EPA Report
April 1979

An Evaluation of the Kepone Contamination of the Plankton of the James River

by

Robert A. Jordan, Patricia A. Goodwin,
Charles E. Sutton, V. Joseph Lascara,
Peter A. Van Veld and Richard K. Carpenter

Grant Number R804993010

Project Officer

Tudor T. Davies
Gulf Breeze Environmental Research Laboratory
Gulf Breeze, Florida 32561

Gulf Breeze Environmental Research Laboratory
Office of Research and Development
U. S. Environmental Protection Agency
Gulf Breeze, Florida 32561

ABSTRACT

The objective of this study was to determine the extent of the contamination of the zooplankton and phytoplankton of the James River with Kepone. During the period June 1977 - May 1978 all zooplankton samples taken within the sixty mile section of the James River between Hopewell and Hampton Roads showed detectable levels of Kepone, ranging from 0.10 - 16 ppm on a dry weight basis. Kepone levels in phytoplankton samples ranged from non-detectable to 2.06 ppm, while levels in suspended detritus ranged from .016 - 1.71 ppm. These results indicated that Kepone was available via the food chain to filter feeding mollusks and to active plankton feeders, including finfish.

The Kepone levels in zooplankton samples taken in April and May 1978 were lower than the levels in the 1977 samples, reflecting either a seasonal depression of Kepone uptake, or possibly a temporally declining trend of Kepone contamination of the plankton. Samples of amphipods of the species *Corophium lacustre*, obtained from the James River in the summers of 1976, '77, and '78, exhibited an apparent order of magnitude decline in Kepone levels between 1977 and 1978.

Calculated estimates of the total mass of Kepone present in the zooplankton ranged from 2.4 - 214 g, for the study area as a whole. These amounts are small, relative to the estimated total of 100,000 pounds distributed throughout the sediments, water, and biota of the James River, but they are in a biologically available form with a rapid turnover rate.

CONTENTS

FIGURES

TABLES

Introduction

The plankton of the James River represents a potential mobile pool of contaminants, including Kepone, that are susceptible to accumulation from the water by living organisms. Kepone present in contaminated plankton would be subject to dispersal by currents throughout the James River and possibly into Chesapeake Bay, and during its period of residence within the open water it would be available for assimilation by plankton-consuming crustaceans, shellfish, and finfish.

Laboratory studies have shown that Kepone can be accumulated by unicellular algae (Walsh et al. 1977) and by crustaceans (Schimmel and Wilson 1977) from solution in water, and that it can be transferred from lower to higher levels in an estuarine food chain (Bahner et al. 1977). A field investigation was required to determine if detectable levels of Keponewere actually present in samples of James River plankton, and therefore if this community was in fact significant in the maintenance and movement of Kepone in this estuary.

Objectives

The present study was intended to provide determinations of concentrations of Kepone in zooplankton and phytoplankton samples taken from stations located in the segment of the river between Hopewell and Hampton Roads. A secondary objective was to evaluate temporal trends of Kepone concentrations in plankton samples taken during different seasons within this zone.

Methods

During the study both direct and indirect estimates of Kepone levels in James River plankton were obtained. Direct estimates were made by analyzing plankton concentrates, obtained by separating zooplankton or phytoplankton organisms from the detritus and inorganic sediment suspended in the river. Indirect estimates were obtained during the suspended sediment cruises in August 1977 and April-May 1978 (see Suspended sediment section of this contract report). Samples of the total seston, separated from the river water by centrifugation during these cruises, were analyzed for Kepone, and the proportions of plankton and detritus in the samples were determined by microscopic examination. When, over a series of seston samples the Kepone concentration varied directly with the plankton proportion, the Kepone concentration in the plankton could be estimated using simultaneous equations.

The plankton samples used for the direct Kepone determinations were obtained from net tows. Depending on the sampling conditions encountered, the nets used were of 76, 110, or 202 micron mesh and were attached to 12.5 cm dia. Clarke-Bumpus or

18.5 cm dia. bongo frames. The raw samples usually contained plankton and detritus, but little or no inorganic sediment. The samples intended for Kepone analysis were stored on ice in acetone-rinsed glass jars for transport to the laboratory. In the laboratory the organisms were separated from the detritus, in most instances by rinsing the samples through screens of plankton netting. Occasionally the plankton and detritus settled at different rates, permitting separation based on this property. Cladocerans tended to accumulate at the surface film in undisturbed samples, so when these zooplankters were present they could be skimmed off, leaving mostly copepods and detritus in the remainder of the sample. Finally, large diatoms such as Coscinodiscus sp. tended to adhere to glass surfaces, and this behavior was exploited in separating several of the samples. Most of the attempts at sample separation using these techniques yielded sample fractions that were composed almost exclusively of zooplankton. These fractions were saved for Kepone analysis. Whenever fractions that were exclusively phytoplankton or exclusively detritus were obtained, they were also saved for analysis. Figure 1 shows the separation procedure employed on one of the sampling dates.

When a sample fraction was judged to be sufficient in purity and quantity for analysis, it was concentrated on a pre-weighed glass fiber filter (Gelman Type A/E) that had been subjected to the Kepone extraction procedure for cleaning. The concentrated sample was then stored in a freezer. Prior to analysis each sample fraction was dried to constant weight in a desiccator. The sample and filter were placed in a Whatman cellulose extraction thimble and extracted for a minimum of 18 hours in a micro-Soxhlet extraction apparatus, which initially contained 40 ml of a 50/50 mixture of diethyl ether and petroleum ether. Five samples and a blank could be extracted concurrently on the setup illustrated in Fig. 2. Heat was supplied by three heat lamps controlled by separate dimmer switches.

Following the extraction step, the entire volume of the solvent mixture was cleaned by column chromatography utilizing florisil as the packing (EPA 1975). The clean solution was analyzed by gas chromatography, and the concentration of Kepone present in the original sample was calculated from the resulting chromatogram.

At each field sampling station plankton samples in addition to those intended for Kepone analysis were obtained and preserved in 5% buffered formalin, containing the stain Phloxine B, for subsequent microscopic examination. Water temperature, salinity, dissolved oxygen, and Secchi Disk transparency measurements were also performed with each set of plankton samples.

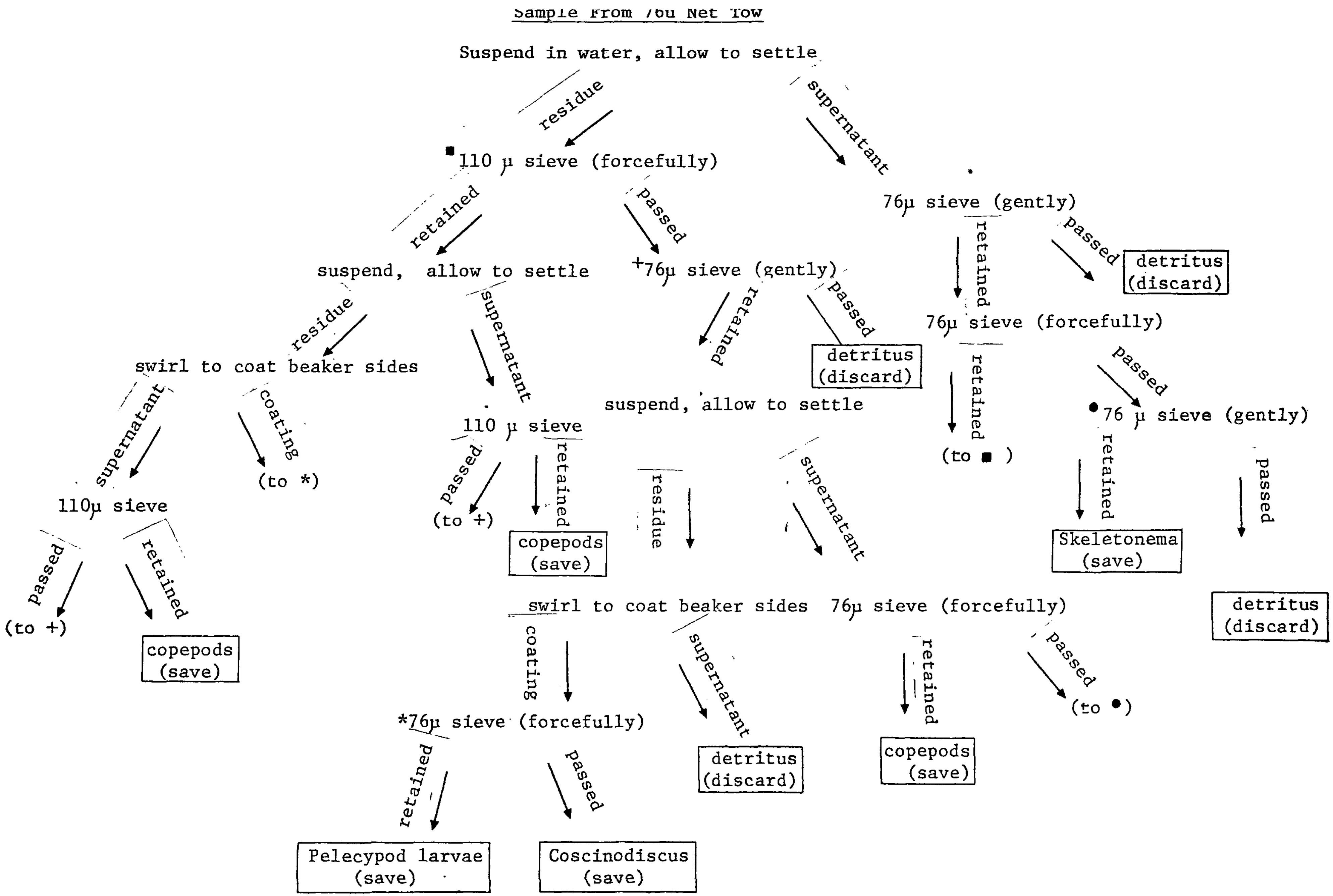


Figure 1. Sample separation procedure, 13 September 1977.

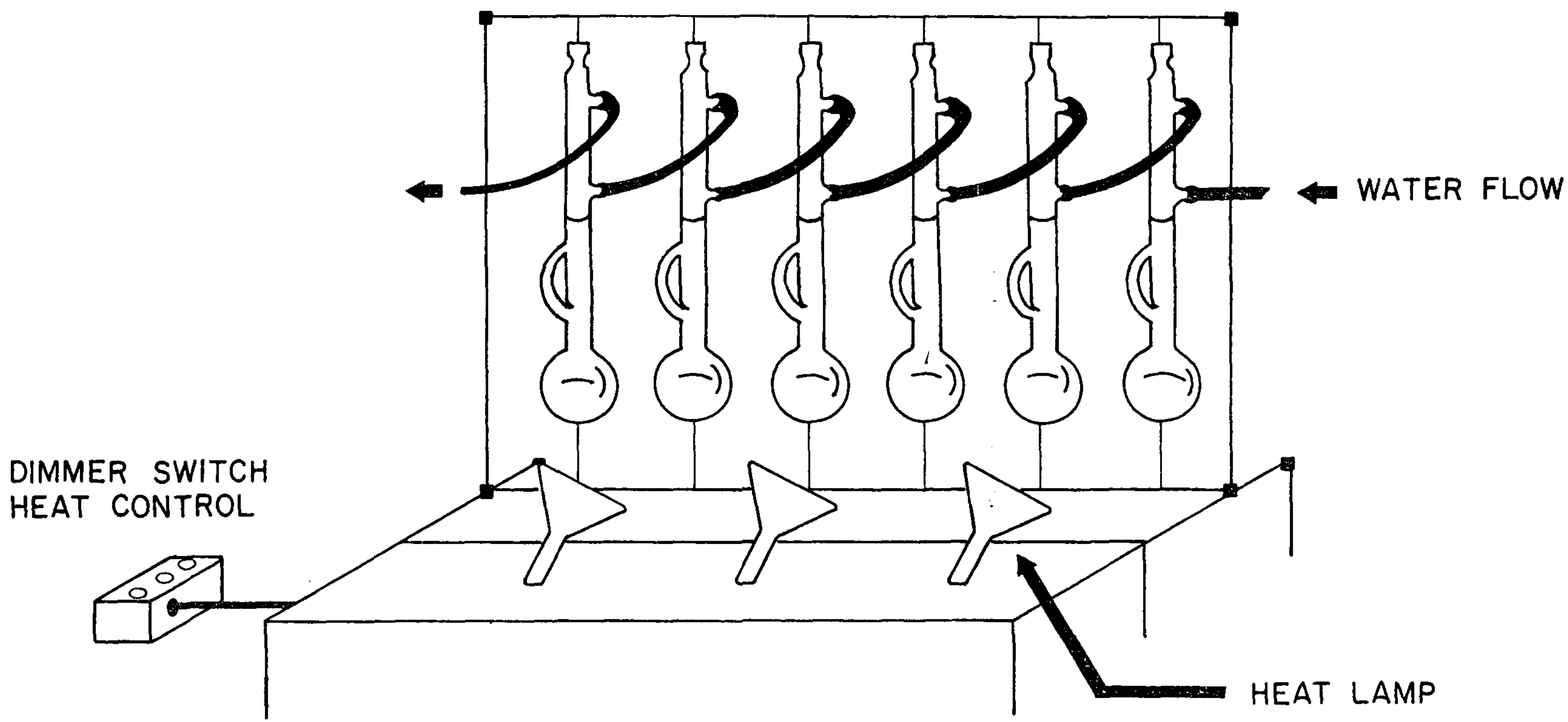


Figure 2. Micro-Soxhlet extraction unit used for extracting Kepone from plankton samples.

Results

1977 Seasonal Series

The sampling effort and Kepone analysis results for 1977 are summarized chronologically in Table 1. Figure 3 shows the stations referred to in this table, and indicates their positions relative to river mile points. Table 2 contains the results of zooplankton counts performed on the 1977 preserved samples.

A brief examination of Table 1 indicates that Kepone was detected in all of the 1977 samples. The majority of the samples analyzed contained mixtures of two or more taxa of zooplankton. These samples generally contained higher concentrations of Kepone than did the samples of phytoplankton, which in turn contained higher concentrations than the detritus samples.

The 1977 zooplankton Kepone results are summarized in two figures. Figure 4 presents the spatial distribution of the Kepone levels determined for the period 23 June to 19 October 1977, during which there were ten sampling runs, scattered widely in time. Bottom water salinities are also indicated. The results for the period 28 November to 13 December, during which seven stations were covered within two weeks, appear separately in Fig. 5.

During both of these sampling periods the zooplankton Kepone levels tended to be highest within the section of the river extending from Weyanoke Point (Station Red 76, MP60) downstream to Jamestown Island (Station Black 55, MP40). The maximum concentration, approximately 16 ppm, was determined in two samples, a mixture of copepod nauplii and copepods of the genus _Acartia_ obtained on 10 August at station Red 64 (approximately MP45), and a subsample containing copepods of the genus _Eurytemora_ obtained on 28 November at station Red 76 (MP60). A subsample of cladocerans (_Bosmina_ sp.) from the same set of net tows that yielded the copepod subsample containing 16 ppm Kepone had a Kepone level of only 1.3 ppm. One other set of net tows, taken on 13 September at station Red 66 (approximately MP45), provided two separate zooplankton fractions, copepods (_Acartia_ sp.) and pelecypod larvae (probably _Rangia cuneata_), that differed substantially in their Kepone concentrations. These two sets of results indicate that the Kepone levels in the other zooplankton samples, most of which consisted of mixtures of two or more types of organisms, were influenced by the taxonomic composition of the samples.

This observation complicates the interpretation of the differences in zooplankton Kepone levels among different sections of the James River, since within comparisons of these zones taxonomic composition was not held constant. The zone in which the highest zooplankton Kepone levels were found (MP40-60) is also

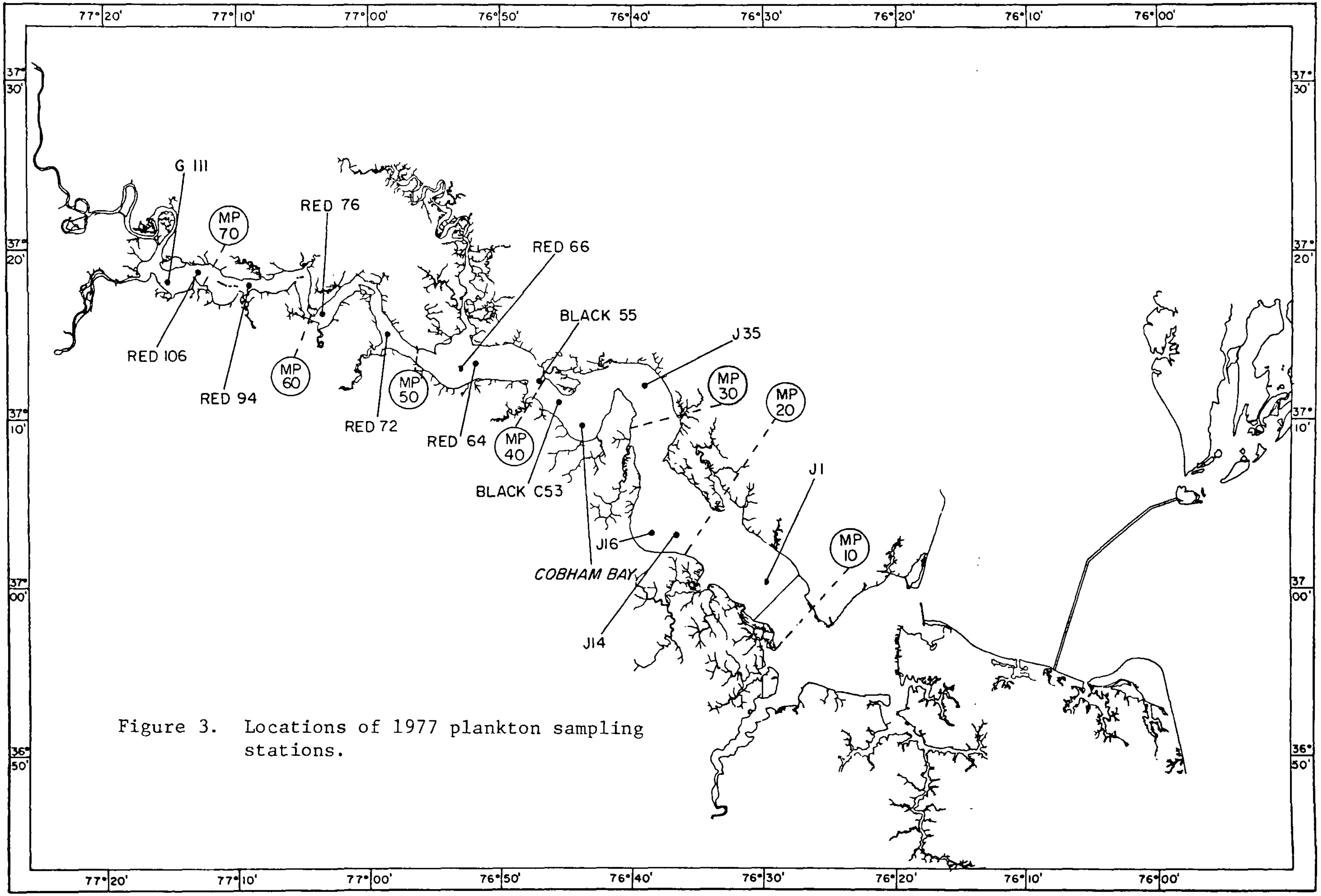


Figure 3. Locations of 1977 plankton sampling stations.

TABLE 1 (cont.)

Date	Station	Type of Sample	Kepone conc. (ppm)
Nov. 28	Chippokes Pt. Buoy Red 72	Zooplankton-copepods, cladocerans	2.86
		Detritus	.75
Nov. 28	Weyanoke Pt. Buoy Red 76	Zooplankton-cladocerans	1.27
		Zooplankton-copepods	15.58
		Detritus (coarse)	1.71
		Detritus (fine)	.63
Nov. 28	Westover Buoy Red 94	Zooplankton-copepods, cladocerans	2.02
		Detritus	.53
Dec. 6	Jamestown Island Buoy Black 55	Zooplankton-copepods	6.31
		Detritus	.54
Dec. 6	Hog Pt. Buoy B & W J35	Zooplankton-copepods	4.08
Dec. 13	Burwell Bay Buoy J14	Zooplankton-copepods	3.46
		Detritus (coarse)	.034
		Detritus (fine)	.12
Dec. 13	James R. Bridge Buoy B & W J1	Zooplankton-copepods, nauplii	3.16

TABLE 2. QUANTITATIVE ZOOPLANKTON DATA-1977
NO. OF INDIVIDUALS PER M^3

Station Date	Red 64 10 Aug.	Red 66 13 Sept.	Red 76 22 Sept.
Organism			
Copepod nauplii	5260	96,060	912
Barnacle nauplii	40	330	
Polychaete larvae		1470	11
Pelecypod larvae	400	92,070	11
Acartia sp.	1690	6270	388
Eurytemora sp.	10	160	878
Cyclopoid copepods			
Harpacticoid copepods		810	23
Bosmina sp.			513
Cladocerans (other)			11
Rotifers	170	80	11
Total	7570	197,250	2758

(continued)

TABLE 2 (cont.)

Station / Date	Red 94 27 Sept.	B1.55 27 Sept.	J16 5 Oct.	J16 11 Oct.
Organism				
Copepod nauplii	127	1155	1195	1155
Barnacle nauplii			925	402
Polychaete larvae			10	88
Pelecypod larvae			156	100
Acartia sp.			1995	352
Eurytemora sp.	5	44		13
Cyclopoid copepods	5	11	1101	502
Harpacticoid copepods		44		
Bosmina sp.	90	3454	31	
Cladocerans (other)	47	44		
Rotifers	330	2024		
Total	604	6776	5413	2612

(continued)

TABLE 2 (cont.)

Organism	Station Date: Bl.55 19 Oct.	Red 72 28 Nov.	Red 76 28 Nov.	Red 94 28 Nov.
Copepod nauplii	138	10,613	13,027	16,059
Barnacle nauplii	768			
Polychaete larvae	264			
Pelecypod larvae			26	
Acartia sp.	229			
Eurytemora sp.		2118	4342	10,472
Cyclopoid copepods		965	460	271
Harpacticoid copepods	12	47		
Bosmina sp.		1318	1277	7419
Cladocerans (other)				158
Rotifers		282	945	158
Total	1411	15,343	20,077	34,537

(continued)

TABLE 2 (cont.)

Station / Date	B1.55 6 Dec.	J35 6 Dec.	J14 13 Dec.	J1 13 Dec.
Organism				
Copepod nauplii	238	80		1312
Barnacle nauplii				62
Polychaete larvae			35	211
Pelecypod larvae				220
Acartia sp.	10	23	23	960
Eurytemora sp.	278	776	822	
Cyclopoid copepods	159	46		
Harpacticoid copepods		160		141
Bosmina sp.	10	11		
Cladocerans (other)				
Rotifers				1902
Total	695	1096	880	4808

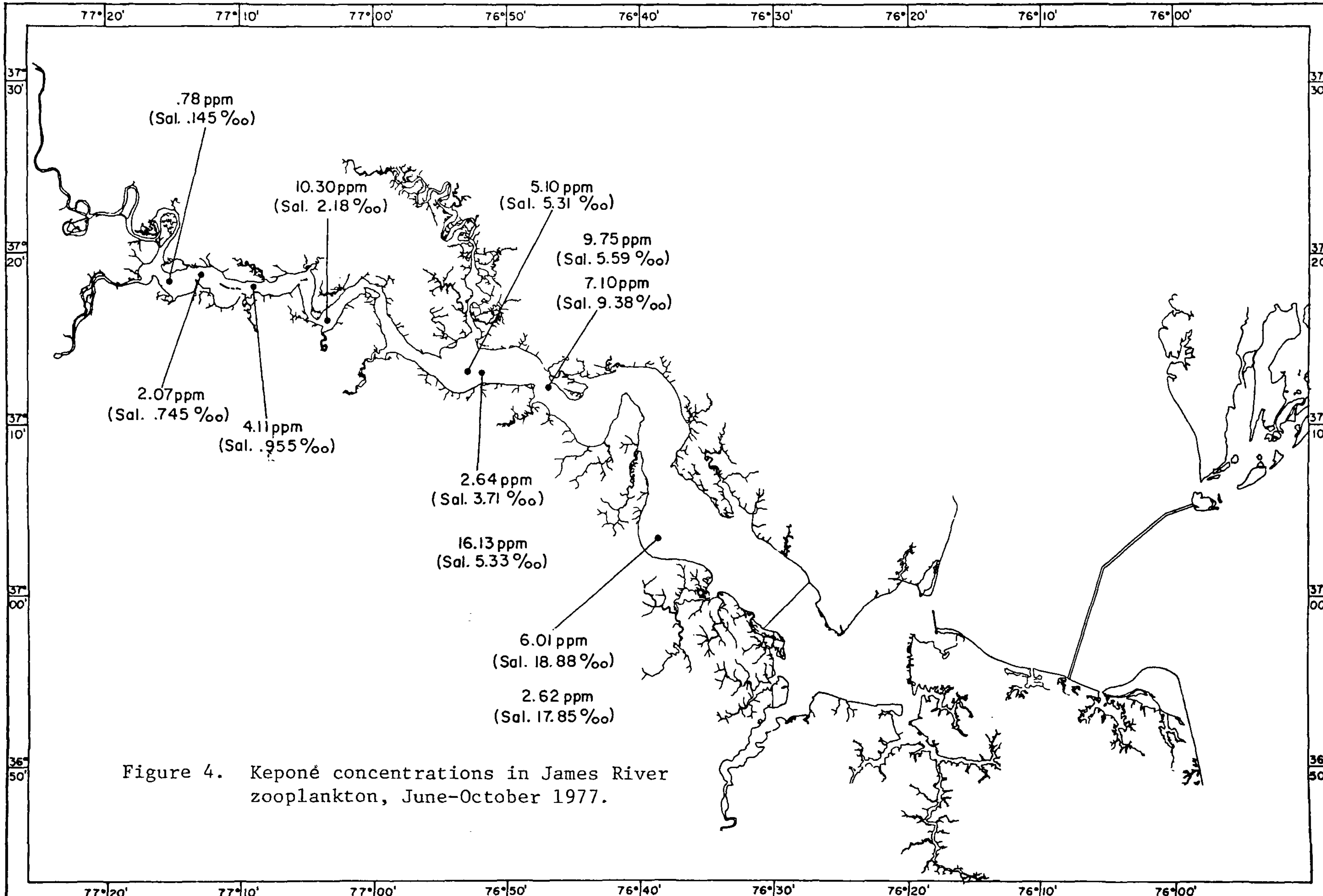


Figure 4. Keponé concentrations in James River zooplankton, June-October 1977.

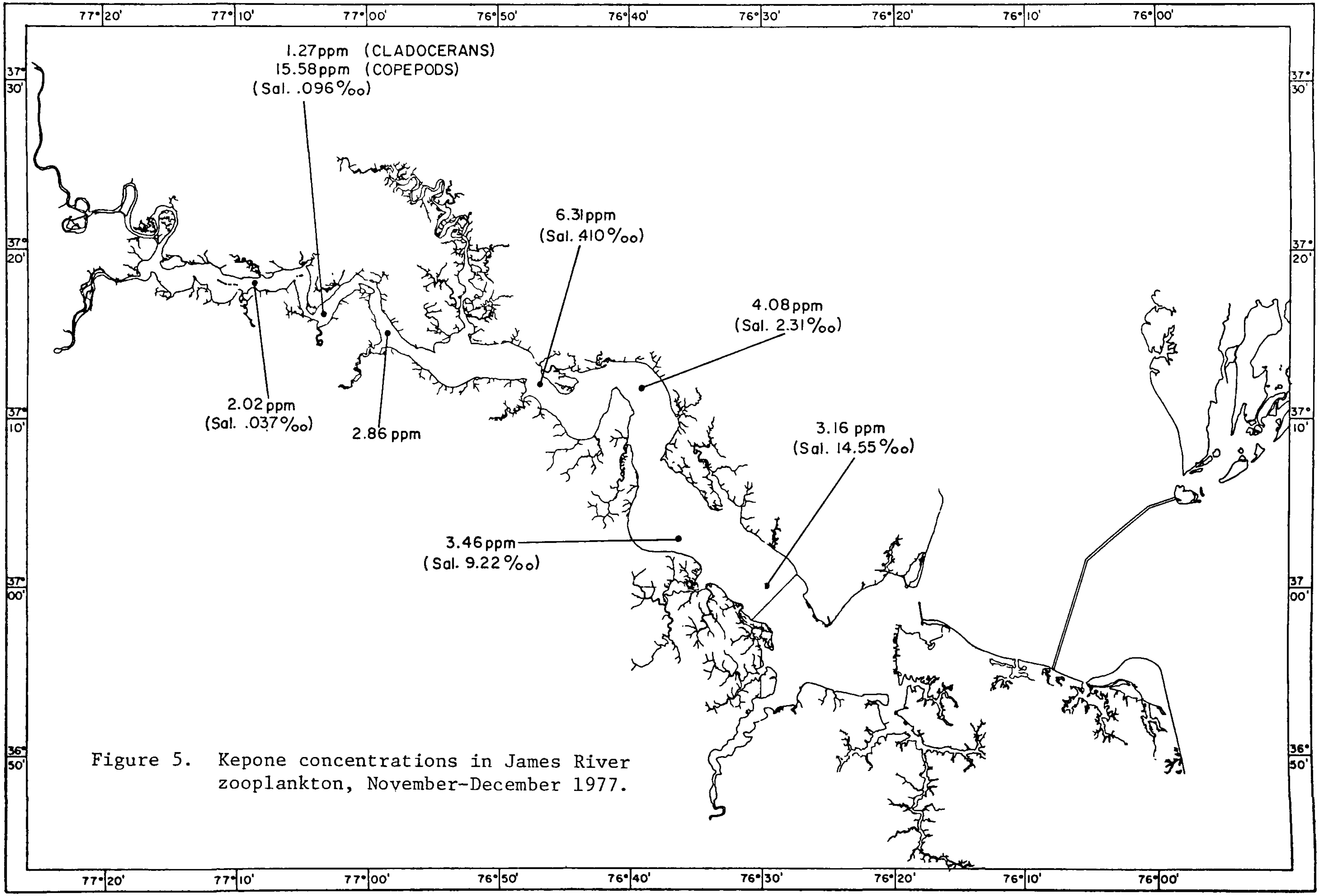


Figure 5. Kepone concentrations in James River zooplankton, November-December 1977.

where suspended sediment levels are characteristically higher than elsewhere in the river, and where the highest levels of Kepone have appeared in the bottom sediments (Nichols and Trotman 1977). On this basis it is tempting to conclude that the 1977 zooplankton samples exhibited a Kepone distribution that closely reflected the spatial pattern of Kepone in the bottom sediments. However, because of the limited number and incomplete taxonomic breakdown of the plankton samples,this conclusion is weakly supported, and it would be more appropriate to summarize the data in terms of a concentration range for the study area as a whole: approximately 1 ppm - 16 ppm for mixed zooplankton assemblages for both the June - October and November - December periods. More extensive sampling, with separation of the samples into more clearly defined taxonomic entities, would be required to accurately define the spatial pattern of the contamination of the James River zooplankton with Kepone.

In Figure 6 the Kepone concentrations determined for the phytoplankton subsamples obtained in 1977 are summarized. These concentrations were representative of Kepone levels in the large diatoms (70 - 100 microns), of the genera <u>Skeletonema</u> and <u>Coscinodiscus</u> (Table 1). Three of these samples were obtained in the middle zone of the river, where the bottom sediment Kepone levels have been highest, and their Kepone concentrations were higher than in the sample from a lower river station, J16.

Table 3 presents an indirect calculation of the Kepone concentrations in the suspended sediment and phytoplankton fractions of total seston samples obtained by centrifugation in August 1977. The results of analyses of five seston samples were used, three of which were taken at low slack tide and had relatively low Kepone levels, and two of which were taken at high slack tide and were relatively high in Kepone. The phytoplankton and sediment proportions of each sample were derived from microscopic examinations of preserved aliquots. Average values for the two sample groups were employed in constructing two equations, which were solved simultaneously for the Kepone concentrations in the suspended sediment and phytoplankton. The phytoplankton value, 1.12 ppm, agreed closely with the concentrations obtained directly for the phytoplankton subsamples obtained from the 1977 net tows (Fig. 6). The indirect estimate, however, represented the Kepone concentration in a smaller size range of phytoplankton (2-20 microns), which consisted of microflagellates, cryptophytes, chlorophytes, and small dinoflagellates, as well as diatoms.

The indirect calculation also yielded an estimate of the Kepone concentration in the suspended sediment fraction of the seston. This fraction consisted of mineral particles and organic detritus particles and aggregates, with a median size of 2.5 microns and a size range of .5 - 100 microns. The Kepone concentration estimate, .03 ppm, was lower than the values obtained by

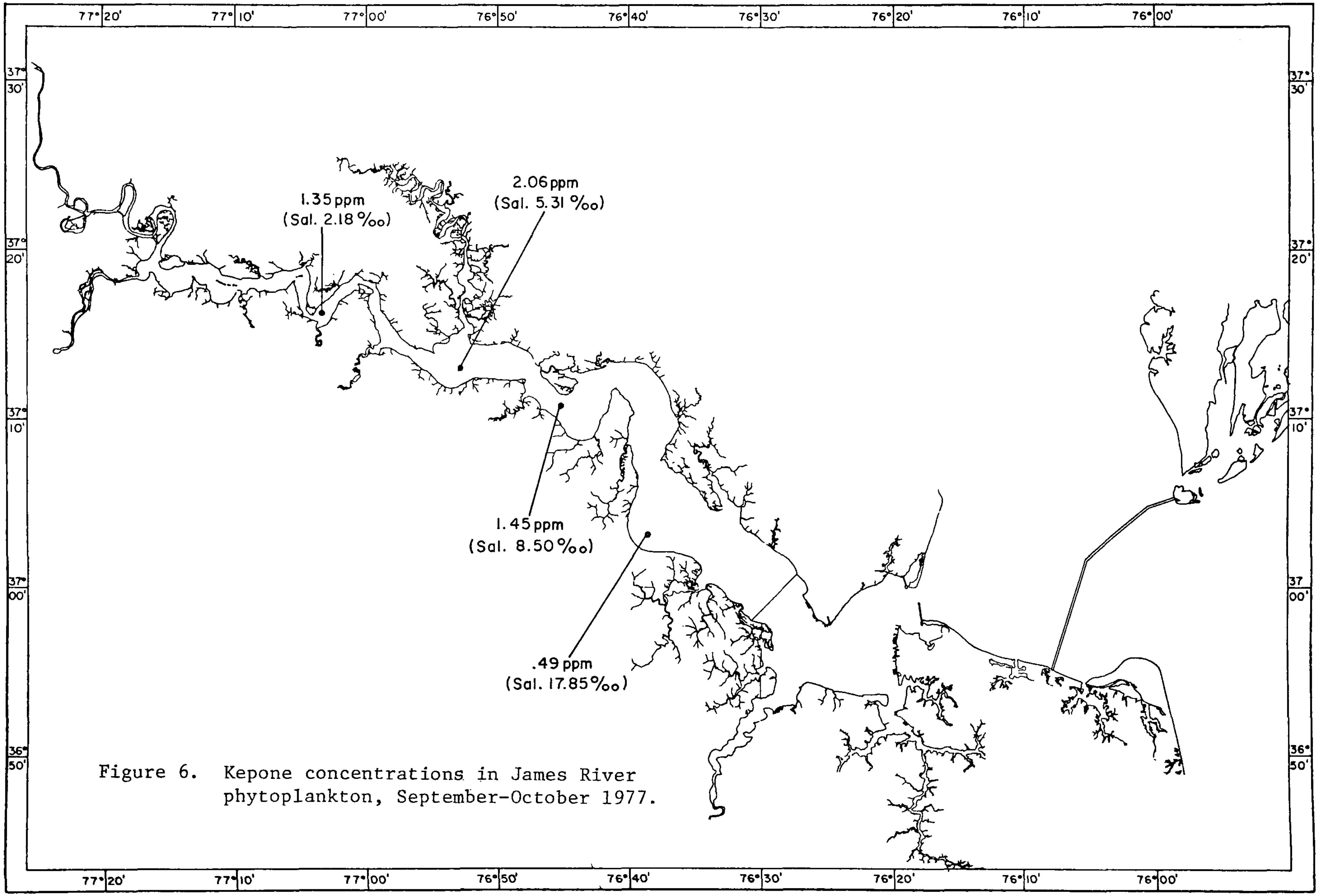


Figure 6. Kepone concentrations in James River phytoplankton, September-October 1977.

TABLE 3. INDIRECT CALCULATION OF KEPONE CONCENTRATIONS IN PHYTOPLANKTON AND SUSPENDED SEDIMENT, BRANDON PT. (MP54), 24-25 AUG. 1977

Initial Data

Samples	Average g Kepone per g seston	Average g Phytoplank. per g seston	Average g sediment per g seston
Three, taken at low slack tide	$.0597 \cdot 10^{-6}$	.02753	.9725
Two, taken at high slack tide	$.165 \cdot 10^{-6}$	.1243	.8757

Mass balance equations

Low slack

$$.0597 \cdot 10^{-6} \text{g Kepone} = (.02753 \text{g Phytopl.}) \left(\frac{x \text{g Kepone}}{\text{g Phytopl.}}\right) + (.9725 \text{g sed.}) \left(\frac{Y \text{g Kepone}}{\text{g sed.}}\right)$$

High slack

$$.165 \cdot 10^{-6} \text{g Kepone} = (.1243 \text{g Phytopl.}) \left(\frac{x \text{g Kepone}}{\text{g Phytopl.}}\right) + (.8757 \text{g sed.}) \left(\frac{Y \text{g Kepone}}{\text{g sed.}}\right)$$

Solution

Low slack

$$.02753X = .0597 \cdot 10^{-6} - .9725Y$$
$$X = 2.1685 \cdot 10^{-6} - 35.325Y$$

substituting into high slack:

$$.165 \cdot 10^{-6} = (.1243)(2.1685 \cdot 10^{-6} - 35.325Y) + .8757Y$$
$$.1045 \cdot 10^{-6} = 3.5153Y$$
$$Y = .02973 \cdot 10^{-6}$$

$$X = 2.168 \cdot 10^{-6} - (35.325)(.02973 \cdot 10^{-6})$$
$$X = 1.1183 \cdot 10^{-6}$$

Result

Kepone concentration in sediment = .030 ppm
Kepone concentration in phytoplankton = 1.12 ppm

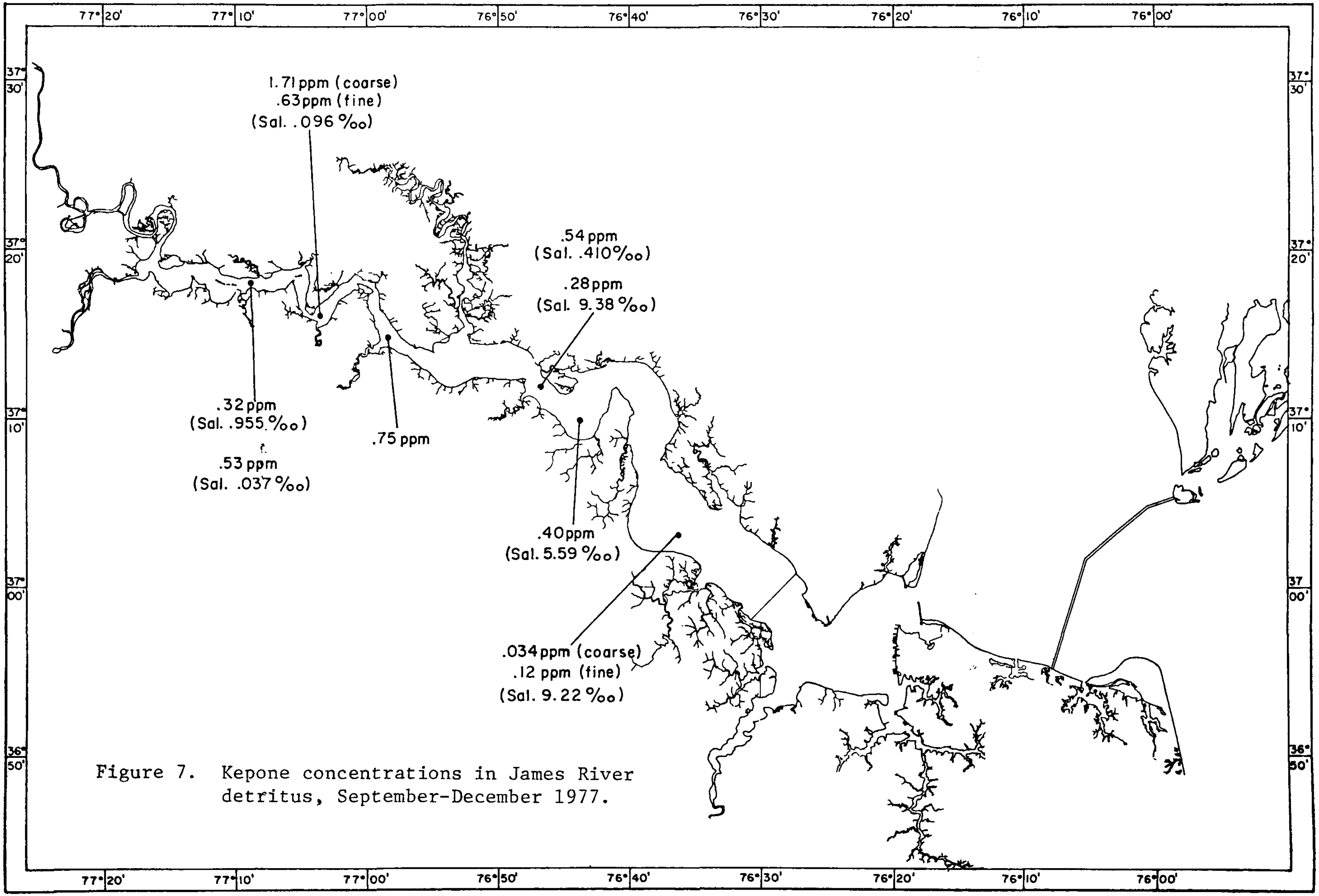


Figure 7. Kepone concentrations in James River detritus, September-December 1977.

TABLE 1. CHRONOLOGICAL SUMMARY OF THE 1977 JAMES RIVER KEPONE PLANKTON STUDY

Date	Station	Depth (m)	Sal. (°/oo)	Temp. (°C)	D.O. (mg/l)	Secchi Depth (m)
June 23	Jordan Pt. Buoy Red 106	0	.140	26.0	4.28	.45
		10	.745	25.4	4.04	
	off Bailey Creek Fl G111	0	.140	25.9	4.10	-
		1	.145	25.8	4.38	
July 19	off Chickahominy R. mouth, Buoy Red 64	0	3.27	31.2	6.17	.50
		9	3.71	30.4	5.67	
Aug. 10	off Chickahominy R. mouth, Buoy Red 64	0	4.48	29.8	7.28	.71
		9	5.33	29.1	5.50	
Sept. 6	Jamestown Island Buoy Black C53	0	6.65	29.4	8.98	.97
		8	8.50	28.8	7.10	
Sept. 13	off Chickahominy R. mouth, Buoy Red 66	0	4.41	24.8	7.58	.70
		4	5.31	24.8	7.22	
Sept. 22	Weyanoke Pt. Buoy Red 76	0	1.31	25.0	5.64	.63
		7.5	2.18	25.2	5.94	
Sept. 27	Westover Buoy Red 94	0	.564	24.0	6.39	.47
		4	.955	24.0	5.56	
Sept. 27	Jamestown Island Buoy Black 55	0	8.42	25.4	7.80	.85
		12	9.38	25.1	7.00	
Oct. 5	Burwell Bay Buoy J16	0	16.02	19.9	8.15	1.29
		2.5	18.88	19.8	7.88	
Oct. 11	Burwell Bay Buoy J16	0	17.02	18.6	8.59	.97
		2	17.85	18.3	7.88	
Oct. 19	Jamestown Island Buoy Black 55	0	5.49	14.5	9.15	.46
		1.5	5.59	14.6	9.55	
Nov. 16	Cobham Bay	0				
		2				

(continued)

TABLE 1 (cont.)

Date	Station	Type of Sample	Kepone conc. (ppm)
June 23	Jordan Pt. Buoy Red 106	Zooplankton-cladocerans	2.07
	off Bailey Creek Fl G111	Zooplankton-cladocerans	.78
July 19	off Chickahominy R. mouth, Buoy Red 64	Zooplankton-copepods	2.64
Aug. 10	off Chickahominy R. mouth, Buoy Red 64	Zooplankton-copepods & nauplii	16.13
Sept. 6	Jamestown Island Buoy Black C53	Phytoplankton-*Coscinodiscus* sp.	1.45
Sept. 13	off Chickahominy R. mouth, Buoy Red 66	Zooplankton-copepods	5.10
		Zooplankton-pelecypod larvae	1.43
		Phytoplankton-*Coscinodiscus* sp., *Skeletonema costatum*	2.06
Sept. 22	Weyanoke Pt. Buoy Red 76	Zooplankton-copepods, cladocerans	10.30
		Phytoplankton-*Skeletonema costatum*	1.35
Sept. 27	Westover Buoy Red 94	Zooplankton-cladocerans, rotifers	4.11
		Detritus	.32
Sept. 27	Jamestown Island Buoy Black 55	Zooplankton-copepods, nauplii	7.10
		Detritus	.28
Oct. 5	Burwell Bay Buoy J16	Zooplankton-copepods, nauplii	6.01
Oct. 11	Burwell Bay Buoy J16	Zooplankton-copepods, nauplii	2.62
		Phytoplankton-*Coscinodiscus* sp., *Skeletonema costatum*	.49
Oct. 19	Jamestown Island Buoy Black 55	Zooplankton-copepods, nauplii	9.75
Nov. 16	Cobham Bay	Detritus	.40

(continued)

TABLE 1 (cont.)

Date	Station	Depth (m)	Sal. (⁰/oo)	Temp. (°C)	D.O. (mg/l)	Secchi Depth (m)
Nov. 28	Chippokes Pt. Buoy Red 72	--				
Nov. 28	Weyanoke Pt. Buoy Red 76	0 10	.094 .096	8.4 8.4	10.91 10.75	.41
Nov. 28	Westover Buoy Red 94	0 6	.035 .037	7.8 7.8	10.68 10.89	-
Dec. 6	Jamestown Island Buoy Black 55	0 6	.271 .410	9.5 9.4	10.80 11.00	.28
Dec. 6	Hog Pt. Buoy B & W J35	0 7	1.74 2.31	9.7 9.6	10.56 12.16	-
Dec. 13	Burwell Bay Buoy J14	0 4.5	7.06 9.22	5.2 5.0	11.92 9.30	.53
Dec. 13	James R. Bridge Buoy B & W J1	0 9.0	14.55 14.55	5.4 5.6	10.30 10.30	1.10

(continued)

direct analyses of detritus subsamples (Fig. 7), which were representative of the relatively coarse material retained by plankton netting.

The results of both the direct and indirect procedures indicated that the Kepone concentrations in phytoplankton exceeded the concentrations in the remainder of the seston, and that the concentrations in both seston fractions were lower than the concentrations in zooplankton samples. The presence of Kepone in the phytoplankton and suspended detritus indicated that the food chain was a possible route for incorporation of Kepone into the zooplankton, which in turn was a potential source for Kepone contamination of higher trophic levels.

1978 Intensive Survey

In late April and early May of 1978 an intensive effort was conducted to evaluate the Kepone content of the James River seston during a spring freshet, when an exceptionally large flux of suspended sediment was anticipated. In conjunction with the suspended sediment sampling, an intensive plankton sampling program was undertaken, involving the collection of numerous samples in rapid succession.

The locations of the sampling stations are shown in Fig. 8. Table 4 presents the hydrographic and plankton data chronologically, and Table 5 presents the counts of organisms per m^3 of river water. Three or four plankton sampling runs were conducted at each station. The results of the Kepone analyses of the zooplankton samples are summarized in Fig. 9, in terms of the ranges of Kepone concentrations obtained for mixed zooplankton assemblages.

As in 1977, Kepone was detected in the zooplankton from all the stations sampled, but the concentrations, which ranged from 0.16 - 1.1 ppm for the study area as a whole, were lower than the concentrations in the 1977 zooplankton samples. The two stations located farthest downstream in the river, J25 and J8, where bottom salinities ranged from 2 - 10 $^{o}/oo$, exhibited the narrowest ranges of zooplankton Kepone levels. At the other four stations, where the water was almost fresh, the Kepone concentrations varied appreciably from sample to sample, in a pattern that appeared to relate more to the tide stage than to the time of day (Fig. 10).

As in the 1977 study, the differences in Kepone concentrations within a set of samples seemed to be due to differences in the taxonomic composition of the samples. For example, the sample obtained at 2250 hr at station J20, which had the lowest Kepone concentration observed at this station (Fig. 10), also had the highest proportion of harpacticoid copepods (Table 5). This

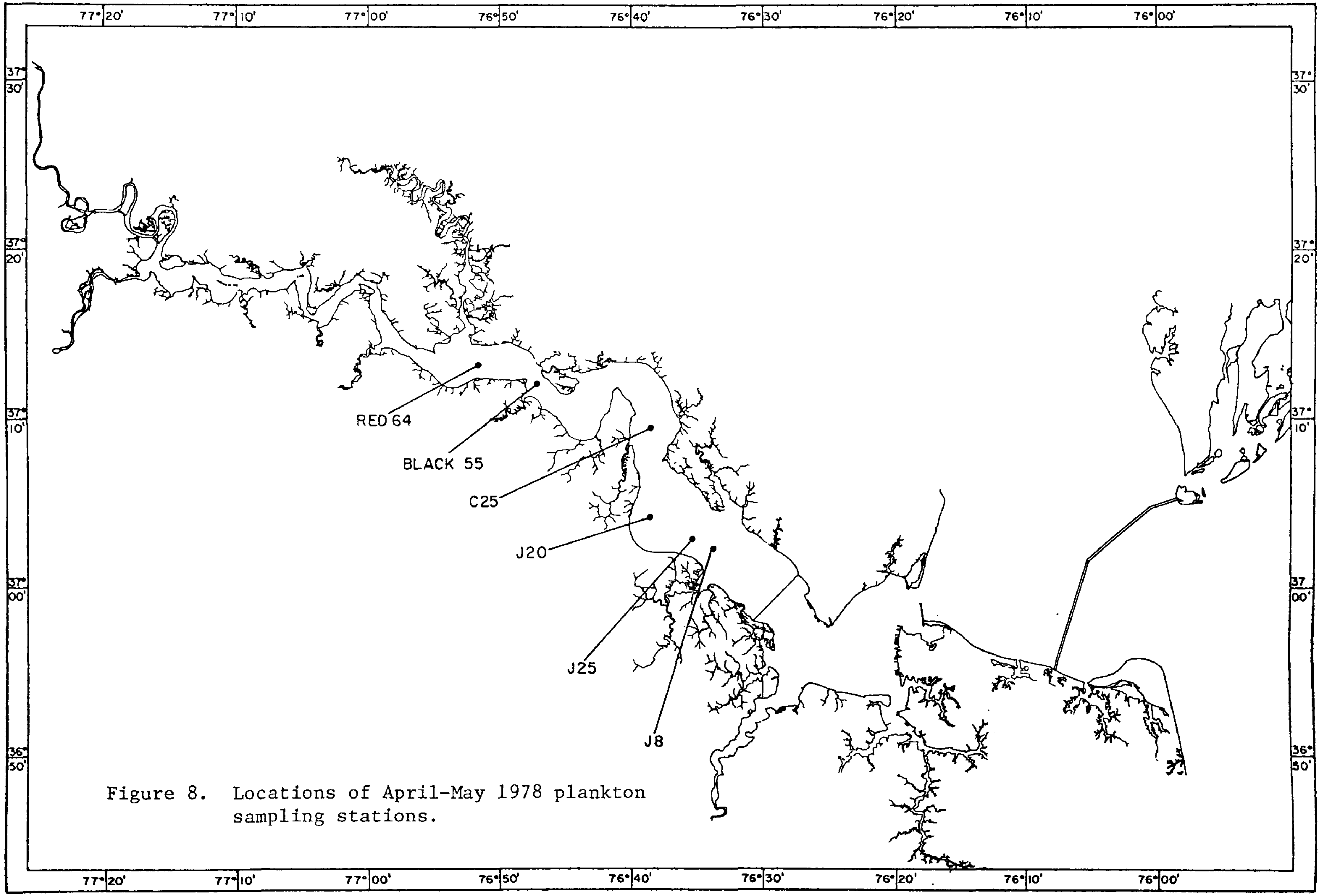


Figure 8. Locations of April-May 1978 plankton sampling stations.

TABLE 4. SUMMARY OF RESULTS OF JAMES RIVER KEPONE PLANKTON STUDY, APRIL-JUNE 1978

Date	Station	Time (EST)	Depth (m)	Secchi Depth (m)	Sal. (^{o}/oo)	Temp. (°C)	D.O. (mg/l)	Tide
Apr. 29	Burwell Bay Buoy Black & White J25	1258	0 9.5	.52	3.34 6.75	16.7 13.2	10.40 8.90	Fl.
Apr. 30	Burwell Bay Buoy Black & White J25	0830	0 6	.53	3.07 8.17	13.9 13.0	9.03 8.47	Ebb
Apr. 30	Burwell Bay Buoy Black & White J25	1726	0 9.5	.37	2.14 7.36	13.9 13.3	8.90 8.62	Fl.
May 1	Burwell Bay Buoy J20	1137	0 6	.32	.315 .389	14.4 14.4	8.82 8.39	Ebb
May 1	Burwell Bay Buoy J20	1705	0 7	.28	.326 .305	14.7 14.7	8.39 8.64	Fl.
May 1	Burwell Bay Buoy J20	2250	0 6.5	.33	.363 .762	14.4 14.3	8.43 8.43	Ebb
May 2	Burwell Bay Buoy J20	0440	0 6	-	.230 .220	14.2 14.0	8.44 8.39	Fl.
May 2	White Shoals Buoy Black & White J8	1340	0 6.5	.41	2.52 5.18	14.2 13.8	8.41 8.12	Ebb
May 2	White Shoals Buoy Black & White J8	1725	0 6	.41	2.38 9.11	14.6 13.3	8.82 8.43	Fl.
May 2	White Shoals Buoy Black & White J8	2210	0 7	-	2.44 10.06	14.3 13.2	9.12 8.53	Ebb
May 3	White Shoals Buoy Black & White J8	0331	0 5	-	2.17 2.85	14.0 13.9	8.45 8.25	Ebb
May 3	Fort Eustis Buoy C25	2020	0 6	-	.138 .172	14.6 14.6	8.33 8.76	Fl.
May 4	Fort Eustis Buoy C25	0312	0 5	-	.138 .135	14.7 14.6	8.25 8.21	Ebb

(continued)

TABLE 4. (continued)

Date	Station	Type of Sample	Kepone conc. (ppm)
Apr. 29	Burwell Bay Buoy Black & White J25	Zooplankton-copepod nauplii (90%)	.16
		Zooplankton-copepods (90%)	.55
Apr. 30	Burwell Bay Buoy Black & White J25	Zooplankton-copepod nauplii (97%)	.29
		Zooplankton-copepods (50%)	.36
Apr. 30	Burwell Bay Buoy Black & White J25	Zooplankton-copepods (50%), copepod nauplii (20%), cladocerans (25%)	.43
May 1	Burwell Bay Buoy J20	Zooplankton-cladocerans (60%), copepods (40%)	.47
		Zooplankton-cladocerans (50%), copepods & nauplii (50%)	.37
May 1	Burwell Bay Buoy J20	Zooplankton-cladocerans (30%), rotifers (30%), copepods (30%)	.80
		Zooplankton-cladocerans (45%), copepods (45%)	.29
		Phytoplankton-*Melosira* sp.	N.D*
May 1	Burwell Bay Buoy J20	Zooplankton-cladocerans (50%), copepods (50%)	.19
		Zooplankton-amphipods	.19
May 2	Burwell Bay Buoy J20	Zooplankton-cladocerans (50%), copepods (30%), rotifers (20%)	.93
May 2	White Shoals Buoy Black & White J8	Zooplankton-barnacle nauplii (50%) copepod nauplii (30%), copepods (20%)	.30
May 2	White Shoals Buoy Black & White J8	Zooplankton-barnacle & copepod nauplii (50%), copepods & cladocerans (50%)	.34
May 2	White Shoals Buoy Black & White J8	Zooplankton-copepods (95%), nauplii & cladocerans (5%)	.38
		Zooplankton-barnacle nauplii (95%), copepods & copepod nauplii (5%)	.94
		Zooplankton-amphipods	.10

*N.D. not detectable

(continued)

TABLE 4. (continued)

Date	Station	Time (EST)	Depth (m)	Secchi Depth (m)	Sal. (o/oo)	Temp. (°C)	D.O. (mg/l)	Tide
May 4	Fort Eustis Buoy C25	0950	0 5.5	.32	.145 .138	14.6 14.4	8.43 8.27	Fl.
May 5	Jamestown Is. Buoy Black 55	0220	0 9	-	.085 .089	13.8 13.7	8.49 8.47	Ebb
May 5	Jamestown Is. Buoy Black 55	1054	0 8	.29	.089 .078	13.9 13.8	8.25 8.10	Fl.
May 5	Jamestown Is. Buoy Black 55	1656	0 9	.24	.082 .078	13.9 13.9	8.41 8.94	Ebb
May 5	Jamestown Is. Buoy Black 55	2229	0 7.5	-	.082 .099	13.7 13.7	8.13 7.82	Fl.
May 6	off Chick. R. Buoy Red 64	0755	0 5	.24	.068 .073	13.5 13.4	8.60 8.23	Ebb
May 6	off Chick. R. Buoy Red 64	1325	0 5.5	.29	.080 .087	16.6 14.2	8.54 8.74	Fl.
May 6	off Chick. R. Buoy Red 64	2134	0 5	-	.071 .073	14.2 14.2	8.83 8.07	Fl.
May 7	off Chick. R. Buoy Red 64	0457	0 4.5	-	.064 .066	14.3 14.0	8.36 7.72	Ebb
May 31	Chesapeake B. entrance Buoy R12	0730	0 8.5	2.55	17.3 26.6	19.2 17.9	8.53 7.33	
May 31	Hampton Roads Buoy N18	1222	0 4	1.00	14.1 14.8	20.9 20.3	6.84 6.24	
June 15	James River Bridge Buoy J1	1052	0 6	.82	7.03 17.4	23.6 22.0	7.53 5.52	

(continued)

TABLE 4. (continued)

Date	Station	Type of Sample	Kepone conc. (ppm)
May 3	White Shoals Buoy Black & White J8	Zooplankton-copepods (98%), nauplii & cladocerans (2%)	.39
May 3	Fort Eustis Buoy C25	Zooplankton-cladocerans (50%), copepods (40%), amphipods (10%)	.97
		Polychaetes	.29
May 4	Fort Eustis Buoy C25	Zooplankton-cladocerans (50%), copepods (50%)	.30
		Phytoplankton-*Melosira* sp. (95%)	N.D.
May 4	Fort Eustis Buoy C25	Zooplankton-copepods (50%), cladocerans (50%)	.62
May 5	Jamestown Is. Buoy Black 55	Zooplankton-copepods (70%), cladocerans (30%)	.83
May 5	Jamestown Is. Buoy Black 55	Zooplankton-cladocerans (60%), copepods (40%)	.48
		Phytoplankton-*Melosira* sp.	N.D.
May 5	Jamestown Is. Buoy Black 55	Zooplankton-copepods (60%), cladocerans (40%)	.29
		Zooplankton-copepods (50%), cladocerans and nauplii (50%)	1.12
		Phytoplankton-*Melosira* sp.	N.D.
		Detritus	.09
May 5	Jamestown Is. Buoy Black 55	Zooplankton-copepods (70%), cladocerans (25%), amphipods (5%)	.22
May 6	off Chick. R. Buoy Red 64	Zooplankton-cladocerans (70%), copepods (30%)	.20
May 6	off Chick. R. Buoy Red 64	Zooplankton-cladocerans (50%), copepods (50%)	.20
		Phytoplankton-*Melosira* sp.	N.D.
May 6	off Chick. R. Buoy Red 64	Zooplankton-cladocerans (90%), copepods (10%)	.75

(continued)

TABLE 4. (continued)

Date	Station	Type of Sample	Kepone conc. (ppm)
May 7	off Chick. R. Buoy Red 64	Zooplankton-cladocerans (70%), copepods (30%)	.16
May 31	Chesapeake B. entrance Buoy R12	Zooplankton-copepods (98%), cladocerans (2%)	N.D.
May 31	Hampton Roads Buoy N18	Zooplankton-copepods (80%), cladocerans and nauplii (20%)	.15
June 15	James River Bridge Buoy J1	Zooplankton-copepod nauplii (45%), copepods (10%)	.34

TABLE 5. QUANTITATIVE ZOOPLANKTON DATA-MAY 1978, NO. OF INDIVIDUALS PER M^3

Station Date Time (EST)	J20 1 May 1137	J20 1 May 1705	J20 1 May 2250	J20 2 May 0440
Organism				
Copepod nauplii	3893	4525	157	1132
Barnacle nauplii	27			
Polychaete larvae	55		22	113
Acartia sp.	55	65		
Eurytemora sp.	603	582	22	736
Cyclopoid copepods	1700	1164	247	2321
Harpacticoid copepods	1316	517	4418	906
Bosmina sp.	1700	2457	1166	1698
Cladocerans (other)	27			113
Rotifers	877	1875	381	2944
Amphipods			1	
Total	10,253	11,185	6414	9963

(continued)

TABLE 5 (cont.)

Station Date Time (EST)	J8 2 May 1340	J8 2 May 1725	J8 2 May 2210	J8 3 May 0331
Organism				
Copepod nauplii	10,904	19,705	3004	13,400
Barnacle nauplii	10,719	7955	4318	2108
Polychaete larvae	123			
Acartia sp.	185	730	2948	989
Eurytemora sp.	246	766	652	676
Cyclopoid copepods	185	255	425	833
Harpacticoid copepods	123	2299	538	2030
Bosmina sp.	123	255	198	260
Cladocerans (other)			28	
Rotifers	308	620	198	182
Amphipods				
Total	22,916	32,585	12,129	20,478

(continued)

TABLE 5 (cont.)

Station Date Time (EST)	C25 3 May 2020	C25 4 May 0312	C25 4 May 0950
Organism			
Copepod nauplii	2333	1363	2586
Polychaete larvae	99	45	
Acartia sp.	298	45	58
Eurytemora sp.	3176	545	842
Cyclopoid copepods	3127	3771	3370
Harpacticoid copepods	2134	136	87
Bosmina sp.	2432	1181	1743
Cladocerans (other)	50	45	87
Rotifers	4169	4726	4968
Amphipods			
Total	17,818	11,857	13,741

(continued)

TABLE 5 (cont.)

Station Date Time (EST)	BL55 5 May 0220	BL55 5 May 1054	BL55 5 May 1656	BL55 5 May 2229
Organism				
Copepod nauplii	382	681	744	752
Polychaete larvae				
<u>Acartia</u> sp.	116	47	138	90
<u>Eurytemora</u> sp.	565	258	165	873
Cyclopoid copepods	1164	869	1984	1023
Harpacticoid copepods	133	24	165	813
<u>Bosmina</u> sp.	432	657	1681	1023
Cladocerans (other)	33	94	303	30
Rotifers	665		2866	1114
Amphipods	17			120
Total	3507	2630	8046	5838

(continued)

TABLE 5 (cont.)

Station Date Time (EST)	Red 64 6 May 0755	Red 64 6 May 1325	Red 64 6 May 2134	Red 64 7 May 0457
Organism				
Copepod nauplii	107	525	150	86
Polychaete larvae				
Barnacle nauplii				
Acartia sp.	36	93	38	29
Eurytemora sp.		93	338	86
Cyclopoid copepods	1002	803	488	547
Harpacticoid copepods	72	31	375	547
Bosmina sp.	609	1267	544	403
Cladocerans (other)	143	93	150	86
Rotifers	895	2132	807	201
Amphipods			38	29
Dipteran larvae		62	19	29
Total	2864	5099	2947	2043

(continued)

TABLE 5 (cont.)

Station Date Time (EST)	J25 30 Apr. 0830	J25 30 Apr. 1726
Organism		
Copepod nauplii	1684	32211
Polychaete larvae		135
Barnacle nauplii	282	270
Acartia sp.	87	169
Eurytemora sp.	87	809
Cyclopoid copepods	22	337
Harpacticoid copepods	11	776
Bosmina sp.		101
Cladocerans (other)		
Rotifers	22	911
Amphipods		
Dipteran larvae		
Total	2195	35,719

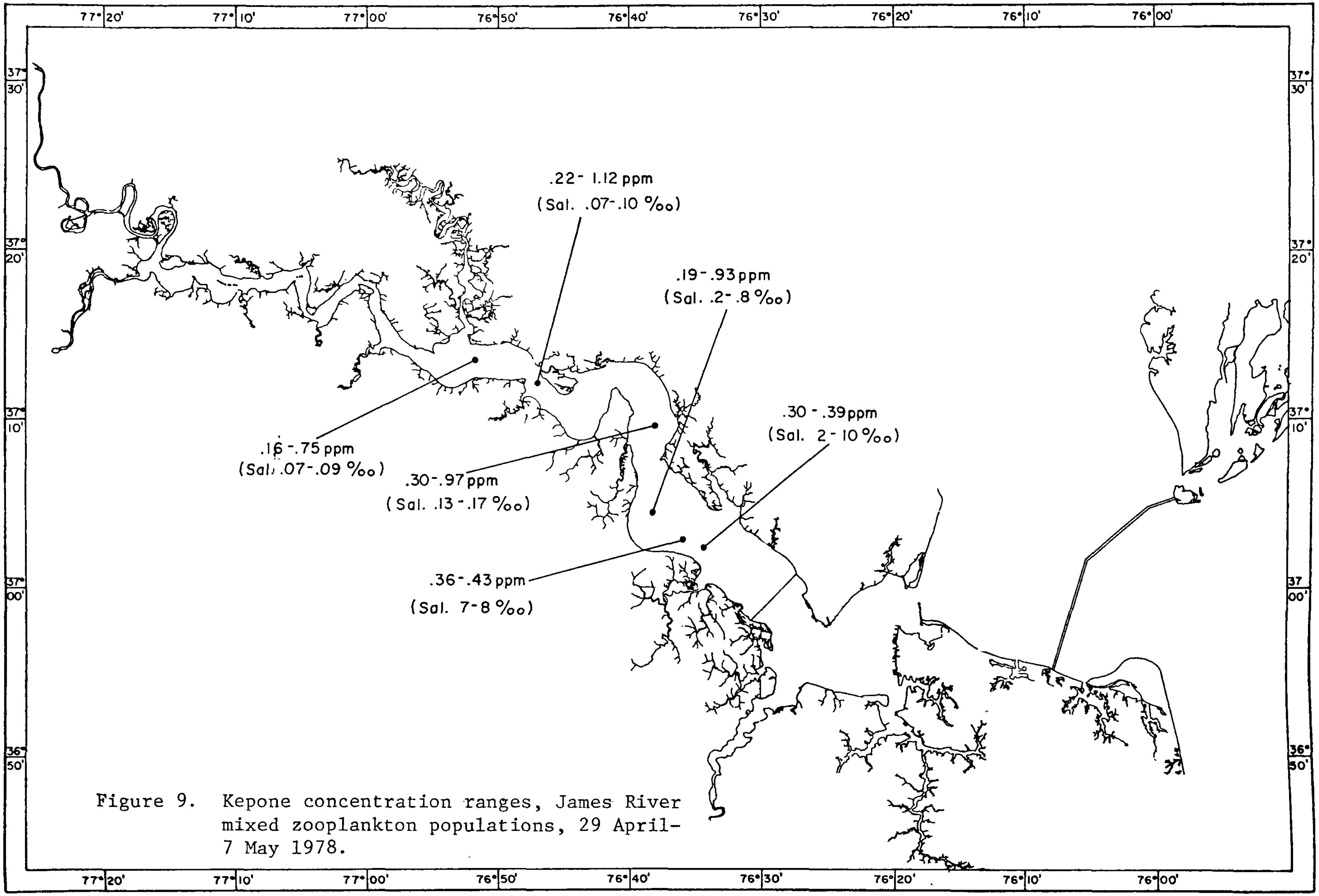
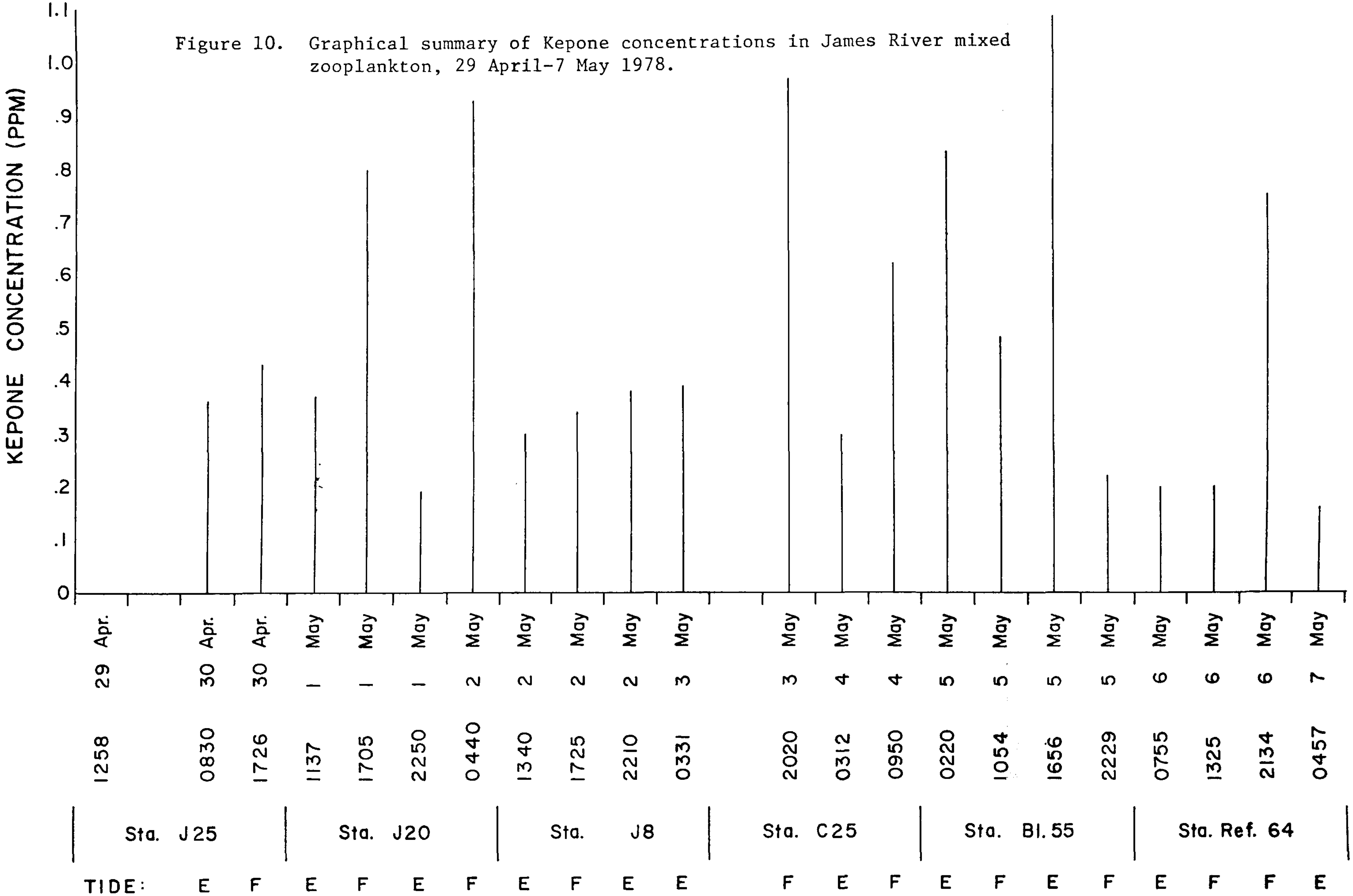


Figure 9. Kepone concentration ranges, James River mixed zooplankton populations, 29 April-7 May 1978.

Figure 10. Graphical summary of Kepone concentrations in James River mixed zooplankton, 29 April-7 May 1978.



suggested that the harpacticoids were relatively low in Kepone, and the large numbers that occurred in this sample diluted the Kepone present in the cladocerans and other groups of copepods.

Several of the net tows taken during the 1978 study yielded more than one sample fraction for Kepone analysis (Table 4). The samples taken at station J25 suggested that adult copepods were higher in Kepone than were copepod nauplii (0.55 vs 0.16 ppm at 1258 hr, 0.36 vs 0.29 ppm at 0830 hr). The samples from station J8 suggested that barnacle nauplii were the zooplankters with the highest kepone levels at the higher salinity stations (0.94 ppm, vs 0.38 ppm for copepods and 0.10 ppm for amphipods). The samples obtained at the freshwater stations were generally mixtures of copepods and cladocerans, and the differences in Kepone levels among the samples showed no distinct relationship to differences in proportions of these two gross taxonomic groups.

Zooplankton samples were taken at three additional stations downstream from the area included in the intensive survey, in May and June 1978 (Table 4). Kepone was not detected in a sample from the Chesapeake Bay entrance, but was present at 0.15 ppm in a sample from Hampton Roads, and at 0.34 ppm in a sample from immediately upstream of the James River Bridge.

The analyses of phytoplankton subsamples obtained during the 1978 study yielded Kepone concentrations below the level of detection of the method (Table 4). One detritus subsample, from station Black 55, was analyzed and had a Kepone concentration of 0.09 ppm.

An attempt was made to obtain an indirect estimate of the Kepone concentration in the phytoplankton, by using the same method employed in August 1977 (Table 6). The result, 0.76 ppm, is similar to the earlier indirect estimate (Table 3), but it seems high relative to the distinctly lower Kepone levels in the zooplankton in the 1978 study. The indirect estimate for the Kepone level in suspended sediment, 0.016 ppm, is of the same order of magnitude as the direct estimate for detritus and as the levels found in most of the total seston samples in the 1978 study (see suspended sediment section of this report).

In the 1978 suspended sediment Kepone survey, surface and bottom samples were taken by centrifugation hourly over a period of approxmiately 25 hours at each of the stations indicated in Fig. 8. The Kepone levels in these seston concentrates varied from sample to sample, and the samples from station J8 varied over the widest range. During the centrifugation of each sample, a volume of river water was passed through a 63 micron sieve to concentrate a sample of the large size fraction of the seston, which was preserved for subsequent microscopic analysis. Since the zooplankton samples obtained from the net tows exhibited higher Kepone levels than the total seston samples, it was sus-

TABLE 6. INDIRECT CALCULATION OF KEPONE CONCENTRATIONS IN PHYTOPLANKTON AND SUSPENDED SEDIMENT, STATION J8, 2 MAY 1978

Initial data

Sample	g Kepone per g seston	g Phytoplankton per g seston	g sediment per g seston
Bottom seston	$.09 \cdot 10^{-6}$	.0993	.9007
Surface seston	$.16 \cdot 10^{-6}$	.1938	.8062

Mass balance equations

Bottom seston

$$.09 \cdot 10^{-6} \text{ g Kepone} = (.0993\text{g Phytopl.})\left(\frac{X\text{g Kepone}}{\text{g Phytopl.}}\right) + (.9007\text{g sed})\left(\frac{Y\text{g Kepone}}{\text{g sed.}}\right)$$

Surface seston

$$.16 \cdot 10^{-6} \text{ g Kepone} = (.1938\text{g Phytopl.})\left(\frac{X\text{g Kepone}}{\text{g Phytopl.}}\right) + (.8062\text{g sed.})\left(\frac{Y\text{g Kepone}}{\text{g sed.}}\right)$$

Solution

Bottom seston

$$.0993X = .09 \cdot 10^{-6} - .9007Y$$
$$X = .9063 \cdot 10^{-6} - 9.070Y$$

substituting into surface seston:

$$.16 \cdot 10^{-6} = (.1938)(.9063 \cdot 10^{-6} - 9.070Y) + .8062Y$$
$$.01564 \cdot 10^{-6} = .9516Y$$
$$Y = .01644 \cdot 10^{-6}$$

$$X = .9063 \cdot 10^{-6} - (9.070)(.01644 \cdot 10^{-6})$$
$$X = .757 \cdot 10^{-6}$$

Result

Kepone concentration in sediment = .016 ppm
Kepone concentration in phytoplankton = .76 ppm

pected that the zooplankton present in the large particle fraction of a seston sample could have been the source of some or most of the Kepone extracted from the sample. Thus the composition of the 63 micron sieve samples could be examined in an attempt to interpret the variation in Kepone levels observed among the total seston samples. Selected sieve samples were examined to determine the ratios of zooplankton to detritus, in terms of the relative areas of microscope fields covered by these two categories. In Fig. 11, Kepone concentration in the total seston has been plotted vs zooplankton: detritus ratio in the >63 micron fraction for two stations. A positive relationship is suggested by the plot for station J8, but not for station Red 64. The reason for this difference may be the fact that station J8 was the station where the Kepone concentrations in the mixed zooplankton varied the least from sample to sample (Fig. 10). This was therefore the station where the variation in total zooplankton content of the seston would be expected to relate the most directly to the variation in sestonic Kepone. At the other stations, such as Red 64, where the zooplankton Kepone levels were more variable, probably due to variations in the taxonomic composition of the plankton, a gross estimate of the total zooplankton abundance would be less closely related to the Kepone content.

Estimates of the Magnitude of the Zooplankton Reservoir

The zooplankton counts per unit volume of river water (Tables 2 and 5) and the concentrations of Kepone per unit mass of zooplankton (Tables 1 and 4) were used in an attempt to estimate the total mass of Kepone that was present in the zooplankton in the study area, during the sampling periods. Estimates of the dry weights of individual zooplankters were obtained from the literature (Nakai 1955), and these were used to convert the zooplankton counts for the taxonomic groups actually included in the Kepone analyses, to estimates of mass per cubic meter (Tables 7 and 8). Most of these estimates were within the range of values determined during a survey of lower Chesapeake Bay zooplankton (Jacobs 1978). Multiplication by the measured Kepone concentrations in the zooplankton yielded Kepone concentrations per cubic meter of river water (Tables 7 and 8, Figs. 12 - 14). The final step was to factor in estimates of the water volumes present in the sections of the James River included in the study area (Cronin 1971), and calculate the total mass of Kepone present in the zooplankton in each river section (Table 9).

These estimates are conservatively low, since only the zooplankton taxa actually analyzed for Kepone were included in the calculations. Even if they underestimate the actual quantity by one or two orders of magnitude, however, the conclusion would be the same: The zooplankton compartment, evaluated during the study period, contained a minute fraction of the estimated 100,000 pounds of Kepone (Bellanca and Gilley 1977) present in the river system. Nonetheless, the zooplankton Kepone represents

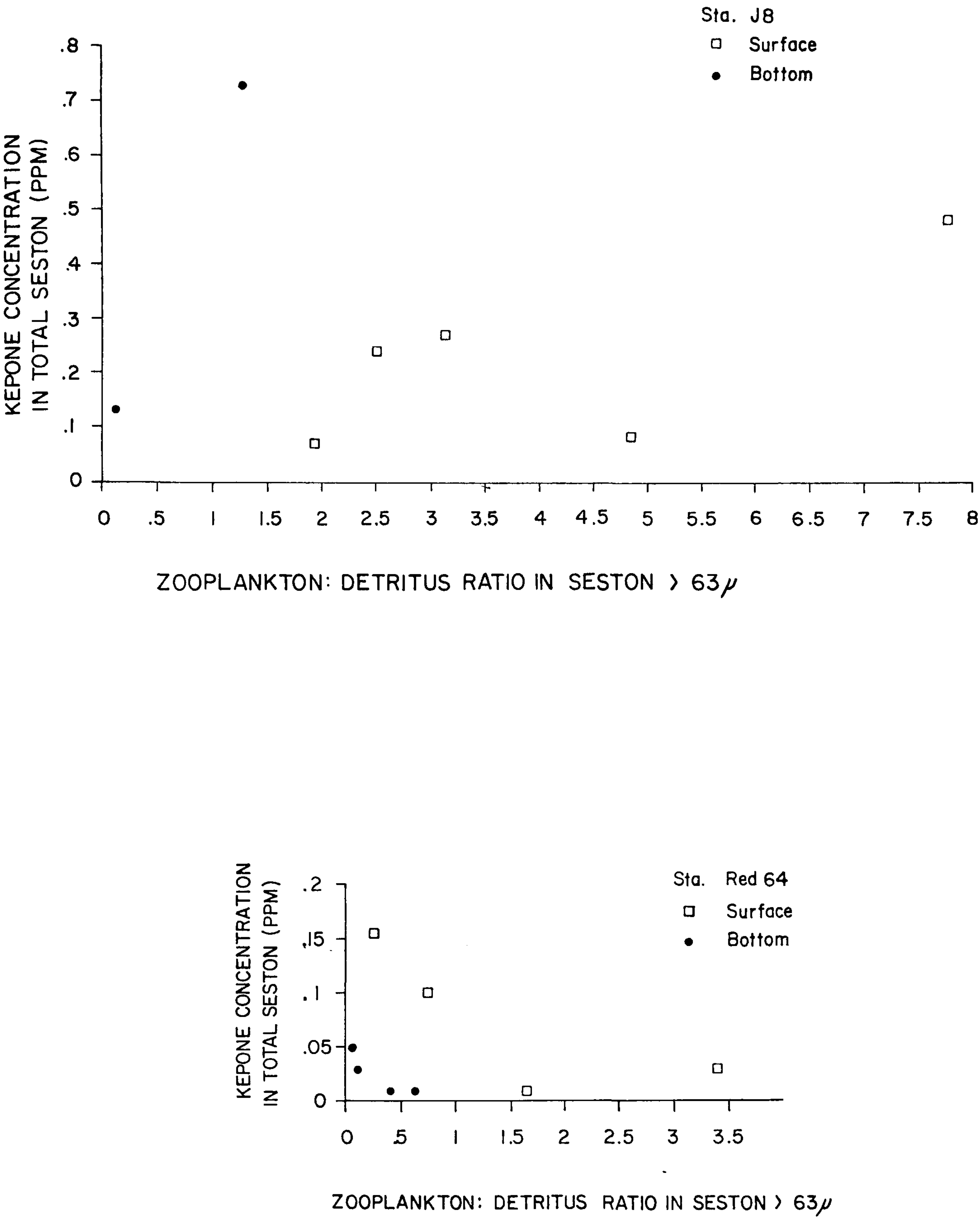


Figure 11. Kepone concentration vs zooplankton: detritus ratio in coarse seston fractions, May 1978.

TABLE 7. ESTIMATES OF KEPONE IN ZOOPLANKTON, PER UNIT VOLUME OF RIVER WATER (1977)

Station	Date	Type of Sample	Kepone Content of Zoopl. (ppm= 10^{-3} μg/mg)	Zoopl. Counts (No./m^3)	Zoopl. Dry wt. (mg/m^3)	Kepone in Zoopl. (μg/m^3)
Red 64	10 Aug.	copepods, nauplii	16.13	7000	11.1	.18
Red 66	13 Sept.	copepods	5.10	7240	28.3	.14
Red 76	22 Sept.	copepods, cladocerans	10.30	1813	8.63	.09
Red 94	27 Sept.	cladocerans, rotifers	4.11	467	0.82	.003
B1.55	27 Sept.	copepods, nauplii	7.10	1254	1.33	.009
J16	5 Oct.	copepods, nauplii	6.01	5216	16.29	.098
J16	11 Oct.	copepods, nauplii	2.62	2424	5.71	.015
B155	19 Oct.	copepods, nauplii	9.75	1147	2.60	.025
Red 72	28 Nov.	copepods, cladocerans	2.86	4448	22.1	.063
Red 76	28 Nov.	cladocerans	1.27	1277	6.38	.008

(continued)

TABLE 7. (continued)

Station	Date	Type of Sample	Kepone Content of Zoopl. (ppm= 10^{-3} ug/mg)	Zoopl. Counts (No./m^3)	Zoopl. Dry wt. (mg/m^3)	Kepone in Zoopl. (ug/m^3)
Red 76	28 Nov.	copepods	15.58	4802	24.0	.37
Red 94	28 Nov.	copepods, cladocerans	2.02	18,320	91.6	.18
B1.55	6 Dec.	copepods	6.31	447	2.24	.014
J35	6 Dec.	copepods	4.08	1005	4.68	.019
J14	13 Dec.	copepods	3.46	845	4.20	.015
J1	13 Dec.	copepods, nauplii	3.16	2475	5.44	.017

TABLE 8. ESTIMATES OF KEPONE IN ZOOPLANKTON, PER UNIT VOLUME OF RIVER WATER (1978)

Station	Date	Time (EST)	Type of Sample	Kepone Content of Zoopl. (ppm= 10^{-3} µg/mg)	Zoopl. Counts (No./m^3)	Zoopl. Dry wt. (mg/m^3)	Kepone in Zoopl. (µg/m^3)
J25	30 Apr.	0830	copepod nauplii	.16	1684	1.35	.0002
			copepods	.55	207	.38	.0002
J25	30 Apr.	1726	copepods, nauplii cladocerans	.43	34,403	74.90	.032
J20	1 May	1137	copepods, nauplii cladocerans	.37	9294	28.65	.011
J20	1 May	1705	cladocerans, rotifers copepods	.80	6660	23.58	.019
J20	1 May	2250	cladocerans, copepods	.19	5853	20.43	.0039
J20	2 May	0440	cladocerans, rotifers, copepods	.93	8718	28.24	.026
J8	2 May	1340	copepods, nauplii	.30	22,362	33.42	.010
J8	2 May	1725	copepods, nauplii barnacle nauplii, cladocerans	.34	31,965	47.87	.016
J8	2 May	2210	copepods, nauplii cladocerans	.38	11,931	30.60	.012
J8	3 May	0331	copepods, nauplii cladocerans	.39	20,296	24.98	.010

(continued)

TABLE 8. (continued)

Station	Date	Time (EST)	Type of Sample	Kepone Content of Zoopl. (ppm= 10^{-3}ug/mg)	Zoopl. Counts (No./m^3)	Zoopl. Dry wt. (mg/m^3)	Kepone in Zoopl. (ug/m^3)
C25	3 May	2020	cladocerans, copepods	.97	11,217	51.52	.050
C25	4 May	0312	cladocerans, copepods	.30	5723	28.30	.0085
C25	4 May	0950	cladocerans, copepods	.62	6187	30.70	.019
B1.55	5 May	0220	copepods, cladocerans	.83	2443	11.83	.010
B1.55	5 May	1054	copepods, cladocerans	.48	1949	9.65	.0046
B155	5 May	1656	copepods, nauplii cladocerans	1.12	5180	22.31	.025
B155	5 May	2229	copepods, cladocerans	.22	3852	17.54	.0039
Red 64	6 May	0755	copepods, cladocerans	.20	1862	9.13	.0018
Red 64	6 May	1325	copepods, cladocerans	.20	2380	11.75	.0023

(continued)

TABLE 8. (continued)

Station	Date	Time (EST)	Type of Sample	Kepone Content of Zoopl. (ppm= $10^{-3}\mu g/mg$)	Zoopl. Counts (No./m^3)	Zoopl. Dry wt. (mg/m^3)	Kepone in Zoopl. ($\mu g/m^3$)
Red 64	6 May	2134	copepods, cladocerans	.75	1933	8.88	.0067
Red 64	7 May	0457	copepods, cladocerans	.16	1698	7.37	.0012

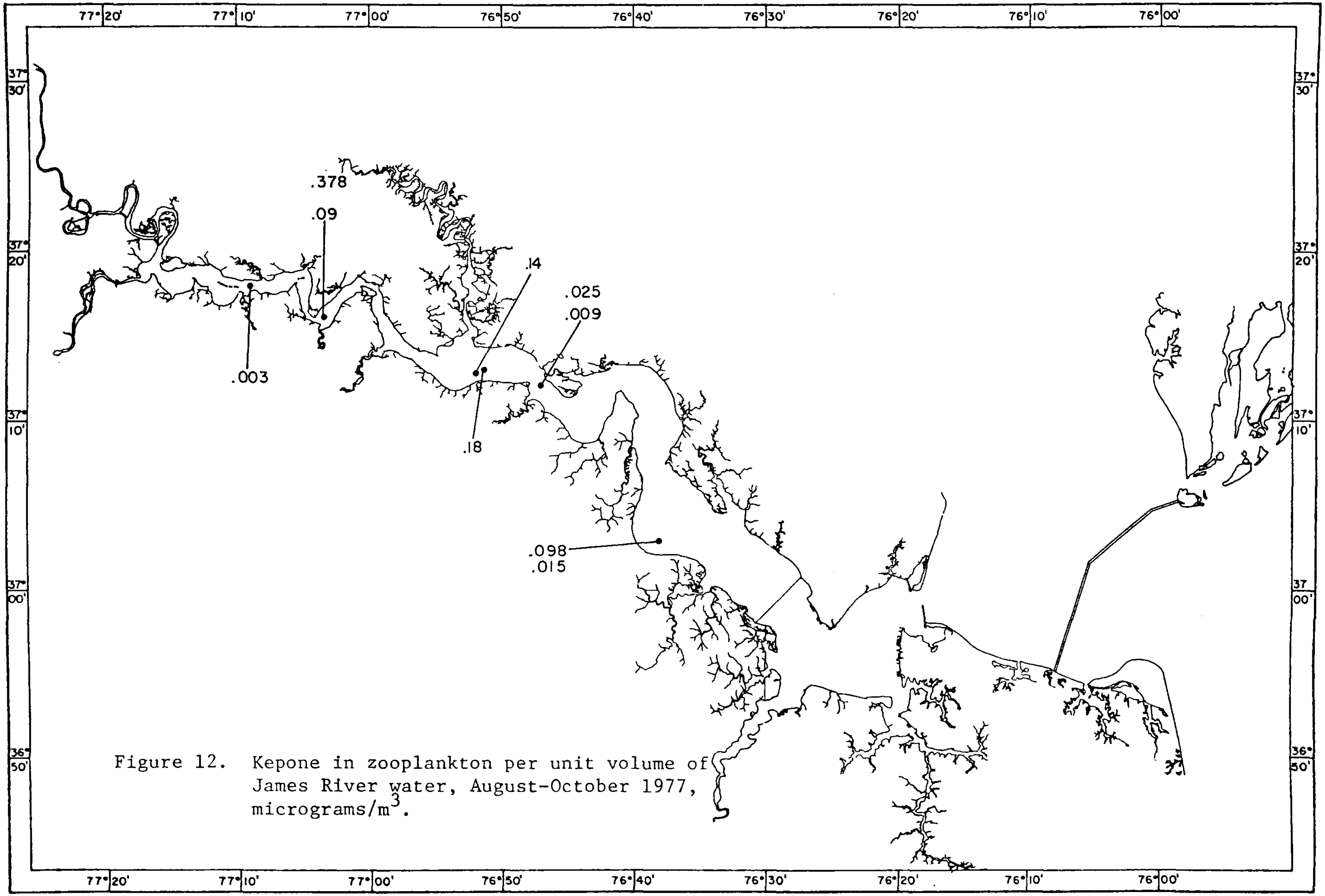


Figure 12. Kepone in zooplankton per unit volume of James River water, August-October 1977, micrograms/m^3.

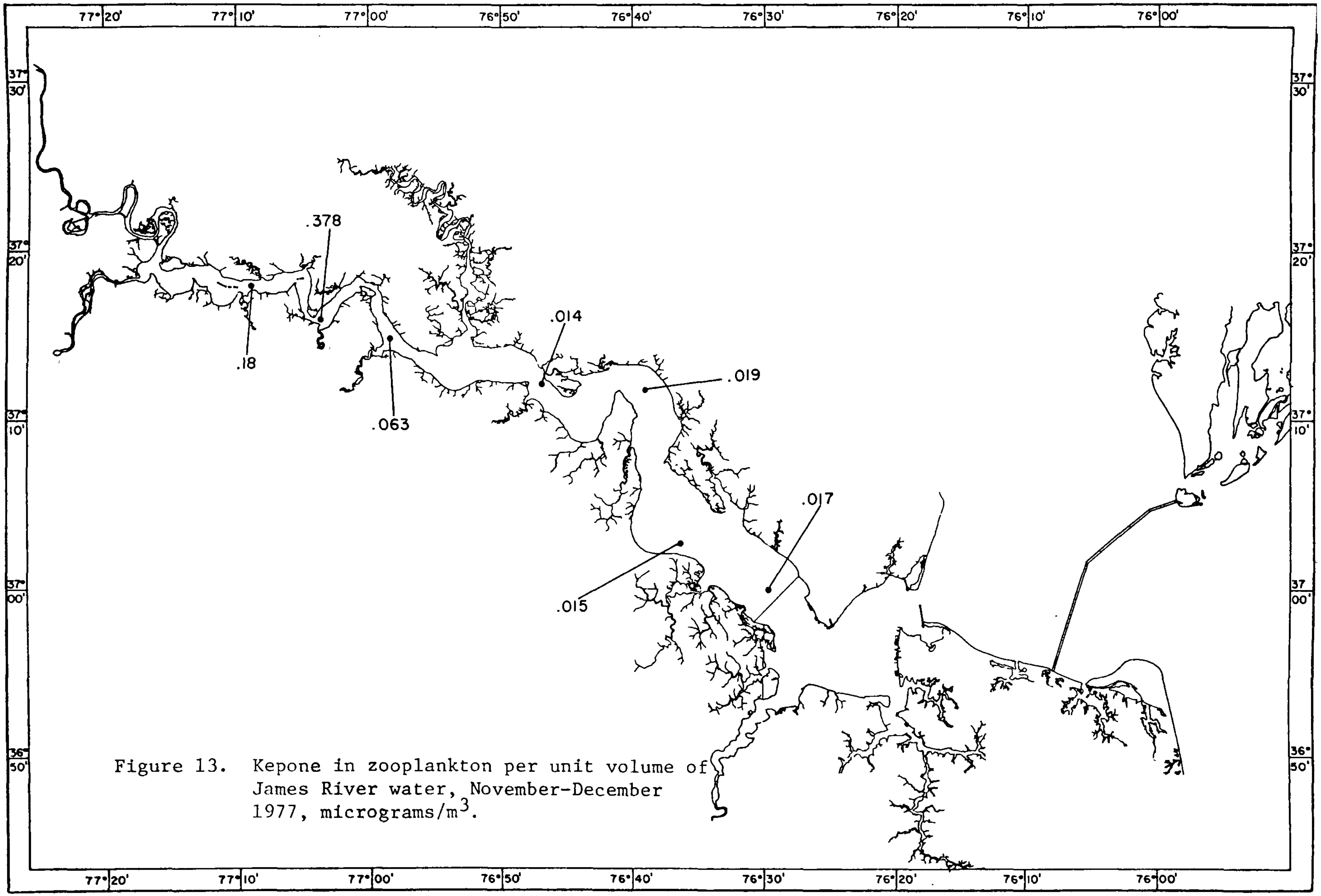


Figure 13. Kepone in zooplankton per unit volume of James River water, November-December 1977, micrograms/m^3.

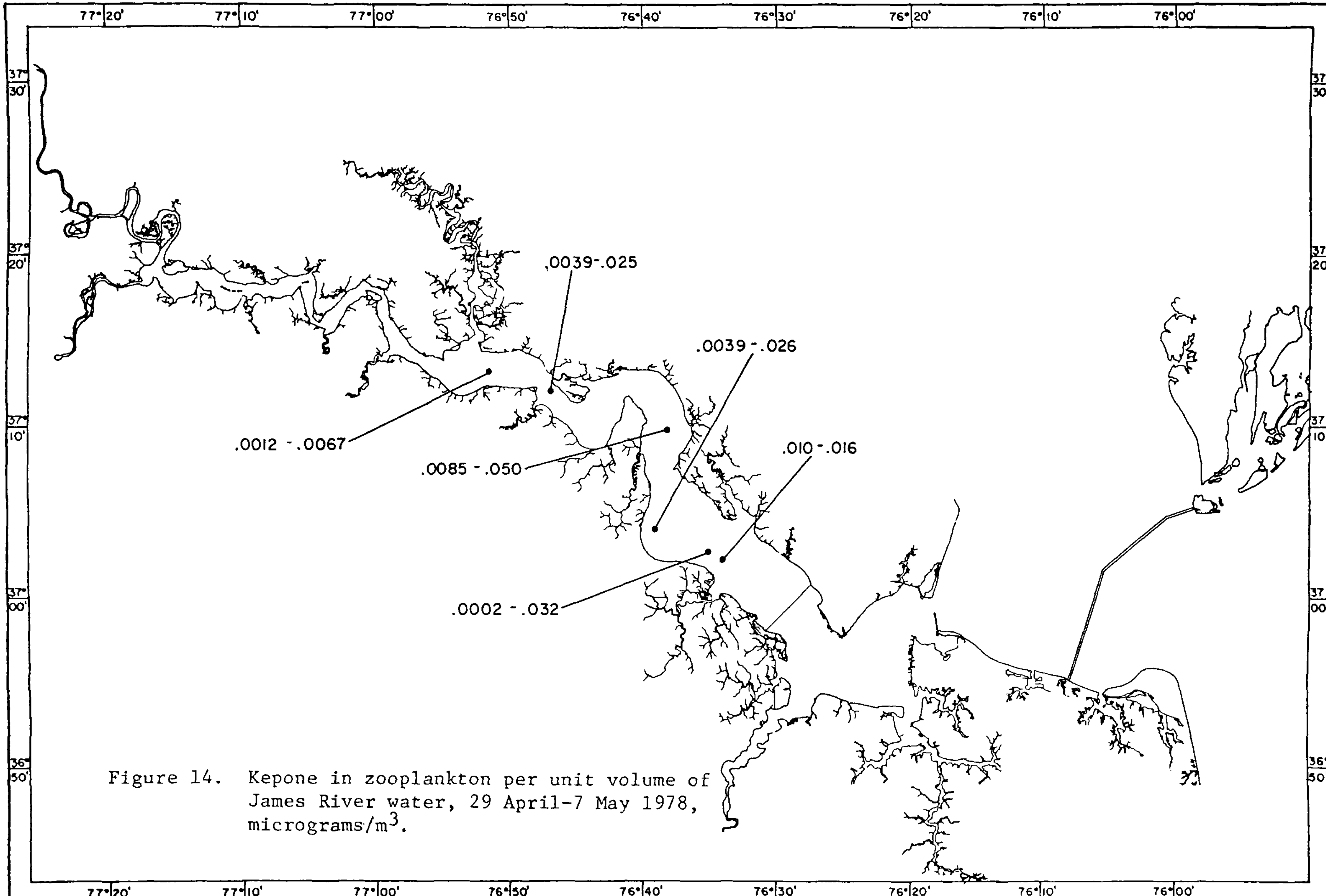


Figure 14. Kepone in zooplankton per unit volume of James River water, 29 April-7 May 1978, micrograms/m^3.

TABLE 9. ESTIMATED TOTAL MASS OF KEPONE IN JAMES RIVER ZOOPLANKTON

River Segment	MLW Water vol. (10^6 m^3)	Aug. - Oct. 77 g	Nov. - Dec. 77 g	Apr. - May 78 g
James R. Bridge to Burwell Bay (CMP 10-20 in Cronin 1971)	522	7.84-51.19	7.84-8.88	.10-16.72
Burwell Bay to Hog Pt. (MP 20-30 in Cronin 1971)	309	4.64-30.32	5.88-	1.21-15.47
Hog Pt. to Jamestown Island (MP 30-35 in Cronin 1971)	118	1.07-2.96	1.66	.46-2.96
Jamestown Island to Sturgeon Pt. (MP 35-50 in Cronin 1971)	336	46.99-60.41	21.14	.40-8.39
Sturgeon Pt. to Appomattox R. (MP 50-70 in Cronin 1971)	184	.55-69.53	33.11-69.53	.22-1.23
Total		61.09-214.41	69.63-107.09	2.39-44.77

TABLE 10. KEPONE LEVELS IN *COROPHIUM LACUSTRE* TAKEN FROM FOULING PLATES INCUBATED AT THREE STATIONS IN THE JAMES RIVER

Sampling period	Kepone (ppm) dry wt. basis
June, August 1976 (combined)	6.1
June 1977	4.7
June 1978	0.43
August 1978	0.32

a biologically available pool of the contaminant with a turnover time on the order of weeks, in contrast to the sediment pool, which contains most of the Kepone and which is becoming gradually buried or diluted by uncontaminated sediment (Nichols and Trotman 1977).

The total zooplankton Kepone estimates present in Table 9 appear to decline with time, especially between the Nov. - Dec. 1977 and Apr. - May 1978 sampling periods. Whether this represents a long term trend or a seasonal fluctuation cannot be determined without continued sampling. However, there is a set of Kepone analyses of crustaceans sampled from the James River in three separate years, that can be examined in relation to this question. The organism analyzed was Corophium lacustre, a tube dwelling epibenthic amphipod collected on artificial substrates at three stations located between mile points 30 and 40 (Fig. 3). The Kepone concentrations in these samples, expressed on a dry weight basis, appear in Table 10. They are similar to the concentrations in the 1977 and 1978 zooplankton samples, and show an order of magnitude decline between June 1977 and June 1978.

Conclusion

It would be satisfying to conclude this report optimistically with the statement that the Kepone contamination of the James River plankton is declining rapidly with time. However, the amount of sampling performed in this study was not sufficient to support such a sweeping generalization. The most significant finding was that the plankton throughout the study area has been contaminated with Kepone, and that Kepone, therefore, has in fact been available via the food chain route to the shellfish and finfish in the system. The instantaneous magnitude of the zooplankton Kepone reservoir during the study was on the order of hundreds of grams, but this was in a form readily available for transfer to other groups of organisms.

References

Bahner, L. H., A. J. Wilson, Jr., J. M. Sheppard, J. M. Patrick, Jr., L. R. Goodman, and G. E. Walsh. 1977. Kepone® bioconcentration, accumulation, loss, and transfer through estuarine food chains. Ches. Sci. 18(3): 299-308.

Bellanca, M. A. and W. F. Gilley. 1977. The current efforts of Virginia agencies to monitor Kepone in the environment. IN: The Kepone Seminar II, Easton, Md. Sept. 19-21, 1977. Published by U.S. E.P.A. Region III.

Cronin, W. B. 1971. Volumetric, areal, and tidal statistics of the Chesapeake Bay estuary and its tributaries. Special Report No. 20, Ref. 71-2, Johns Hopkins University, Chesapeake Bay Institute, 135 pp.

Jacobs, F. 1978. Zooplankton distribution, biomass, biochemical composition and seasonal community structure in lower Chesapeake Bay. Ph.D. Thesis, University of Virginia. 105 pp.

Nakai, Z. 1955. The chemical composition, volume, weight, and size of the important marine plankton. IN: Spec. Publ. No. 5, Fisheries Agency, Ministry of Agriculture and Forestry, Tokai Regional Fisheries Research Laboratory. Translated from Japanese.

Nichols, M. M. and R. C. Trotman. 1977. Kepone in James River sediments. IN: The Kepone Seminar II, Easton, Md. Sept. 19-21, 1977. Published by U.S. E.P.A., Region III.

Schimmel, S. C. and A. J. Wilson, Jr. 1977. Acute toxicity of Kepone® to four estuarine animals. Ches. Sci. 18(2): 224-7.

Walsh, G. E., K. Ainsworth, and A. J. Wilson. 1977. Toxicity and uptake of Kepone in marine unicellular algae. Ches. Sci. 18 (2):222-3.