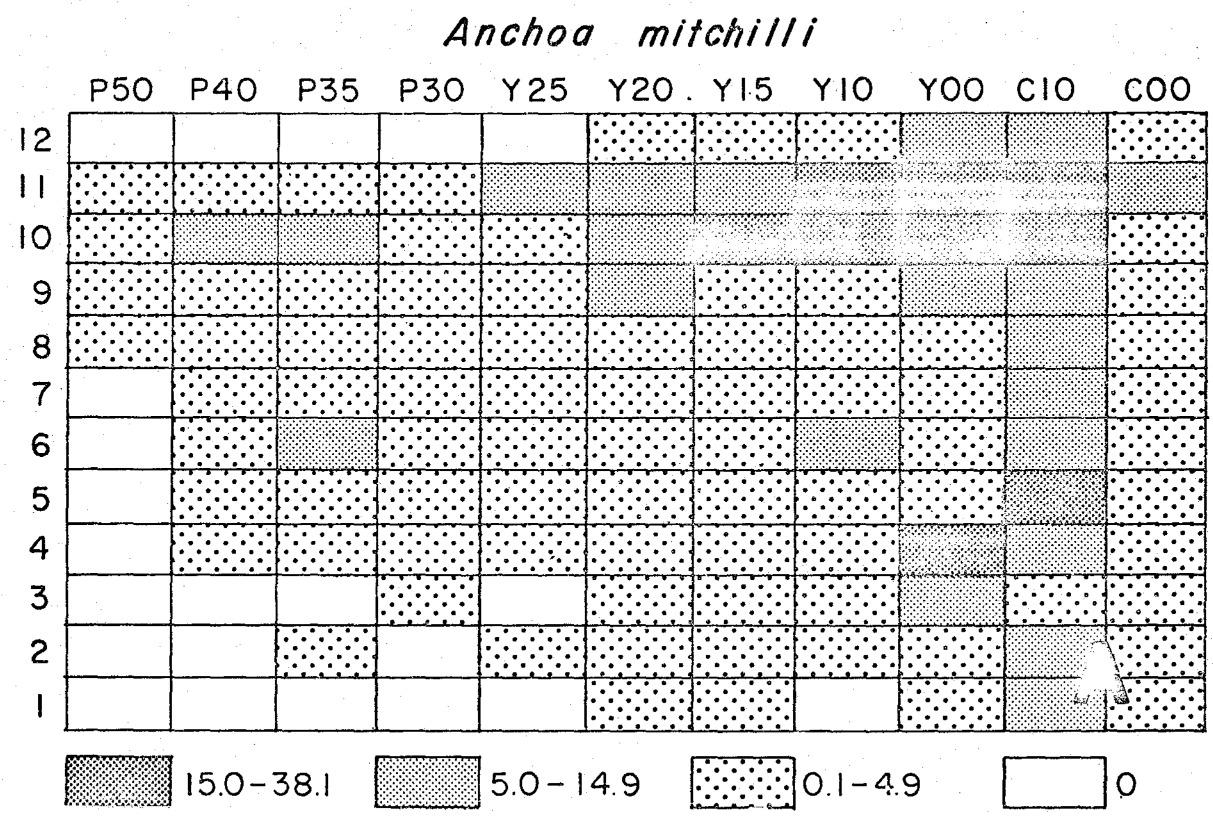
Leiostomus xanthurus (spot) (Fig. 4C) (0-30‰, 6-29 C) was present from May to December with the largest number being found in the summer from C10 to Y15 at mean bottom temperatures greater than 24 C. Abundance began to decrease in September as the monthly trend in mean bottom temperature became negative

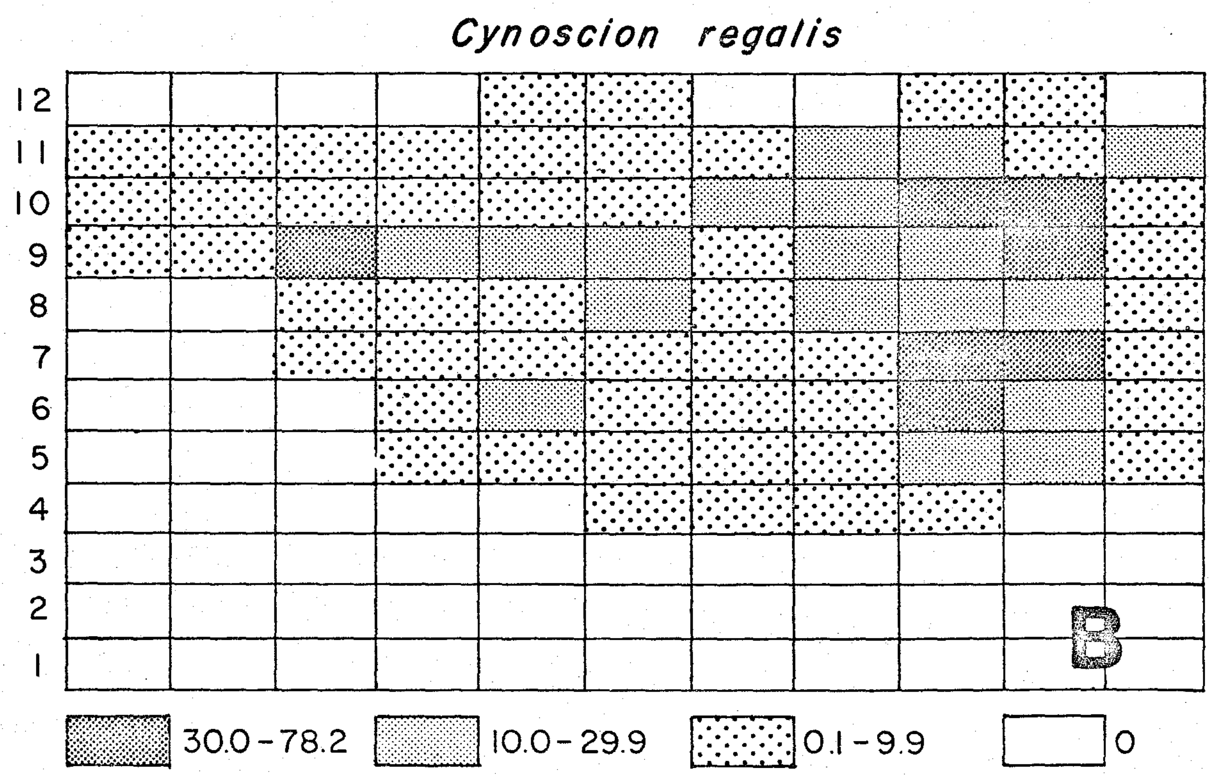
Table 20

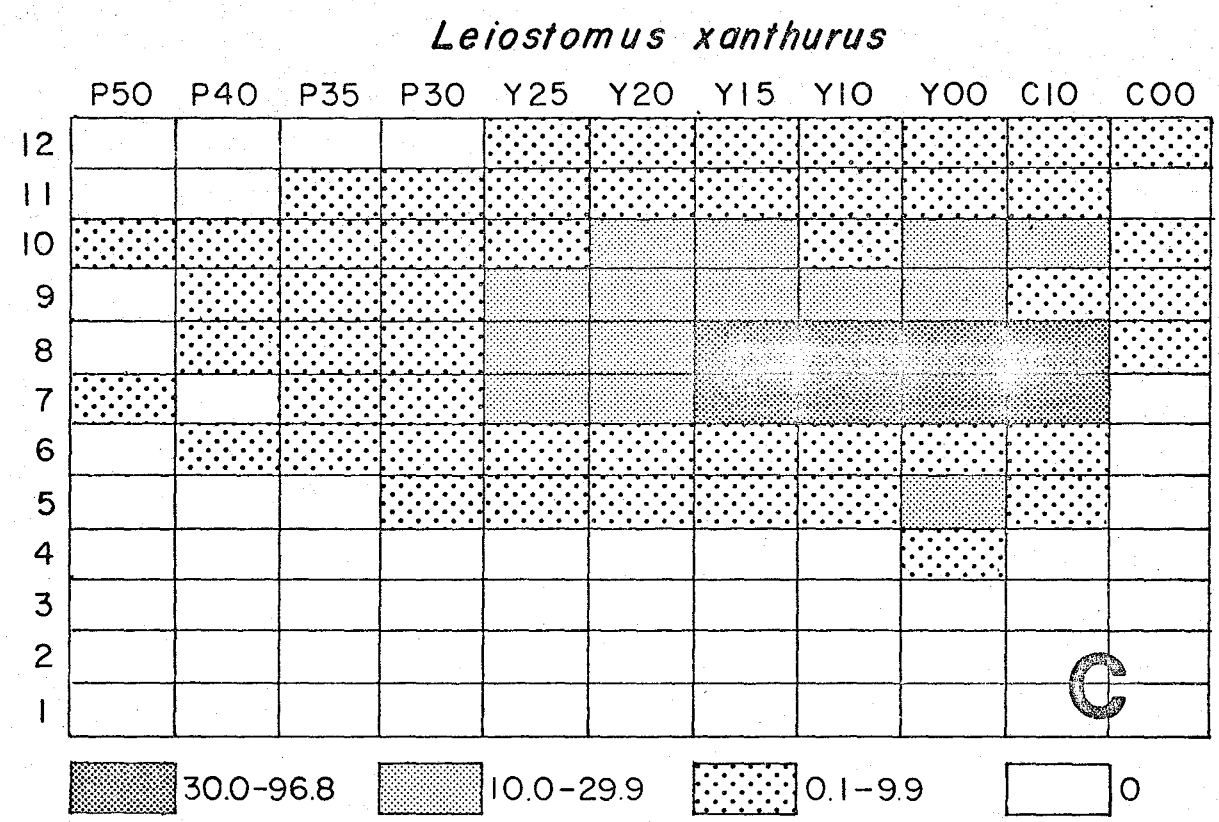
Percent of total catch and cumulative percent of total catch of twelve major species in the Chesapeake-York-Pamunkey estuary, 1967-1971

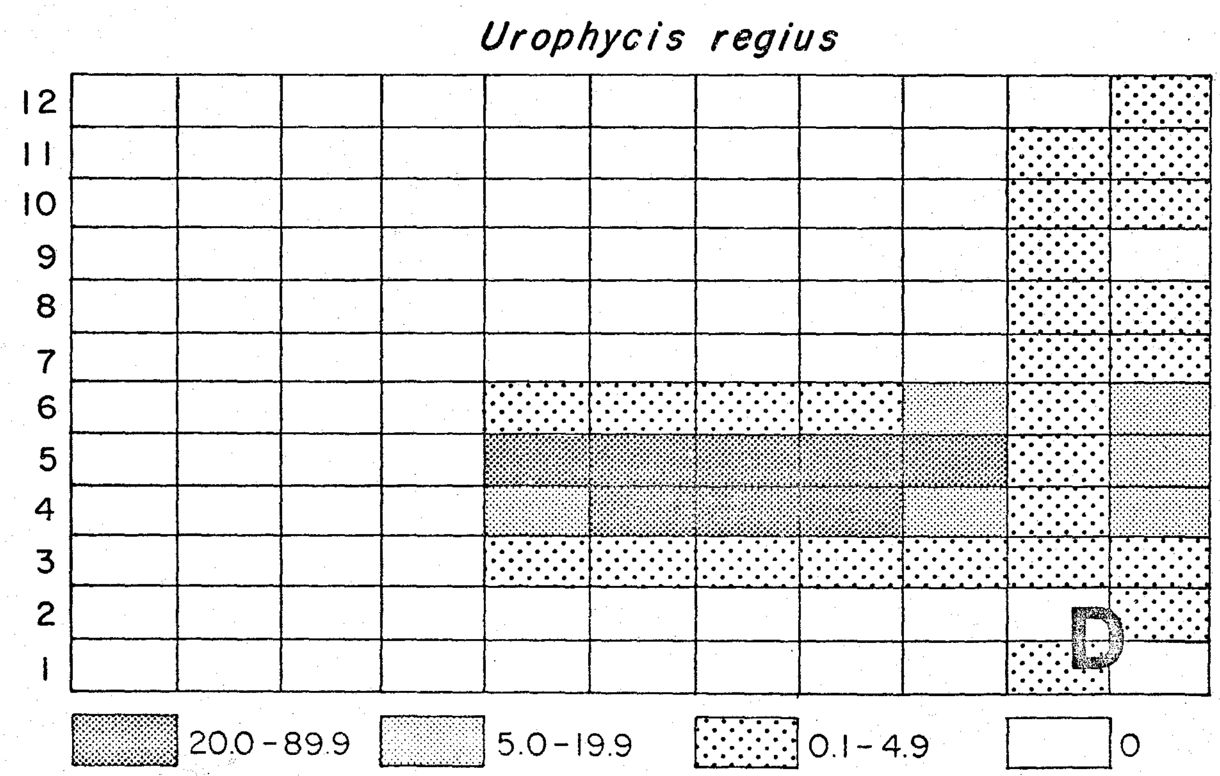
Species	Percent	Cumulative Percent
Trinectes maculatus	53.2	53.2
Morone americana	10.7	63.9
Leiostomus xanthurus	5.8	69.7
Cynoscion regalis	4.5	74.2
Anchoa mitchilli	4.3	78.5
Bairdiella chrysura	3.9	82.4
Micropogon undulatus	2.6	85.0
Ictalurus catus	2.5	87.5
Urophycis regius	1.6	89.1
Morone saxatilis	1.3	90.4
Opsanus tau	1.1	91.5
Ictalurus punctatus	0.6	92.1

Figure 4. The spatial and temporal distribution of twelve major species in the Chesapeake-York-Pamunkey estuary. Abundance is expressed in terms of the antilog of the transformed (ln (X+1)) mean number at each station each month for the period 1967 - 1971.


Anchoa mitchilli
P50 P40 P35 P30 Y25 Y20 Y15 Y10 Y00 C10 C00
12
11
10
9
8
7
6
5
4
3
2
1
A
15.0-38.1
5.0-14.9
0.1-4.9
0


Cynoscion regalis
12
11
10
9
8
7
6
5
4
3
2
1
B
30.0-78.2
10.0-29.9
0.1-9.9
0


Leiostomus xanthurus
P50
P40
P35
P30
Y25
Y20
Y15
Y10
Y00
C10
C00
12
11
10
9
8
7
6
5
4
3
2
1
C
30.0-96.8
10.0-29.9
0.1-9.9
0


Urophycis regius
12
11
10
9
8
7
6
5
4
3
2
1
D
20.0-89.9
5.0-19.9
0.1-4.9
0

(Table 11). Juveniles were captured as far upstream as P50 in July and October (see Pacheco, 1962).

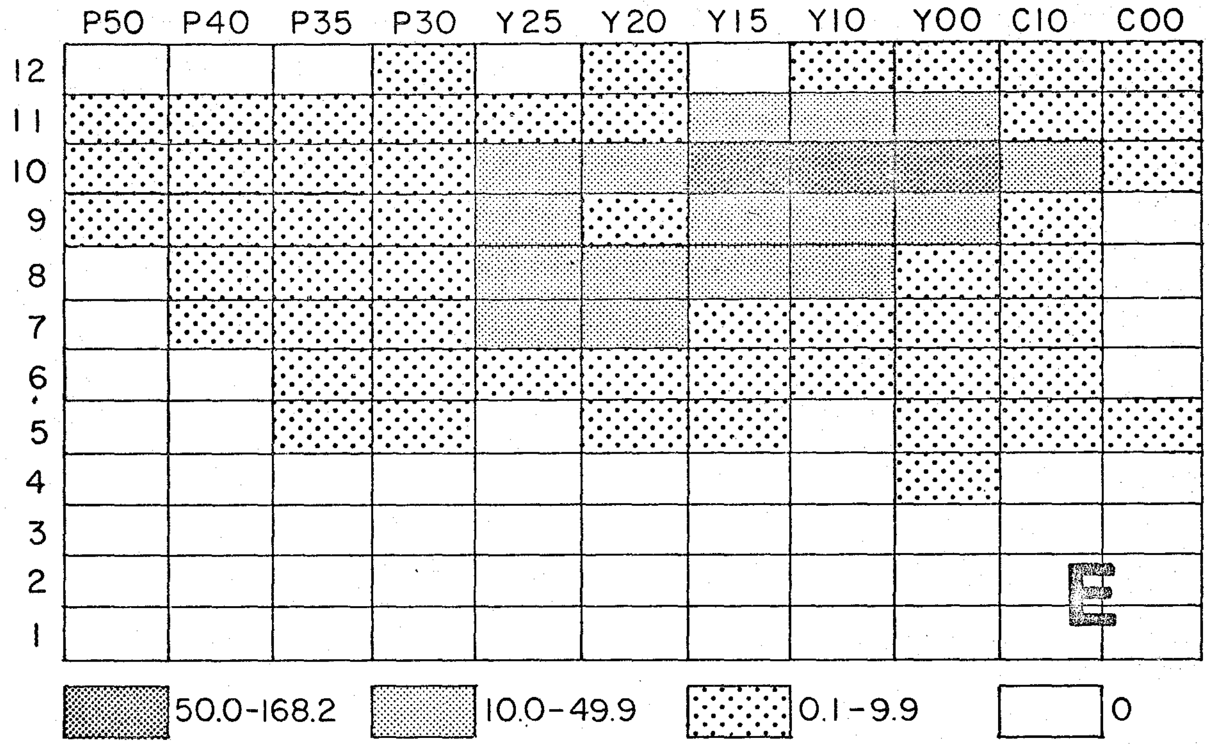
Urophycis regius (spotted hake) (Fig. 4D) (7-20‰, 5-25 C) was present throughout the year at stations C10 and C00. During the spring juveniles entered the York River proper, stayed briefly, and departed by July. Upstream migration is apparently limited to water greater than 7‰ salinity and is initiated by temperatures greater than 18 C (Barans, 1972). During April and May U. regius was the second highest ranked species in the York River channel.

Bairdiella chrysura (silver perch) (Fig. 4E) (1-31‰, 6-29 C) was present from May to December. Large numbers occurred upstream at stations Y25 and Y20 in July and progressed downstream until October, when maximum numbers were reached at station Y00 and their distribution reached from P50 to C00.

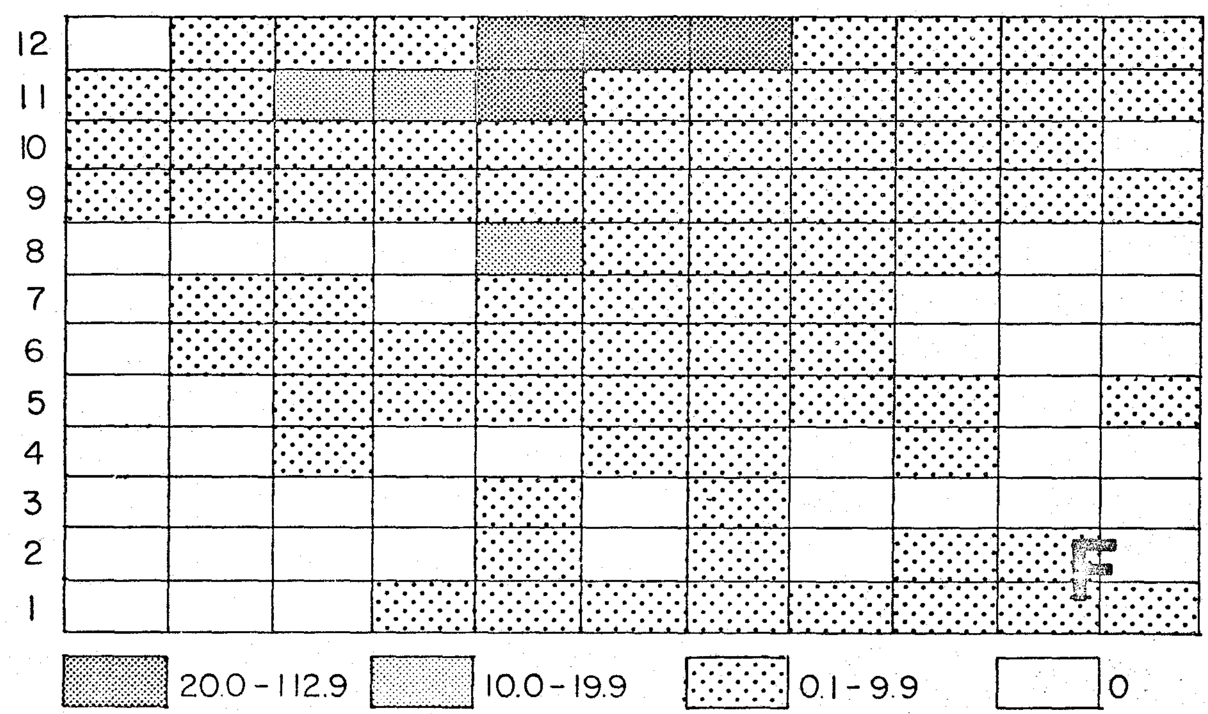
Micropogon undulatus (Atlantic croaker) (Fig. 4F) (0-30‰, 1-29 C) was present throughout the year, at least at some stations. Large numbers occurred upstream at stations Y25 to P35 in November and Y15 to Y25 in December. These fish were primarily young-of-the-year which apparently left the study area after December.

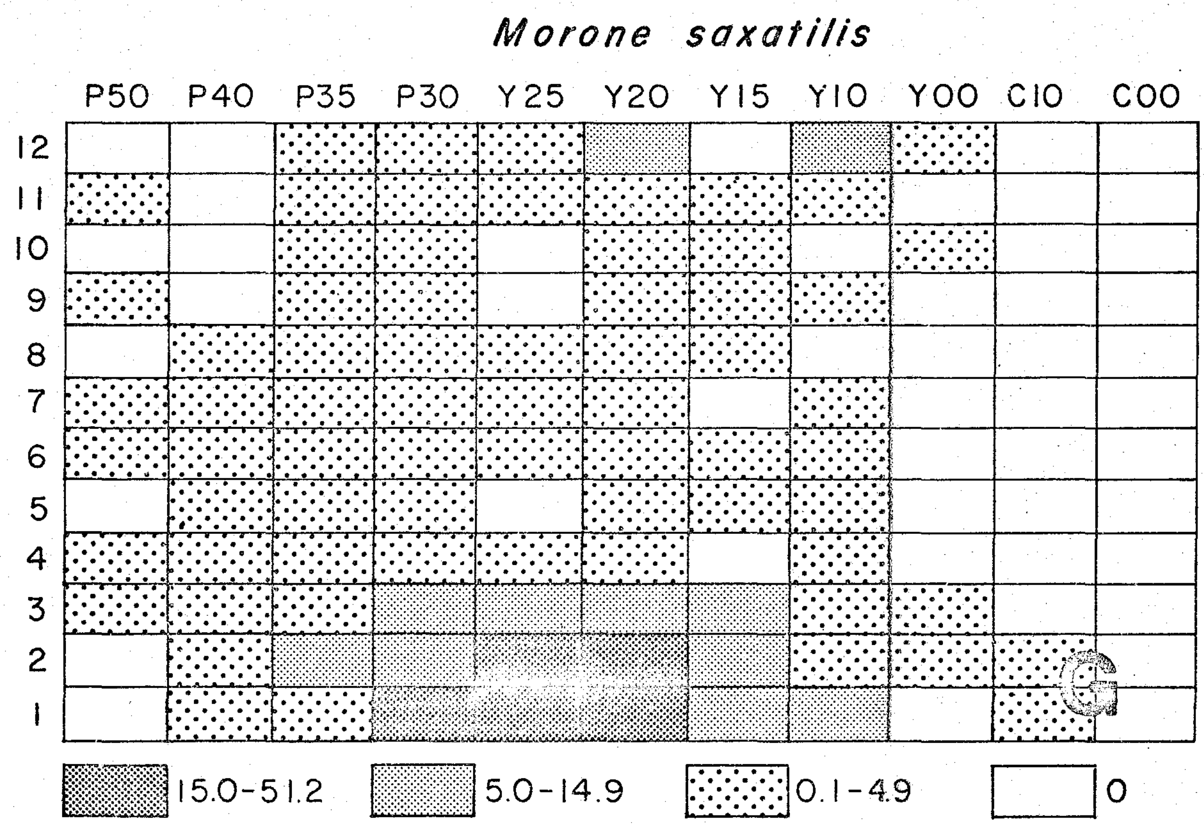
Morone saxatilis (striped bass) (Fig. 4G) (0-27‰, 1-29 C) was abundant from January to March at stations Y15 to P30 when mean bottom temperatures were less than 10 C. The fish were primarily one and two-year old fish, and this distribution pattern apparently reflects their movement into the channel

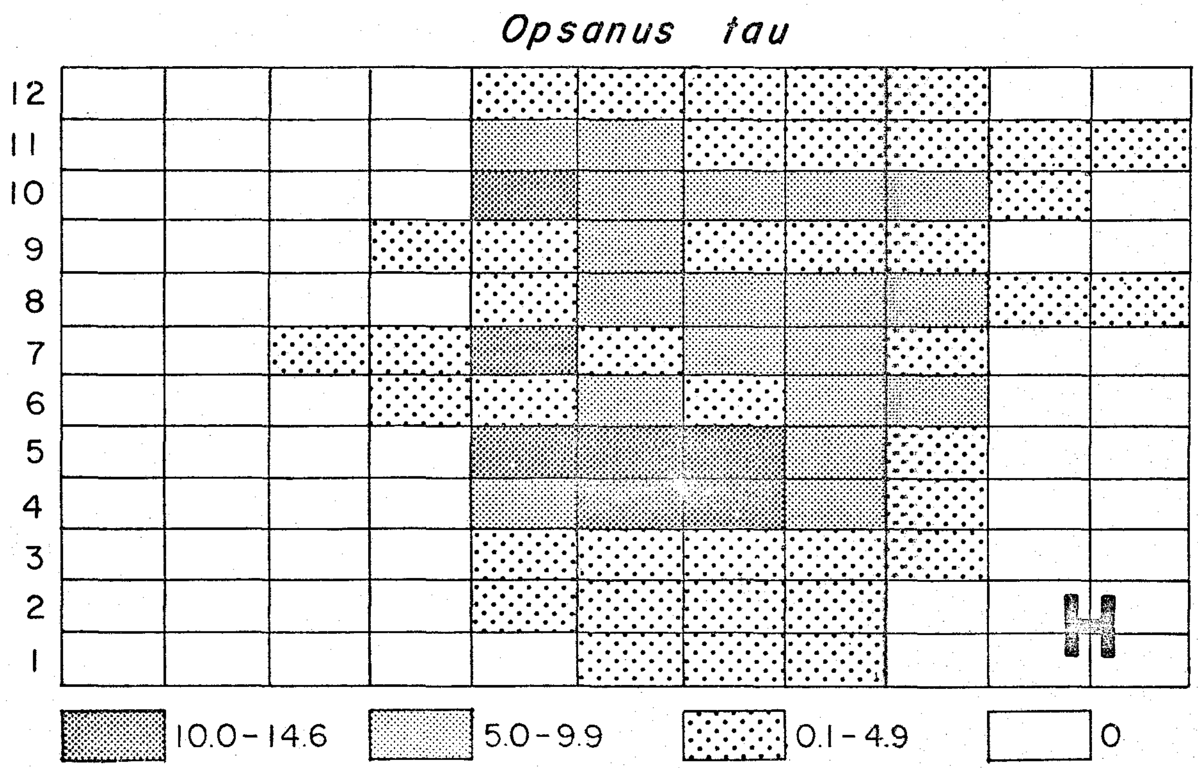
Bairdiella chrysura



Micropogon undulatus




Morone saxatilis
P50 P40 P35 P30 Y25 Y20 Y15 Y10 Y00 C10 C00
12 11 10 9 8 7 6 5 4 3 2 1
G
15.0-51.2
5.0-14.9
0.1-4.9
0


Opsanus tau
12 11 10 9 8 7 6 5 4 3 2 1
H
10.0-14.6
5.0-9.9
0.1-4.9
0

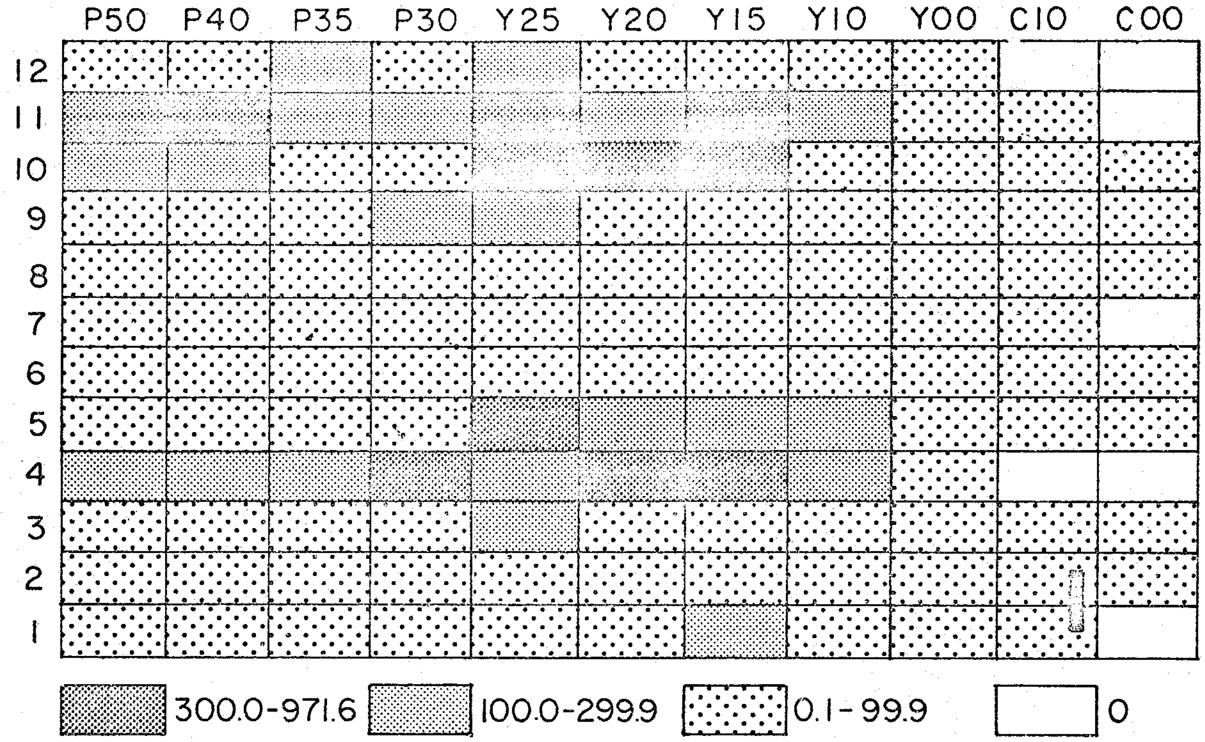
and possibly their inability to avoid the fishing gear at low temperatures.

Opsanus tau (oyster toadfish) (Fig. 4H) (5-30‰, 1-29 C) was fairly abundant from April to October in the York River proper. The distribution of this species was somewhat unusual in that abundance decreased gradually downstream of areas of high abundance (Y25) but decreased abruptly upstream of Y25. This distribution coincides with the distribution of oyster reefs in the York River (Larsen, personal communication).

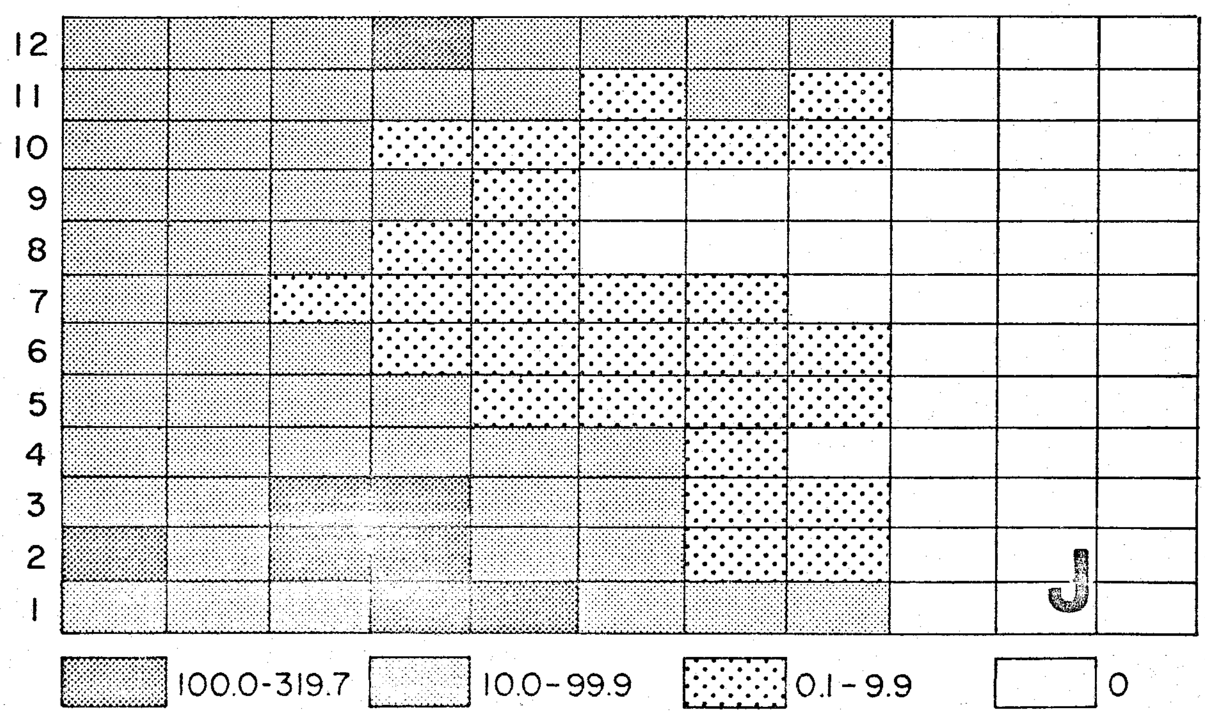
Trinectes maculatus (hogchoker) (Fig. 4I) (0-31‰, 1-29 C) was caught at every station almost every month. In the York and Pamunkey rivers T. maculatus had peaks in abundance during the spring and fall at mean bottom temperatures of about 13 to 30 C (Table 10). The hogchoker spawns during the summer, primarily at salinities of 10 to 16‰ in the Patuxent River, Maryland (Dovel, et al., 1969). In the York River channel numbers of hogchokers decline in the summer which suggests that spawning may occur in shoaler water. In October and November juveniles are concentrated in fresh water while older individuals are concentrated downstream, thus forming a disjunct distribution with large numbers from P40 to P50 and Y15 to Y25.

Morone americana (white perch) (Fig. 4J (0-23‰, 1-31 C) shows a spatial distribution which closely follows the monthly trend in changes of bottom temperature (Table 11). As temperatures begin to decrease in August in the Pamunkey

Trinectes maculatus



Morone americana



River, large numbers begin to move downstream and reach Y10 in December and January. Conversely, as temperatures begin to increase in February, these larger numbers tend to move back upstream.

Ictalurus catus (white catfish) (Fig. 4K) (0-21‰, 2-31 C) was primarily a low salinity species, being most abundant in the Pamunkey River. However, during late spring increases in freshwater runoff, it was found as far downstream as Y10.

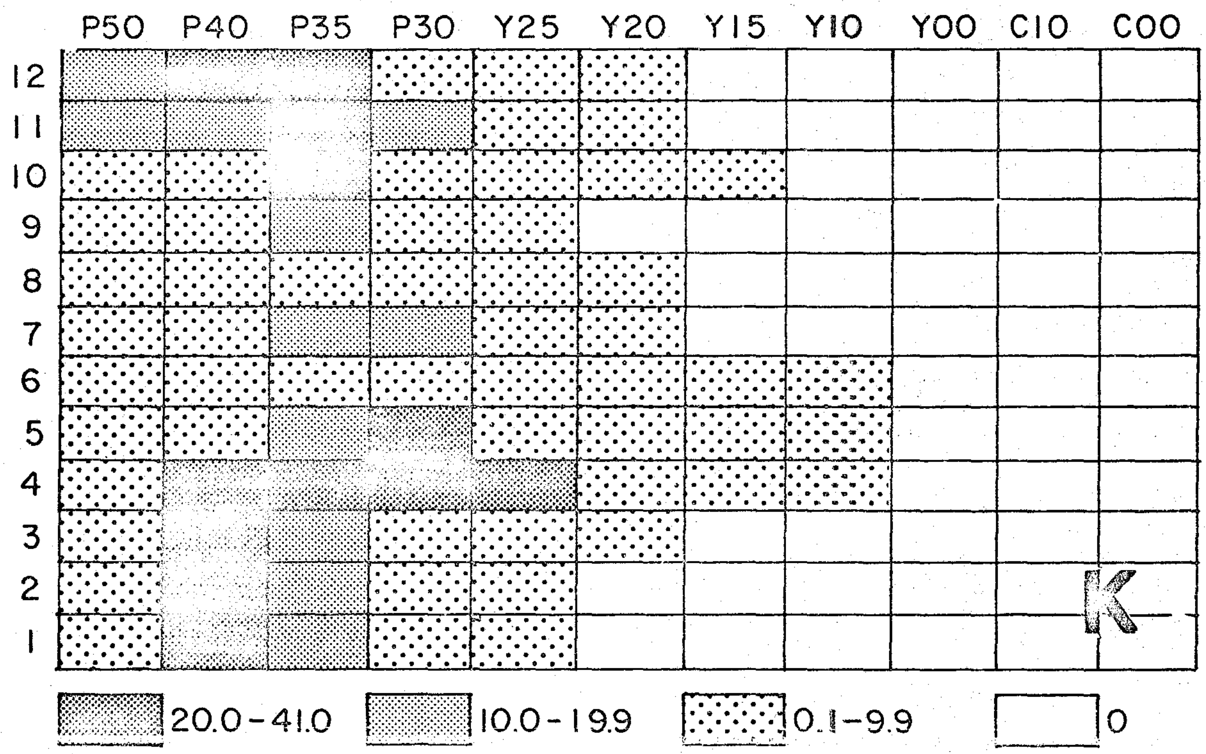
Ictalurus punctatus (channel catfish) (Fig. 4L) (0-10‰, 2-30 C) was most abundant in fresh water at P50 although it occasionally was found as far downstream as Y25.

Six of the above mentioned species, C. regalis (Fig. 4B), L. xanthurus (Fig. 4C), U. regius (Fig. 4D), B. chrysura (Fig. 4E), M. undulatus (Fig. 4F) and M. saxatilis (Fig. 4G) have similar spatial distributions from about Y10 to P35 and all use this area for nursery or feeding grounds for juveniles or young.

Urophycis regius appears to be the most opportunistic. It enters the area in March and April when M. saxatilis and M. undulatus are at their lowest levels (Fig. 5A), and departs in June when L. xanthurus, C. regalis, and B. chrysura, are increasing in abundance (Fig. 5B).

It is interesting and possibly coincidental that the abundance curves for M. saxatilis and M. undulatus (Fig. 5A) vaguely resemble classical predator-prey density curves

Ictalurus catus



Ictalurus punctatus

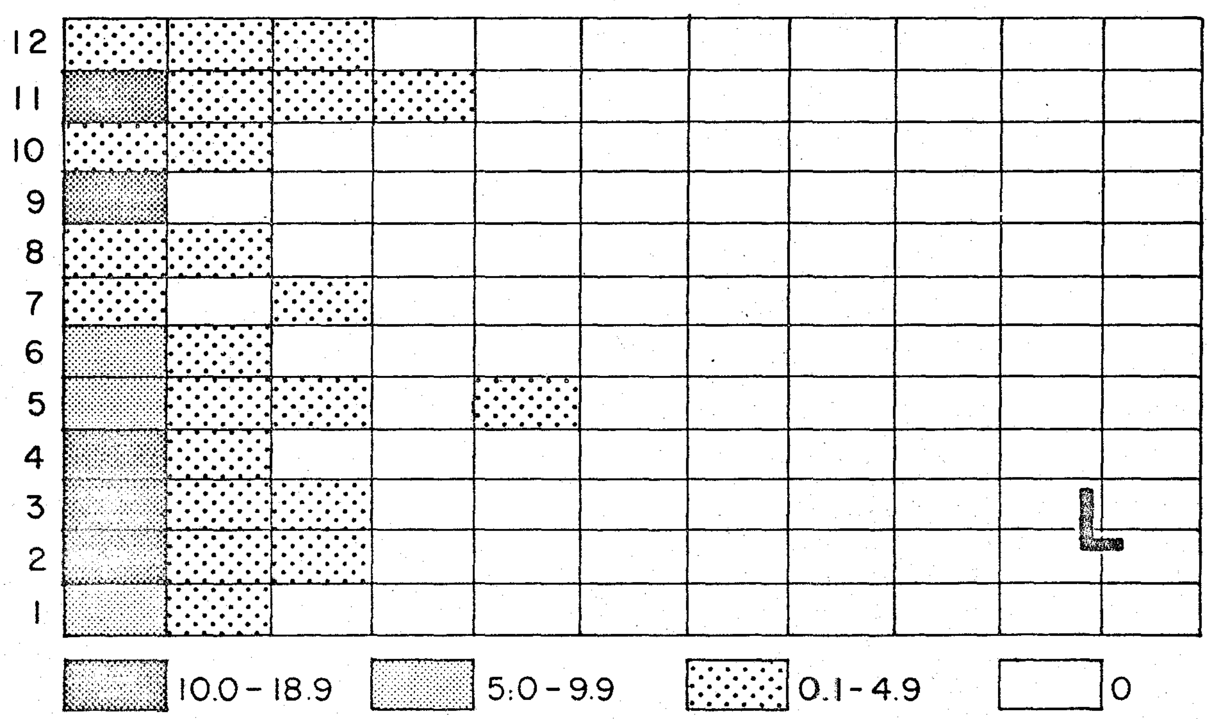
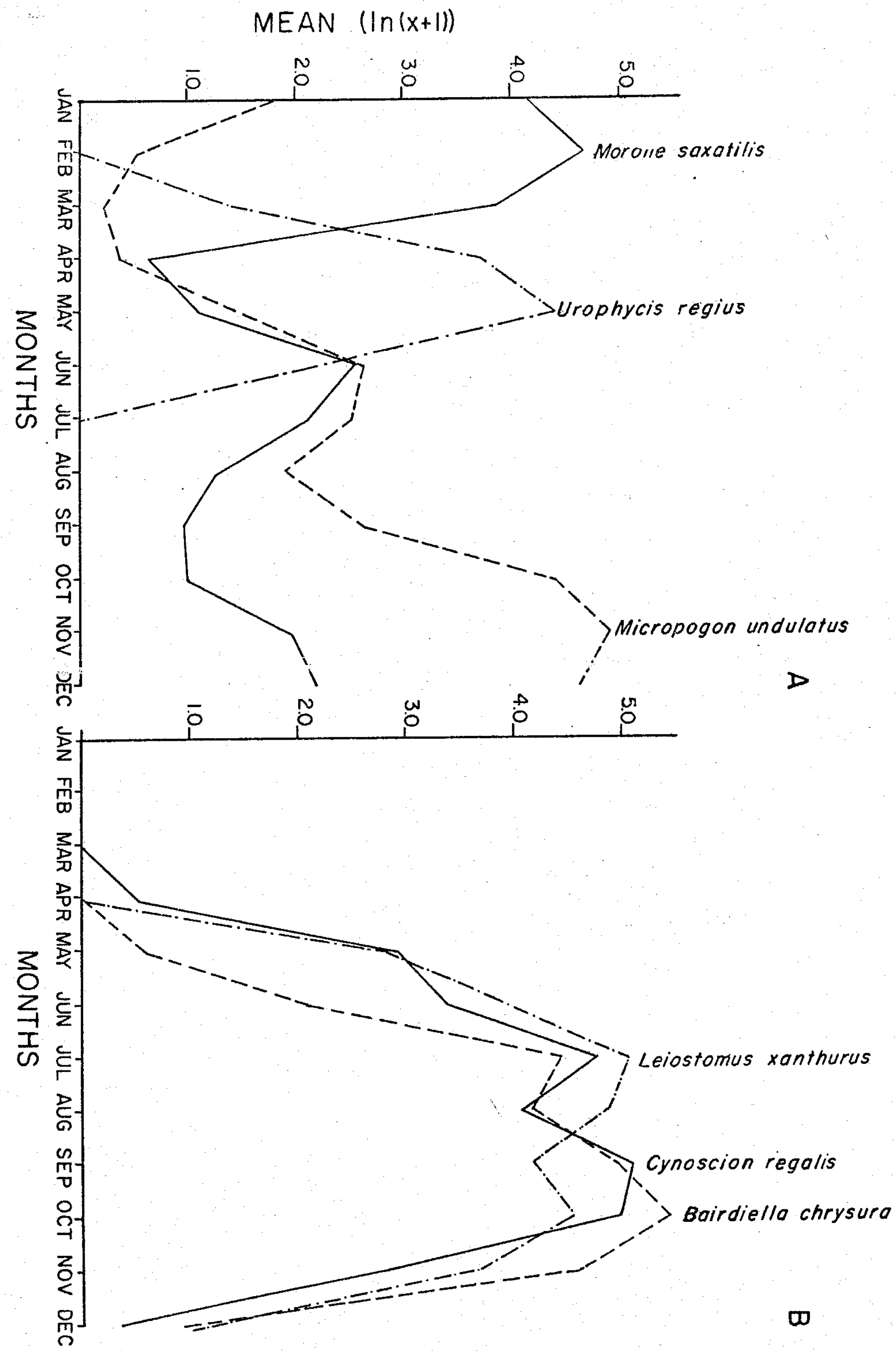


Figure 5. The transformed mean (ln (X+1)) number of individuals per month of six major species at stations Y10 through P35, 1967 - 1971.

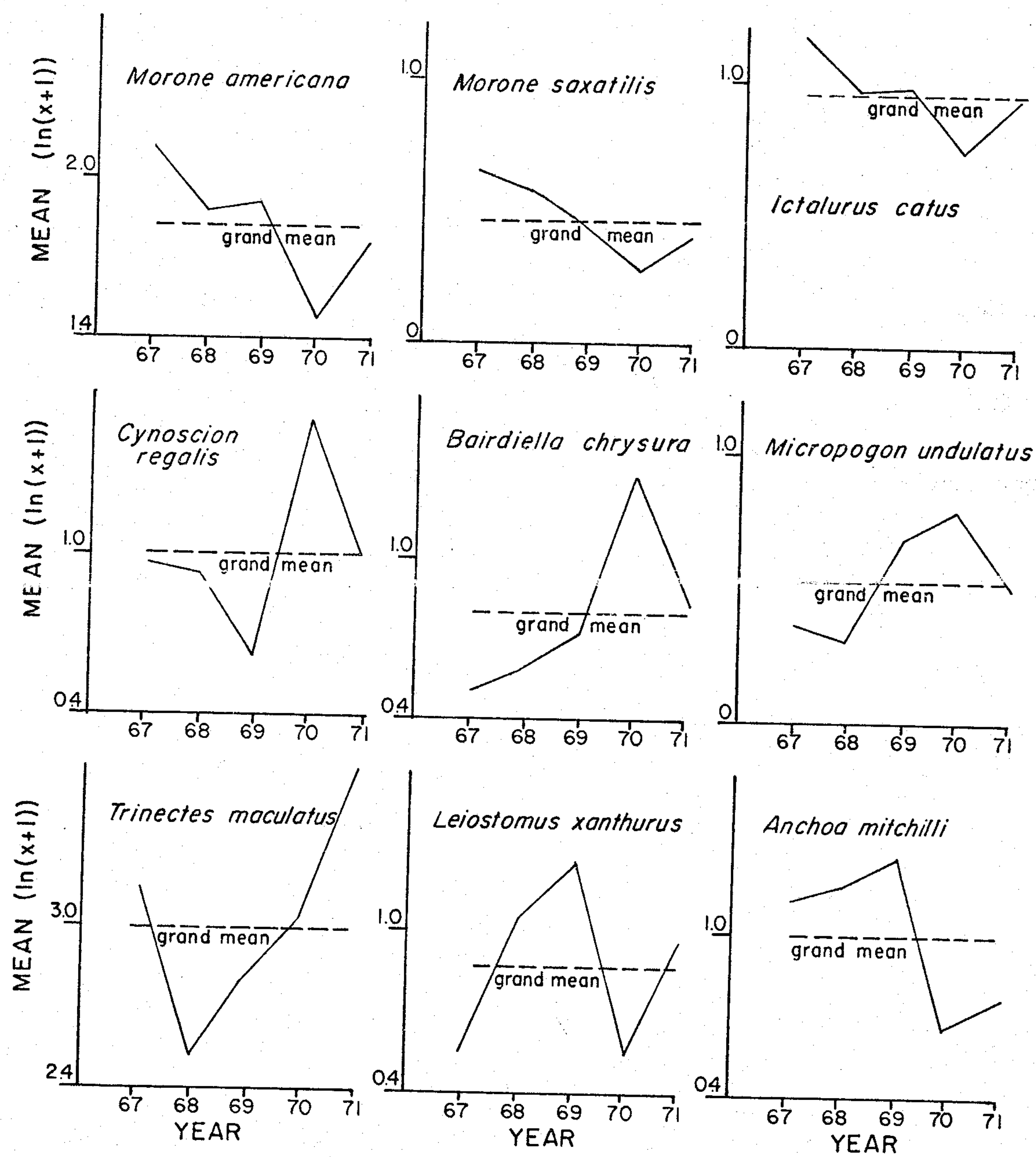

MEAN (ln(x+1))
1.0
2.0
3.0
4.0
5.0
JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC
MONTHS
Morone saxatilis
Urophycis regius
Micropogon undulatus
A
Leiostomus xanthurus
Cynoscion regalis
Bairdiella chrysura
B

(Huffaker, 1958). Dovel's (1968) suggestion that M. saxatilis feeds on M. undulatus in the winter may be supportable from the standpoint of cooccurrence.

The remaining three species (Fig. 5B) have bimodal distributions with peaks in July and September or October. Food habit studies (Van Engel and Joseph, 1968; Thomas, 1971) have shown qualitative differences between the three species, and Thomas (1971) has alluded to differences in their habitat preference. However, no detailed study of the spatial and temporal distribution and food habits and preference of these species has been made. Together with M. undulatus and M. saxatilis, these five species are a dominant and economically important part of the estuarine fauna. A detailed study of their use of spatial and food resources could reveal valuable information applicable to resource management.

The annual variation in the transformed (ln(x+1)) mean number of individuals per catch is shown in Figure 6. The effects of strong year classes are evident in C. regalis (1970), B. chrysura (1970), M. undulatus (1969-1970), T. maculatus (1971), and L. xanthurus (1969). Cynoscion regalis experienced a decline in 1969. In September, 1969, the antilog of the transformed (ln(x+1)) mean number per catch was 2.5 compared with the five year mean of 16.9 per catch in September. The cause of this decline may have been the passage of Hurricane Camille through this area in August, 1969 and the subsequent large freshwater runoff, which may have killed or relocated large numbers of juveniles.

Figure 6. The annual variation in the transformed mean (ln (X+1)) number of individuals of nine species in the Chesapeake-York-Pamunkey estuary, 1967 - 1971.


Morone americana
Morone saxatilis
Ictalurus catus
Cynoscion regalis
Bairdiella chrysura
Micropogon undulatus
Trinectes maculatus
Leiostomus xanthurus
Anchoa mitchilli
MEAN (ln(x+1))
grand mean
YEAR
67 68 69 70 71
2.0
1.4
1.0
0
0.4
3.0
2.4

With the exception of *T. maculatus* and *L. xanthurus*, the largest deviation from the five year mean occurred in 1970. The causes and significance of this are beyond the scope of these data.

Conclusions

Three major areas of the channel of the Chesapeake-York-Pamunkey estuary were described from physical and ichthyological parameters. If high diversity is indicative of stability, then the polyhaline Bay stations were generally more stable than the other two areas. However, if stability is viewed as the resistance to seasonal change in number of individuals, species, or diversity, then the Pamunkey stations were the most stable and the Bay stations the least stable.

The information measure of fish diversity (H') is an inadequate measure of stress conditions in the York River channel. Generally low dissolved oxygen concentrations in the channel in the summer were reflected in no change or a slight increase in this index. Changes caused by natural or man-made stress conditions may not be correlated with this index.

Twelve species made up over 92% of the catch. Of these, seven (73.7% of the total catch) were residents and five (18.4% of the total catch) were transients. If *Trinectes maculatus* is eliminated, the remaining six residents are about as abundant as the five transients. These transients, primarily sciaenids, are a major factor in the estuary. An evaluation of the spatial and food resource needs of each resident and transient species is needed to predict the consequences of man-made alterations in the estuary.

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Literature Cited

Barans, C. A. 1972. Spotted hake, *Urophycis regius*, of the York River and lower Chesapeake Bay. *Ches. Sci.* 13(1): 59-62.

Bechtel, T. J. and B. J. Copeland. 1970. Fish species diversity indices as indicators of pollution in Galveston Bay, Texas. Contrib. Mar. Sci. Univ. Tex. 15: 103-132.

Boesch, D. F. 1971. Distribution and structure of benthic communities in a gradient estuary. Ph.D. Diss., College of William and Mary, Williamsburg, Virginia 120 p.

Brehmer, M. L. 1970. Biological and chemical study of Virginia's estuaries. Compl. Rep. OWRR Proj. No. B003 Va., 80 p.

Carriker, M. R. 1967. Ecology of estuarine invertebrates: a perspective. *In*: *Estuaries*, G. Lauff (ed.), AAAS, Washington, D. C. p. 442-487.

Chittenden, M. E. (in press). Effect of a tickler chain and tow duration on trawl catches of the blue crab, *Callinectes sapidus*. *Trans. Am. Fish. Soc.*

Dahlberg, M. D. and E. P. Odum. 1970. Annual cycles of species occurrence, abundance, and diversity in Georgia estuarine fish populations. Am. Midl. Nat., 83(2): 382-392.

Dovel, W. L. 1968. Predation by striped bass as a possible influence on population size of the Atlantic croaker. *Trans. Amer. Fish. Soc.* 97 (4): 313-319.

Dovel, W. L. 1971. Fish eggs and larvae of the upper Chesapeake Bay. N.R.I. Spec. Rept. No. 4, 71 p.

Dovel, W. L., J. A. Mihursky and A. J. McErlean. 1969. Life history aspects of the hogchoker, *Trinectes maculatus*, in the Patuxent River estuary, Maryland. *Ches. Sci.* 10(2): 104-119.

Huffaker, C. B. 1958. Experimental studies on predation: Dispersion factors and predator-prey oscillations. *Hilgardia* 27: 343-383.

Massmann, W. H. 1962. Water temperatures, salinities, and fishes collected during trawl surveys of Chesapeake Bay and York and Pamunkey rivers, 1956-1959. Virginia Institute of Marine Science, Special Scientific Report, No. 27, 27 p.

McHugh, J. L. 1967. Estuarine nekton. *In*: *Estuaries*, G. Lauff (ed.). Publ. No. 83, Am. Assoc. Adv. Sci., Washington, D. C., 757 p.

Musick, J. A. (in press). A checklist of fishes of Chesapeake Bay and the adjacent coastal plain. *In* A checklist of the biota of Chesapeake Bay and the adjacent Virginia Sea. VIMS Spec. Sci. Rep. #65: 174-211.

Pacheco, A. L. 1962. Age and growth of spot in lower Chesapeake Bay with notes on distribution and abundance of juveniles in the York River system. _Ches_. _Sci_. 3(1): 18-28.

Pielou, E. C. 1966. The measurement of diversity in different types of biological collections. _J_. _Theoret_. _Biol_. 13: 131-144.

Sanders, H. L. 1960. Benthic studies in Buzzards Bay, III. The structure of the soft-bottom community. _Limnol_. _Oceanogr_. 5(2): 138-153.

Taylor, C. C. 1953. Nature of variability in trawl catches. _U_. _S_. _Fish_. _Wildl_. _Serv_. _Fish_. _Bull_. 54(83): 145-166.

Thomas, D. L. 1971. The early life history and ecology of six species of drum (Sciaenidae) in the lower Delaware River, a brackish tidal estuary. Ichthyological Assoc. Delaware Prog. Rept. 3 (Pt. III).

Van Engel, W. A. and E. B. Joseph. 1968. Characterization of coastal and estuarine fish nursery grounds as natural communities. Unpublished manuscript, Virginia Institute of Marine Science, Gloucester Point, Virginia. 43 p.

Section VI

Appendices

No Appendices were included in the print copies of this work.