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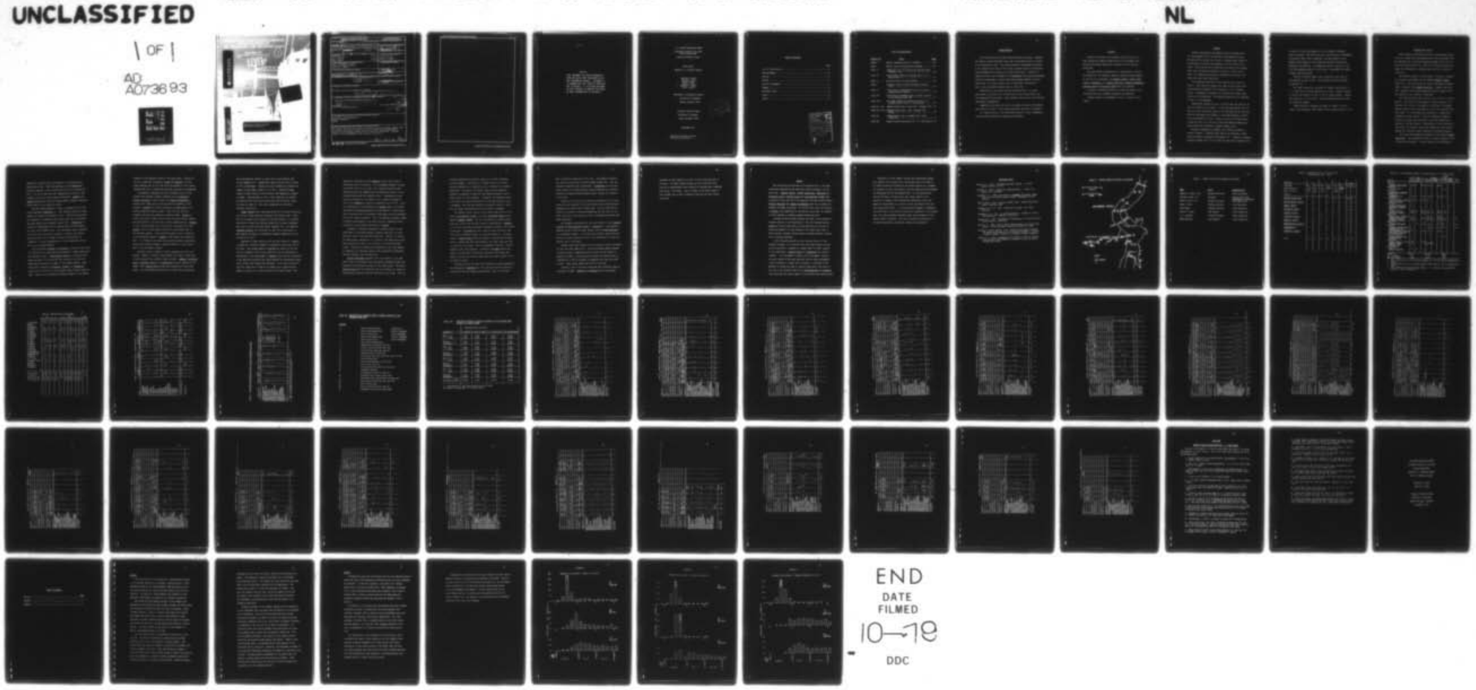

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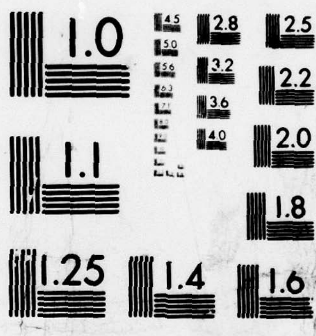

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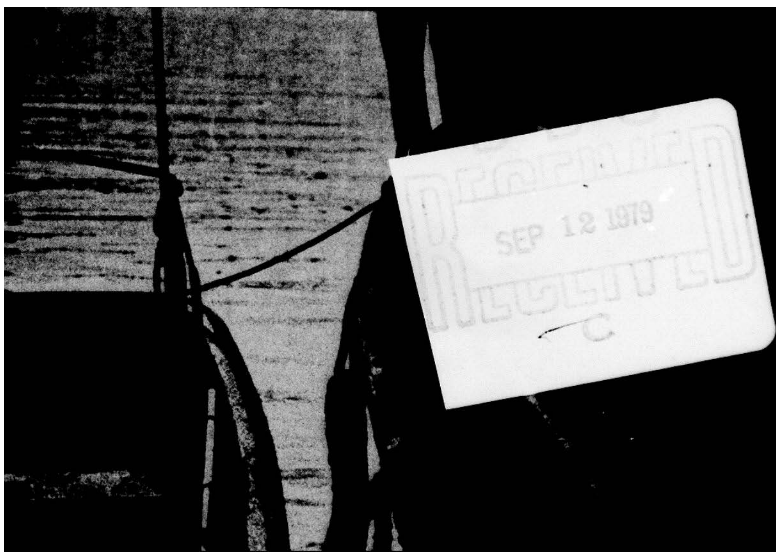

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This report presented the results of sampling of grab and dredge samples from 25 stations in the Del. portion of the C & D Canal system during 1971-72 Patterns of distribution within the study area were identified. Possible effects of the enlargement of the canal are discussed.

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C & D CANAL ECOLOGICAL SURVEY

Biological Survey of the Canal and its Approaches

- Quarterly Benthic Survey -

Final Report

Appendix IV - Delaware Benthos

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September 1973

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ACKNOWLEDGEMENT

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Preparation of this report and the preceding status reports was made easier by the efforts of Ann Taylor who did the illustrations, and the following CMS secretaries: Patty Bradford, Anna LeCates, Doris Mitchell and Marybeth Sparpaglione.

Significant contributions in data processing and statistical analysis were made by Art Olsen of the Biology Department, University of Delaware.

Mr. Joseph Phillips of the Philadelphia District, Corps of Engineers, provided essential liaison and background information.

Abstract

Twenty-five stations in the Delaware portion of the C & D Canal system were sampled between March 1971 and December 1972. Both grab and dredge samples were collected for four stations during 1972.

More than 50,000 invertebrates of 23 species were collected and identified. The dominant organism in grab and dredge samples, as well as in fish stomachs, was Gammarus daiberi, Garveia franciscana, Limnodrilus sp., Neomysis americana, Crangon septemspinosa, Cyathura polita and Chiridotea almyra were also abundant.

Patterns of distribution within the study area seemed to be associated with water chemistry parameters and substrate.

Possible effects of enlargement of the C & D Canal are discussed.

Methods

Benthic invertebrates were sampled quarterly between March 1971 and December 1972 at 15 stations in the Delaware River approaches and the eastern half of the C & D Canal proper (Figure 1). An additional 10 stations were sampled in the first year of the study. Canal stations were located near the center of the channel, while river stations were usually on the 18 ft. contour at the edge of the channel and located by triangulation from shore land marks plus radar fixes (Table XXI).

The individuals involved in field operations are listed in Table I. Three replicate samples were taken at each station from the University of Delaware's R.V. Wolverine, a 52 ft. research vessel. A subsample for sediment size analysis was usually taken from one of the replicates. The sediment analyses will be described in Part B of this appendix.

Sampling was carried out with a $0.1m^2$ Van Veen type grab for the last five quarters of the study. A $0.1m^2$ Petersen grab was used for the first three collections because a Van Veen grab was not available. When this instrument was obtained, it was found necessary to modify it by the addition of 50 lbs. of lead to the top of the grab bucket. A large door was cut in the top to facilitate sediment sampling and reduce shock-wave scattering of animals (Wigley, 1967).

Epifaunal organisms were sampled with biological dredges on several occasions. A Menzies trawl (100cm X 10cm opening, X 300cm long) was tested in September and December 1971. A smaller rectangular biological dredge (42.5 X 24.5 X 43cm) was also used in December 1971.

In June 1972 a Detritus-Sledge built to the design of Ockelmann (1964) was tested. This device was about twice the size of Ockelmann's and carried a 50cm X 20cm X 100cm bag. The wide runners on this sledge reduced digging in soft substrates and gave a satisfactory sampling of the epifauna. The sledge was used at 4 stations in the last three sampling periods of this project to supplement the regular infaunal sampling schedule.

Salinity, dissolved oxygen, water temperature, and turbidity were measured at each station. The techniques used are described in Appendix VII.

Dry weight biomass was calculated for samples from Stations 2, 7, 11, and 19 for all eight quarters of the study. Samples preserved in alcohol were dried in an oven at 70°C to constant weight. Weights were checked at 12 and 24 hours. Covered aluminum dishes were used for drying the samples.

Identification of organisms was based on a number of sources (Smith, 1964; Edmondson, 1959; Pennak, 1953; Watling and Maurer, 1973).

Results & Discussion

Eight quarterly collections were made in the Delaware portion of the C & D Canal study area between March 1971 and December 1972. The combined catch in grabs and epifaunal dredges total 23 species which are listed in Table III. About half of these organisms were caught very infrequently, averaging less than two per quarterly collection.

The dominant organism in these samples, in numbers, frequency of occurrence, and biomass, was the amphipod Gammarus daiberi (Table III). This species was only recently described (Bousfield, 1969), as separate from Gammarus fasciatus, a common fresh water form. Gammarids are epifaunal organisms living in organic debris and vegetation over a variety of substrates.

Fish stomach analyses were carried out on 340 fish of various species. Grab totals are the summation of eight quarters of collections with a total of 459 samples of $0.1m^2$ each. The sledge samples represent three collections at each of four stations totaling $1,000m^2$. If both samples were quantitative, a twenty-fold difference would be expected. Since the dredge was frequently filled with sediment when retrieved, it may have sampled only a fraction of the area covered. Interpretation of data collected in this fashion is limited to qualitative comparisons, and the grab samples are, therefore, better estimators of population density.

The second most abundant invertebrate was the hydroid Garveia franciscana. This organism was found in colonies attached to rock or other hard substrate. It would, therefore, be inefficiently sampled with a bottom grab, and estimates of its abundance are qualitative at best. Substrate materials on which Garveia was found were densely covered, usually with five to ten colonies per cm^2. It is to be noted that this organism was not found in fish stomachs, as were the other common invertebrates. Gammarus and Garveia dominated both grab and dredge samples, together comprising 65% and 88.9% of the respective totals.

The third-ranking species in terms of abundance was the tubificid oligochaete Limnodrilus sp. This organism occurred in large numbers at stations 9-11 (Tables IV & V). Tubificid oliogochaetes are indicators of suboptimal water quality when they are dominant and other species are eliminated (Aston, 1973). Limnodrilus accounted for approximately 9% of organisms taken in grab samples, but only 2.9% of dredge totals. This discrepancy may be explained by the fact that this worm is primarily a burrower and probably would be picked up in a dredge only when bottom material was scooped up. Its poor representation in fish stomachs may also be due to its burrowing behavior.

The two isopods, Cyathura and Chiridotea, accounted respectively for 6.0% and 8.2% of grab samples and appeared in dredge samples and fish stomachs as well. Scolecolepides viridis, a polychaete worm, made up another 5.7% of the total grab collection, but was not a significant contributor to dredge or fish stomach samples. These three species together with Gammarus, Garveia, and Limnodrilus account for more than 90% of the organisms taken in grabs during the study. These can be considered the dominant members of the benthic community of the Delaware portion of the Canal system. Addition of the two, shrimp-like crustaceans, Crangon and Neomysis, from the dredge rankings and the blue crab which was abundant in fish trawls, completes the list of numerically important macroscopic invertebrates.

Two demersal crustaceans were more frequently found in fish stomachs than abundant infaunal organisms such as Limnodrilus. Neomysis americana, a mysid shrimp, and Crangon septemspinosa, a decapod, were respectively second and third in abundance in fish stomachs. Neomysis was third in abundance in dredge samples, but neither shrimp was common in grabs. Since both are efficient swimmers, they would be expected to escape the grab. Crangon is found in the water column as well as near the bottom and was sampled more efficiently by the fish than by either sampling device. Neomysis is also a strong swimmer but is less active in daylight hours than Crangon. Both of these animals occurred in large numbers only in the September samples. This pronounced seasonal cycle is supported by the incidental capture of Crangon in fish trawls only during the fall. It is worthy of note that these relatively mobile invertebrate species show seasonal changes in abundance similar to those seen in most of the fish species studied.

Seasonal cycles in numbers of benthic organisms were less well defined. Numbers of animals in grab samples were lower in March than in other quarters, but otherwise highly variable. Gammarus, Chiridotea almyra, Corophium lacustre, and Limnodrilus were most abundant in the summer, while Cyathura polita showed peak populations during colder months. The environmental periodicities to which these fluctuations were entrained were similar to those shown in the Delaware fish survey (Appendix VII). Temperatures ranged from near zero in winter to 27°C in mid-summer. Salinity was quite variable but tended to be highest in late summer (range 0.1 - 10 °/oo). Dissolved oxygen, being an inverse function of both salinity and temperature, dropped in summer. Concentrations in the 2-3 mg/l range were not unusual. The physical data collected in conjunction with the benthic survey are shown in Tables IX - XVI, which summarizes the individual quarterly collections.

Rangia cuneata shells comprised another 2% of the grab collection, but only six living clams were captured in the entire study. Since most of the shells were collected in the Canal proper, it is hypothesized that the shells are washing through from the upper Chesapeake Bay, where a viable population exists (Appendix III). The amphipod, Corophium lacustre, also accounted for about 2% of individuals in grab samples and might be considered of marginal significance in the ecology of the area.

Comparison of grab totals for 1971 and 1972 (Table IV), suggests a significant increase in numbers of organisms in the second year of the study. The average number of organisms per station in 1972 was 137.6 as compared to 69.2 in 1971 (Table IV), but the difference is attributable to the large number of Garveia in the June 1972 collection. It was mentioned previously that these hydroids are distributed irregularly, because they require hard substrate. Of the 3072 collected in June 1972, 2885 were on rocks in the sample from a single station, number 15, which is in a rocky area east of Pea Patch Island. This sample also contained over 1000 Gammarus, many of which were in association with the hydroids. If, as frequently happens, the grab had failed to pick up the rocks, the collection would have been reduced by about 4000 animals, and the average per station in June would have been about 150 instead of 369.2. Extending this hypothetical calculation to the yearly total, yielded an average for 1972 of 70.9 animals per station as compared to 69.2 in 1971. Since our observations of the distribution of Garveia support the chance occurrence of isolated populations of high density, it seems reasonable to conclude that this extremely large sample was not representative of the overall population. Thus, the apparent increase in number of benthic invertebrates in the Canal area was a sampling artifact produced by the non-random distribution of Garveia.

Grouping of stations by geographic location brought out some differences in the species makeup of benthic populations in representative parts of the study area (Table VI). Stations 1-3 were in the Canal proper; stations 9, 11, 12 north of the Canal near the Pea Patch Island jetty; and 17, 19, 21 south of the Canal near Reedy Island. There were no significant differences in the total numbers of organisms, but individual species were distributed in consistent patterns throughout the two-year study.

Garveia franciscana appeared to be less abundant in the Canal proper than in the Delaware River approaches, presumably because the necessary hard substrate was scarce in the Canal proper. The isopod Cyathura polita was also relatively rare in the Canal, but common at representative stations both north and south of the Canal. This is a burrowing organism which might be expected to be most successful in fine sediments. Distribution of sediment types in the study area was considered as a potential source of variability in benthic populations. Description of sediment types at bottom sampling stations is presented in Table VII, and additional detail will be found in Part B of this appendix. In general, the Delaware portion of the Canal had a well sorted medium to fine sand substrate prior to dredging. This has been altered by siltation at station 2 and 3, with the change correlating well with the times of dredging.

The dominant benthic species in the Canal proper were the polychaete Scolecolepidus viridis, the isopod Chiridotea almyra and the amphipod Gammarus daiberi. All are characteristic of sandy crustaceans and in this study was more limited in distribution. Gammarus, on the other hand being an epifaunal organism is probably less limited by substrate. Chiridotea was also common at sandy stations in the river such as stations 12 and 17 in June 1971 (Table X). The empty valves of Rangia cuneata which are thought to wash through the Canal from its western end, were concentrated in the Canal proper and also to the south of the Canal. This is presumably a function of current movement rather than substrate. Relatively few Rangia shells were found in the area west of Pea Patch Island which dye studies have shown to receive flow from the Canal when flood tides coincide in the two bodies of water.

The area north of the Canal was distinctive in being dominated by the oligochaete, Limnodrilus sp. This worm can thrive in heavy sulfurous silts with low oxygen concentrations. Much of the bottom west of Pea Patch Island was of this type. Grab samples contained oily black silt which had a strong hydrogen sulfide odor. Clay and sand were relatively minor constituents. Limnodrilus occurred only rarely south of the Canal although suitable substrate was available. Possibly the slightly higher average salinity limited its invasion of this area.

Stations to the south of the Canal were dominated by silty substrate with the exception of #17 and #21 which were characterized by moderately well sorted fine to medium sand. Both of these were included in the group of stations representing the area south of the Canal, and may bias the results in favor of organisms associated with sandy substrates.

The organisms associated with this area (Table VI) were Corophium lacustre and Rhithropanopeus harrisi. Corophium is a tube-dwelling amphipod found in brackish waters (Brown, 1971) and Rhithropanopeus is a euryhaline decapod. It is likely that salinity rather than substrate is the most important factor in the localization of these two species south of the Canal.

Biomass values were obtained for four selected stations throughout the two year study (Table VIII). Variation between weights amounted to several orders of magnitude as was the case for the numbers of animals per sample. Replicate grabs totaling $0.3m^2$/station were extrapolated to $1.0m^2$ for purposes of comparison with data from other sources. These values ranged from 0.023 to 1.265 g/m^2.

Station #7 west of Pea Patch Island was most productive based on a quarterly average. Gammarus and Limnodrilus were the dominant organisms in these samples as in most of those collected north of the Canal. The Canal biomass average was only 0.038 g/m^2 which could be an underestimate since stations #2 produced fewer organisms than others in the Canal. Lack of biomass in the Canal proper is also probably due to lack of substrate variation and high current velocities.

Summary

The invertebrate populations in the Delaware part of the Canal system were dominated by the same eight species throughout the two year study. Gammarus daiberi, Garveia franciscana, Limnodrilus sp., Chiridotea almyra, Cyathura polita and Scolecolepides viridis each accounted for more than 5% of the organisms collected in grab samples. Neomysis americana and Crangon septemspinosa were rare in grabs, but abundant in dredge collections. All of the above, with the exception of Garveia, were significant in the diets of local fish, as evidenced by their presence in stomachs examined during the study.

Although variation between samples was large, it was possible to document patterns in the distribution of the more abundant species. Garveia was always associated with hard substrate such as wood or stones and seemed to be less abundant in the Canal proper than at River stations, possibly because frequent dredging prevents accumulation of suitable substrate.

If the siltation observed at Canal stations (Part B of this appendix) persists, it is possible that the present benthic species will be replaced by a community of animals which is better adapted to fine substrates. Cyathura polita and Limnodrilus are potential invaders. It is reasonable to assume that any permanent change in the water quality of the area resulting from the Canal enlargement, would be limited to a slight drop in salinity. Since most of the species now present are able to tolerate fresh water, one would expect only a few brackish forms such as Rhithropanopeus and Corophium to be affected, and overall impact of the salinity drop would be minor.

Examination of fish stomach contents and invertebrate biomass data supports the conclusion that the Delaware end of the Canal is at present relatively unproductive and serves primarily as a highway for transfer of mobile fish species, and their eggs and larvae between the Chesapeake Bay and the Delaware River. Of the species which utilize the Canal, the white perch and catfish should be most sensitive to changes in the invertebrate populations, since they depend on invertebrates as a source of food, and remain within the Canal system year round. It is uncertain what changes in sedimentation will occur in the first few years after completion of the enlargement, but reduced dredging frequency might permit expansion of the Canal's benthic community. This would increase the probability of the Canal supporting a significant resident fish population.

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Figure I - BENTHOS SAMPLING STATIONS IN DELAWARE

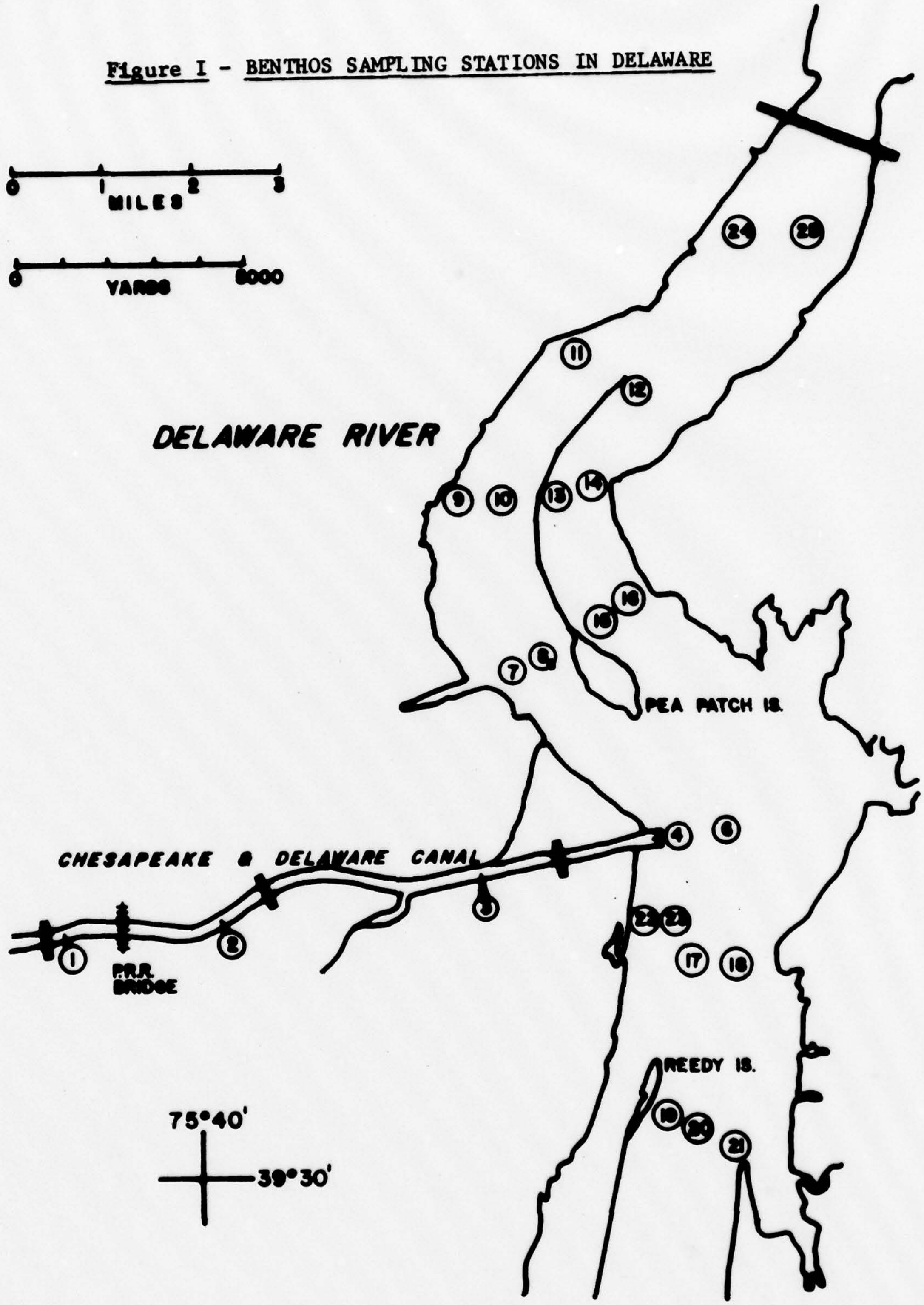

Table I - Benthic Study Field Operations Personnel

NAME	TITLE	Responsibility
Malcolm H. Taylor, Ph.D.	Research Associate	Field Coordinator
William R. Hall, M.S.	Biologist	Identification and Enumeration of Organisms
Ronal W. Smith, M.S.	Resident Biologist	Field Operations
Lanny M. Katz	Graduate Assistant	Field Operations
Neal Parker	Graduate Assistant	Field Operations
Milton W. Cooper	Boat Captain	Vessel Operations
W. F. Carlsten	Utilities Mechanic	Vessel Operations
David Matthews	Boat Engineer	Vessel Operations

Table II - Comparison of 0.1 m^2 Petersen and Van-Veen Grabs (Dec. 1972)

Station #	2		7		12		Total	
Grab Type	Pet.	Van V.	Pet.	Van V.	Pet.	Van V.	Pet.	Van V
Bottom Material	Sand	Silt	Silt	oily Silt	sand	sandy silt		
Grab (% Full)	100	100	70%		100%	85		
Species								
Garveia franciscana					10		10	0
Scolecolepides viridis		2		20	6	13	6	35
Rangia cuneata						1	0	1
Chiridotea almyra		2		8	3	2	3	12
Cyathura polita			4		4	5	8	5
Corophium lacustre			4				4	0
Gammarus daiberi	1	6	11	8			12	14
Rhithropanopeus harrisi			2				2	0
Limnodrilus sp.	9	1		2			9	3
Callinectes sapidus			1				1	0
Total	10	11	22	38	23	21	55	70

Table III - Invertebrates Sampled in Delaware End of C & D Canal System.

Species	Totl. in Grabs[1]	Rank-Grab Sampl.	Cum. %	Totl. Sledge[2]	Rank-Sledge Sampl	Cum %	Totl. in Fish Stom.[3]	Rank-Stom. Samp.	Cum. %
Hydrozoa									
Garveia franciscana	4591	2	65.0	9159	2	88.9			
Nematoda									
Unidentified	8			0			12	9	
Hirudinea									
Helobdella stagnalis	6			2					
Oligochaeta									
Limnodrilus sp.	1314	3	73.9	1099	4	95.8	14	8	
Polychaeta									
Scolecolepides viridis	835	6	93.8	20				1	
Nereis succinea	8			3					
Cirripedia									
Balanus balanoides	37			1			5	10	
Chthamalus fragilis	1			0					
Isopoda									
Cyathura polita	888	5	88.1	222	8	99.0	26	6	
Chiridotea almyra	1210	4	82.1	404	5	96.9	22	7	
Amphipoda									
Monoculodes edwardsi	4			221	9	99.6			
Gammarus daiberi	4969	1	33.8	25,001	1	65.1	3477	1	88.7
Corophium lacustre	272	8		80	10	99.8	27	5	
Mysidacea									
Neomysis americana	71	10	97.4	1530	3	93.0	165	2	92.9
Decapoda									
Crangon septemspinosa	8			367	6	97.8	98	3	95.4
Palaemonetes sp.	1			7					
Rhithropanopeus harrisi	171	9	97.0	225	7	98.5	3		
Callinectes sapidus				1					
Insecta (Larvae)									
Cryptochironomus sp.	5			0			69	4	
Chaoborus sp.	1								
Pelecypoda									
Rangia cuneata (valves)	286	7	95.8	7 + 50 living					
Anadara ovalis	3			0					
Modiolus sp.	2			0					
Ectoprocta									
Amathia vidovici	17	12		0					
TOTAL NO.	14,707			38,384			3919		
No. of Samples	153			12			340		
Avg. No./Samples	96.1			3198.7			11.5		

1. Grab totals are for 15-25 stations sampled in 1971 and 1972 as summarized in Table V.
2. Sledge totals are for 4 stations sampled three times in 1972 as summarized in Table V.
3. Fish stomach totals are for 340 stomachs of 6 species as summarized" in Table IX - XVII of Appendix J."

Table IV - Quarterly Totals for Grab Samples

	1971 Mar	June	Sept	Dec	Total	1972 Mar	June	Sept	Dec	Total	Grand Total
G. franciscana	10	26	102	736	874	120	3072	11	514	3717	4591
Nematode	6				6					0	6
H. stagnalis	1			1	2	2	2			4	6
Limnodrilus sp.	139	189	182	86	596	78	506	95	39	718	1314
S. viridis	197	55	25	41	318	17	177	198	125	517	235
N. succinea	2	4	1	1	8	0	0	0		0	8
B. balanoides		4			4		1		32	33	37
C. fragilis		1			1					0	1
C. polita	207	147	62	200	616	78	90	35	69	272	888
C. almyra	44	236	388	51	791	4	185	266	36	491	1210
M. edwardsi					0	2	2			4	4
G. daiberi	12	728	887	1229	2856	12	1403	79	619	2113	4969
C. lacustre	9	9	91	61	126	13	7	81	1	102	272
N. americana	5	5	5	1	16		1	42	2	45	71
C. septemspinosa	2		1		3			5		5	8
Palaemonetes sp.			0		0		1			1	1
R. harrisi	16	17	18	39	90	17	26	21	17	81	171
Insect larvae	4			1	5		2			2	7
R. cuneata (valves)	37	34	32	34	137	47	61	33	8	149	286
A. ovalis	2	0	0	0	2	0	0	0	1	1	3
Modiolus sp.				1	1		1			1	2
A. vidovici	5	7	1	3	16	0	1	0	0	1	17
Total Organisms	698	1462	1795	2485	6440	390	5538	856	1463	8257	
No. Stations	23	24	24	22	93	15	15	15	15	60	1376
avg/station($0.3m^2$)	30.3	60.9	74.8	113.0	69.2	26.0	369.2	57.7	97.5	137.6	
est. organisms/m^2	101.0	203.0	249.3	376.7		86.7	1230.7	192.3	325.0		

Table V - Quarterly Totals in Detritus - Sledge Collections 1972

Species	Station #2 June	Sept	Dec	Total	Station #7 June	Sept	Dec	Total	Station #11 June	Sept	Dec	Total	Station # 19 Jun	Sept	Dec	Total
G. franciscana						20		20	75	8	4000	4083	21	5000	35	5056
H. stagnalis									2			2				
Limnodrilus sp.	3			3			3	3	15	1000	7	1022		71		71
A. viridis		1	10	11					1	1		2	2	1	4	7
N. succinea													3			3
B. balanoides											1	1				
C. polita	5	2		7	29		9	38	57	23	46	126	39	6	6	51
C. almyra	4	5	15	24	324		5	329	7	19	2	28	7	1	15	23
M. edwardsi									1	220		221				
G. daiberi	531	26	93	650	3300	175	363	3838	16100	1166	107	17373	2170	363	607	3140
C. lacustre					1			1			16	16	62		1	63
N. americana		328		328		100		100		701		701		401		401
C. septemspinosa						50		50		255		255		62		62
Palaemonetes sp.													7			7
R. harrisi					9	1	3	13	4	8	5	17	185	28	12	225
C. sapidus										1		1				
R. cuneata											12	12				
Total/Station/quarter	543	362	118		3663	346	383		16252	3402	4196		2496	5935	680	
Total/Station				1013				4392				23860				9109

Table VI - TOTAL BENTHIC INVERTEBRATES PER YEAR IN GRABS AT REPRESENTATIVE STATIONS

Station Numbers / Location	1971 (1-3) Canal	1971 9,11,12 North	1971 17,19,21 South	1972 (1-3) Canal	1972 9,11,12 North	1972 17,19,21 South	Mean of All[1] Station ± S.D.	Individual Means[2] 1-3 Canal	Individual Means[2] 9,11,13 North	Individual Means[2] 17,19,21 South
Garveia franciscana	7	3	149	51	117	105	72.0±60.8	29.0	60.0	127.0
Nereis succinea	1	3	4	0	0	0		0.5	1.5	2.0
Scolecolepidos vividis	123	10	54	243	34	134	99.6±85.7	183	22	94
Rangia cuneata	54	6	38	62	10	53	37.2±23.9	58	8	45.5
Chirodotea almyra	173	82	117	235	144	71	137.0±61.0	204	113	94
Cyathura polita	6	93	93	8	79	54	55.5±40.2	7.0	86.0	73.5
Corophium lacustre	0	0	47	7	1	71	21.0±30.5	3.5	0.5	59
Gammarus daiberi	64	378	195	176	64	215	182.0±116.0	120	221	205
Rhithropanopeus harrisi	0	1	14	2	1	30	8.0±12.0	1.0	1.0	17.0
Amathia vidovici	0	2	1	2	0	0		1.0	1.0	0.5
Anadara ovalis	0	1	0	0	1	0		0	1.0	0
Limnodrilus sp.	4	265	8	5	479	2	127.2±201.4	4.5	372	5.0
Neomysis americana	0	2	2	0	0	0		0	1.0	1.0
Crangon septemspinosa	0	0	1	0	0	2		0	0	1.5
Helobdella stagnalis	0	0	0	0	2	0		0	1.0	0
Balanus sp.	0	0	0	1	0	0		0.5	0	0
Total	427	847	724	811	932	741				

1. Mean of three groups of stations over two years ± Standard Deviation.
2. Means of two yearly totals for each group of stations.

Table VII - DESCRIPTION OF SEDIMENT TYPES AT BENTHIC STATIONS IN THE DELAWARE STUDY AREA

STATION		
1	Well sorted fine sand	(generally)
2	Well sorted medium sand	(before dredging)
	Poorly sorted silt	(after dredging)
3	Well sorted medium sand	(before dredging)
	Poorly sorted silt	(after dredging)
4	Well sorted medium sand	
6	Moderately well sorted fine silt	
7	Poorly sorted fine silt and clay	
8	Poorly sorted fine sand and silt	
9	Moderately well sorted silt	
10	Well sorted very fine sand with trace of silt	
11	Poorly sorted silt	
12	Well sorted medium to coarse sand	
13	Well sorted fine silt	
14	Poorly sorted silt and very fine sand	
15	Extremely variable	
	Predominantly poorly sorted silt	
16	Moderately well sorted coarse silt	
17	Moderately well sorted fine to medium sand	
18	Very poorly sorted fine silt and clay	
19	Poorly sorted silt	
20	Poorly sorted fine silt and clay	
21	Moderately well sorted medium sand	

Table VIII - DRY WEIGHT BIOMASS AT SELECTED STATIONS IN THE DELAWARE PART OF THE C & D CANAL SYSTEM.

	Biomass/Station ($g/0.3m^2$)			
STATION #	2 (Canal)	7 (3 Mi.North)	11 (5 Mi.North)	19 (3 Mi.South)
March 1971	0.021	0.326	0.003	0.138
1972	0.002	0.027	0.002	0.233
Average	0.012	0.177	0.013	0.185
Average/m^2 (1)	0.040	0.590	0.043	0.616
June 1971	0.016	0.065	0.119	0.046
1972	0.002	0.347	0.062	0.425
Average	0.009	0.206	0.091	0.236
Average/m^2	0.023	0.686	0.303	0.789
Sept.1971	0.027	0.173	0.100	0.067
1972	0.001	0.587	0.025	0.144
Average	0.014	0.380	0.066	0.106
Average/m^2	0.047	1.265	0.220	0.353
Dec. 1971	0.004	0.639	0.055	0.215
1972	0.022	0.029	0.033	0.012
Average	0.013	0.334	0.044	0.114
Average/m^2	0.043	1.112	0.147	0.380
Average/quarter/m^2 (2)	0.038	0.913	0.178	0.535

(1.) Averages per m^2 were extrapolated from $0.3m^2$ data.
(2.) Mean of average per m^2 for each station

Table IX - Summary Benthic Data - March & April 1971

Station No.	1	2	3	4	6	7	8	9	10	11	12	13
Date	3/31	3/31	3/31	4/1	4/1	3/30	3/30	3/30	3/30		3/30	4/1
Time	16:35	16:18	14:30	08:50	11:15	10:20	11:25	12:55	13:40		15:25	13:45
Tide	ebb	ebb	flood	flood	ebb		flood	flood			slack	flood
Water Temp(^{o}C)	6.4	6.3		6.5	6.6	6.5	6.5	6.6	6.7			6.9
Salinity($^{o}/00$)	1.351	1.352		1.134	0.527	0.327	0.5035	0.420	0.603	0.385	0.911	0.266
Dissolved O_2($^{m3}/2$)	5.325	6.34		3.86	5.70	4.87	6.585	6.585	6.43	6.14	6.50	5.79
pH												
Secchi Disc(cm.)	17.cm	24cm		16cm	22cm							26cm
Grab(%Full)	23%	23%	67%	62%	30%	97%	95%	100%	100%		90%	100%
Bottom type	sand	sand gravel mud-clay	sand gravel clay	coarse sand	black mud & clay	Black mud or clay	black mud	black mud & detritus	black mud & detritus	black mud detritus	mud sand pebbles	mud & detritus
Species												
Garveia franciscana				2					4	1		1
Nereis (neanthes) succinea		1										
Scolecolepides viridis	57	15	1			1				2	1	
Rangia cuneata	5		4	10							2	2
Chiridotea almyra		1		3	2							1
Cyathura polita		2			2	133	2			1	4	1
Corophium lacustre												
Gammarus daiberi												
Leptocheirus pinguis						5						
Rhithropanopeus harris				2		6						
Amathia vidovici								1	2			1
Anadara ovalis						1				1		
Limnodrilus sp.								8	19	14	1	1
Chaoborus sp.									1			
Nematode (Unidentified)									33	2		
Chryptochironomus												
Total animals Per Station	62	19	5	17	9	4	146	2	9	29	21	10

Table IX - Summary Benthic Data - March & April 1971

Station No.	14	15	16	17	18	19	20	21	22	23	24	25	Total Animals
Date	4/1	4/1	4/1	3/31	3/31	3/31	3/31	3/31	3/31				
Time	12:43	15:48	14:50	12:00	13:55	0:910	10:00	10:43	---				
Tide	flood	flood	flood	flood	flood	Ebb	Ebb	Ebb	---				
Water Temp(^oC)	6.9		6.7	6.4	6.2	6.1	6.3	6.0	---				
Salinity($^o/00$)	0.232	0.981	0.795	0.729	1.274	0.933	0.783	0.886	---				
Dissolved O_2($^{m3}/2$)	4.13	6.077	5.93	6.285	6.850	6.21	---	5.875	---				
pH													
Secchi Disc(cm.)	24cm		17cm		20cm		24cm	26cm	---				
Grab(%Full)	57%	57%	43%	69%	28%	33%	10%	57%	100%				
Bottom type	black mud & fine sand	mud & gravel & sand	hard gray clay some sand	black mud & sand	black mud & some sand	black mud & clay	sand & gravel	mud sand gravel detritus	mud & sand				
Species													
Garveia franciscana	1						1						10
Nereis (neanthes) succinea						1							2
Scolecolepides viridis	5	3	1	7	4	7		5	34	49			197
Rangia cuneata					2			4	8				37
Chiridotea almyra	2		11	1	3			2	10	3			44
Cyathura polita	5		5	4	2	41			3	1			207
Corophium lacustre													0
Gammarus daiberi	1	1						1	2	7			12
Leptocheirus pinguis		2	1			1							9
Rhithropanopeus harrissi		1				6	1						16
Amathia vidovici	1												5
Anadara ovalis													2
Limnodrilus sp.	3	84	6						3				139
Chaoborus sp.													2
Nematode (Unidentified)		3											1
Chryptochironomus		1											10
* Crangon septemspinosa									1	1			4
Total Animals Per Station	18	95	25	12	11	56	2	12	61	66			
Helobdella stagnallis			1										
Neomysis americana										5			

Table X - Summary Benthic Data - JUNE 1971

Station No.	1	2	3	4	6	7	8	9	10	11	12	13	
Date	6/8	6/8	6/7	6/7	6/7	6/10	6/10	6/10	6/10	6/9	6/9	6/9	
Time	17:25	16:45	16:30		15:50	09:20	09:50	10:30	11:00	14:25	13:50	11:27	
Tide	east strong	east strong	east (2k)	ebb	ebb	flood	flood	flood	flood	ebb	High sl. early ebb	flood	
Water Temp(^{o}C)	22.00	21.90^{o}	21.80^{o}	21.30^{o}		22.30^{o}		22.5			22.5^{o}c		
Salinity(^{o}/00)	1.087	1.3865	2.0965	2.314		0.833		0.628			1.281		
Dissolved O_2(m^3/2)													
pH			7.1	6.85									
Secchi Disc(cm.)		58 cm.				38 cm.		57cm			57cm		
Grab(%Full)	37%	62%	47%	40%	47%	42%	66%	76%	100%	70%	43%	43%	
Bottom type	clay, some fine sand	black mud fine sand	fine sand detritus	sand & gravel clay & mud	clay &mud	clay &mud	clay &mud	mud clay oily sand	oily mud clay	black mud some clay	mud & clay little sand	muddy clay	
Species													
Garveia franciscana		2	1	1	1		2						
Nereis(neanthes) succinea													
Scolecolepides viridis	15	7	5										
Rangia cuneata	4	8	7	1									
Chiridatea almyra	35	14	6	3			7	3	3	6	55	5	
Cyathura polita		2	1		5	32	2	1		24	5		
Corophium lacustre													
Gammarus daiberi	1	13	9	16	7		20	8		88	26	12	
Leptocheirus pinguis						1							
Rhithropanopeus harrisi						2							
Amathia vidovici				1	4								
Anadara ovalis													
Limnodrilus sp.	1							4	54	84			
Total Animals Per Station	56	46	29	22	17	35	31	16	57	202	86	17	

Table X - Summary Benthic Data - June 1971

Station No.	14	15	16	17	18	19	20	21	22	23	24	25	Total Animals
Date	6/9	6/9	6/9	6/8	6/8	6/8	6/8	6/8	5/5	5/5	6/9	6/9	
Time	10:45	09:05	09:57		12:45	13:10	14:15	14:35			12:47	14:15	
Tide	flood	flood	flood	ebb strong	ebb strong	ebb	ebb	ebb			flood	flood	
Water Temp(^{o}C)	22.4	22.4		21.1	21.1	20.8		21.6			22.4		
Salinity($^{o}/00$)	0.479	0.312		3.339	3.4165	4.686		3.304			0.475	1.168	
Dissolved O_2($^{m3}/2$)													
pH													
Secchi Disc(cm.)	26cm.	55cm						35cm			32cm		
Grab(%Full)	53%	53%	27%	66%	32%	60%	73%	60%			40%	60%	
Bottom type	soft mud & detritus	rocks gravel sand & mud	hard muddy clay	sand little mud	clay mud sand gravel	mud clay	finesand mud clay	mud & fine sand	mud sand	mud sand	mud clay detritus	black mud &clay	
Species													
Garveia franciscana	1	11	2				1	2				2	26
Nereis(Neanthes) succinea	1			1		1		1					4
Scolecolepides viridis	3			4			1	8		8	4		55
Rangia cuneata	1			4	4		1	4					34
Chiridatea almyra	20			40	15		5	1		12	6		236
Cyathura polita		7	1		1	5	1	6	3	/2	6	43	147
Corophium lacustre						1		1					2
Gammarus daiberi	275		9	6	40	9	50	36	27	/1	43	32	728
Leptocheirus pinguis								5		/1			7
Rhithropanopeus harris		3				1			11				17
Amathia vidovici	2												7
Anadara ovalis													0
Oligochaet-Tubifex	1	1	5					2			4	33	189
Neomysis americana				1	2	1	1						5
Chthamalus fragilis								1					1
Balanus balanoides								4					4
Total animals Per Station	304	22	17	56	62	18	60	71	41	24	63	110	1462

Table XI - Summary Benthic Data - September 1971

Station No.	1	2	3	4	6	7	8	9	10	11	12	13
Date	9/10	9/9	9/9	9/10	9/10	9/9	9/9	9/9	9/9	9/8	9/8	9/8
Time	0815	0830	1540	0930	1015	1415	1430	1340	1305	1510	1430	1220
Tide	slack	East 0.5	west	slack		flood	flood	flood	flood 2k	flood	flood	flood
Water Temp(^{o}C)	25.4	25.1	25.7	25.4		25.6			25.5	25.2		
Salinity(^{o}/00)	1.67	2.58	2.80	2.71		2.04			1.28	2.06		
Dissolved O_2(^{m3}/2)	4.12	5.04	4.96	3.84		3.54			3.26	3.49		
pH	6.9	7.0	7.1	7.0		6.9			6.8	6.9		
Secchi Disc(cm.)	55.0	55.0	22	22		30			---	40		
Grab(%Full)	40	70	30	50	50	45	65	100	90	70	35	25
Bottom type	sand	m-s	m-s	s&g	m-c	m-c	m-c	0.1 black muc	oil black mud	s-m	m-s	m-s
Species												
Garvia franciscana			1	5	50	1					1	
Nereis succinea												
Scolecolepides viridis	1	6	3	1							6	
Rangia cureata	8	1	2	6								2
Chiridotea almyra	56	39	19	3	1		1			1	4	7
Cyathura polita		1				12				7	4	2
Coriphium lacustre					2	30						
Gammarus daiberi	12	7	20	22	40	16	47	2	3	213	38	184
Leptocheirus pinguis	1					16						
Rhithropanopeus harrisi				1		8					1	
Amathia vidovici												1
Anadara ovalis												
Limnodrilus sp.		1	2					80	69	24		
Palaemonetes												
Crangon septemspinosa												
Neomysis americana			2							1		
Total Animals Per Station	78	55	49	38	93	83	48	82	72	247	55	194

Table XI - Summary Benthic Data - September 1971

Station No.	14	15	16	17	18	.19	20	21	22	23	24	25	Total Animals
Date	9/8	9/8	9/8	9/10	9/10	9/9	9/9	9/9	9/30	9/30	9/8	9/8	
Time	1125	0950	1040	1045	1120	1055	1003	1035	1045	1000	1325	1400	
Tide	flood	late ebb	slack low	ebb0.5	ebb	early flood	ebb 1¼	near slack ebb	ebb 2k	ebb0.5	flood	flood	
Water Temp(^{o}C)	25.0	25.0		25.6		25.4						25.1	
Salinity(^{o}/00)	0.90	0.82		1.51		1.83						0.67	
Dissolved O_2(^{m3}/2)	1.73	1.74		3.74		3.07						1.07	
pH	6.7	6.8		6.7		6.9						6.6	
Secchi Disc(cm.)	33	40		40		40						30.0	
Grab(%Full)	75	40	30	75	30	40	25	30			50	40	
Bottom type	oil m-s	m-c-stone	clay	s-m	c-m	m-c	s&stones	s-m-c	s-m-c	s	stones m-s	oil m-s	
Species													
Garvia franciscana		30		2			1	4	2		5		102
Nereis succinea						1							1
Scolecolepides viridis		1		1			3	1	2				25
Rangia cureata	3			7			1	2					32
Chiridotea almyra	11		1	57	2		101	5	1	72	6	1	388
Cyathura polita		6	2			8			15			5	62
Corophium lacustre			2			23			6				63
Gammarus daiberi	3	44	18	10	28	18	15	11	7	6	69	56	887
Leptocheirus pinguis						9			1			1	28
Rhithropanopeus harrisi		6				2							18
Amathia vidovici													1
Anadara ovalis													0
Limnodrilus sp.				2					2			2	182
*													
Total Animals Per Station	17	87	24	79	30	62	121	27	35	78	80	65	
* Palaemonetes													0
Crangon sept.								1					1
Neomysiraneus						1			1				5

Table XII - Summary Benthic Data - December 1971

Station No.	1	2	3	4	6	7	8	9	10	11	12	13
Date	12/7/71	12/7/71	12/7/71	12/7/71	12/9/71	12/9/72	12/9/71	12/8/71	12/8/71	12/8/71	12/8/71	12/8/71
Time	15:10	08:50	10:25	11:45	15:07	13:30	14:20	15:30	13:55	14:35	13:50	11:53
Tide	West 1K	East .5k	East 1k	East 1.5k	Flood 2k	Flood 2k		Flood 2k	Flood	flood 2k	flood 2k	near slack
Water Temp(°C)	5.0	5.5	5.5	5.5	7.5	6.3	---	6.1	---	6.2	---	---
Salinity(°/00)	1.116	1.054	1.060	1.055	0.563	0.208	---	0.504	---	0.212	---	---
Dissolved O_2(^{m3}/2)	6.0	5.19	4.81	5.48	4.25	3.95	---	4.84	---	3.90	---	---
pH	6.8	7.1	6.8	7.1	6.95	6.8	---	7.1	---	7.0	---	---
Secchi Disc(cm.)	20.0	30.0	20.	20.	30.	30.	---	40.	---	30.	---	---
Grab(%Full)	77.	90.	80.	77.	80.	84.	92	88.	94	100	57	94
Bottom type	Silty-Sand	Silty-Sand	Sand	Ditritus sand	organic silt	organic silt	organic silt	mud	mud	mud	mud clay	oily mud & clay
Species												
Garveia franciscana		1	2	8	---	---	---	---	---	1	---	---
Nereis(Neanthes) succinea	---	---	---	---	---	---	---	---	---	---	---	---
Scolecolepides viridis	5	2	6	1	---	---	1	1	---	---	---	---
Rangia cuneata	3	1	11	---	---	---	---	---	---	---	2	---
Chiridotea almyra	2	1	---	---	1	---	---	2	1	3	6	2
Cyathura polita	---		---	---	1	40		16	---	31	---	---
Corophium lacustre	---	---	---	---	---	4	---	---	---	---	---	---
Gammarus daiberi	1	1	---	---	3	5	53	2	---	1	---	4
Leptocheirus pinguis	---	---	---	---	---	---	---	---	---	---	---	---
Rhithropanopeus harrisi		---	---	---	---	20	---	---	---	---	---	---
Amathia vidovici	---	---	1	---	---	---	---	1	---	---	---	---
Anadara ovalis	---	---	---	---	---	---	---	---	---	---	---	---
Neomysis sp.	---	---	---	---	---	---	---	---	---	---	---	---
Limnodrilus sp.	---	---	---	---	---	---	---	---	16	50	---	---
Modiolus sp.	---	---	1	---	---	---	---	---	---	---	---	---
Chryptochirohomus	---	---	---	---	---	---	---	---	---	1	---	---
Helobdella stagnalis	---	---	---	---	---	---	---	---	---	---	---	---
Total animals per station	11	6	21	9	5	79	55	22	17	87	8	6

Table XII - Summary Benthic Data - December 1971

Station No.	14	15	16	17	18	19	20	21	22	23	24	25
Date	12/8/71	12/8/71	12/8/71	12/9/71	12/9/71	12/9/71	12/9/71	12/9/71	----	----	12/8/71	12/8/71
Time	11:15	09:27	10:15	09:15	10:00	09:48	11:20	10:34	----	----	12:30	13:15
Tide	Near Slack	Late Ebb	Late Ebb	Ebb	Ebb.5k	Ebb.5k	Ebb 1k	Ebb 1k	----	----	early flood	flood
Water Temp(^{o}C)	6.3	6.1	----	6.2	-----	-----	6.0	-----	----	----	-----	6.0
Salinity(^{o}/00)	0.184	0.351	-----	0.740	-----	-----	0.624	-----	----	----	----	0.139
Dissolved O_2(^{m3}/2)	4.65	4.18	----	5.01	-----	-----	4.45	-----	----	----	-----	4.72
pH	6.9	6.8	----	6.8	-----	-----	-----	-----	----	----	-----	6.9
Secchi Disc(cm.)	30	30	----	20	-----	-----	30	-----	----	----	-----	50
Grab(%Full)	80	87	63	93	83	73	.21	50	----	----	53	80
Bottom type	Oily & mud clay	mud & silt	mud & clay	black mud	silt& gravel	organic silt - star	sand & gravel	mud	----	----	mud-clay & silt	black mud & clay
Species												
Garveia franciscana	---	365	----	1	4	-----	38	140	----	----	1	175
Nereis(Neanthes) succinea	----	----	----	----	----	-----	1	----	----	----	----	----
Scolecolepides viridis	----	2	----	4	----	1	2	16	----	----	----	----
Rangia cuneata	----	----	----	2	----	----	----	21	----	----	----	----
Chiridotea almyra	1	----	1	7	5	----	----	4	----	----	9	6
Cyathura polita	----	18	5	----	----	17	5	12	----	----	.1	53
Corophium lacustre	----	1	34	----	----	12	----	10	----	----	----	----
Gammarus daiberi	1	18	981	2	13	5	29	97	----	----	1	2
Leptocheirus pinguis	----	----	----	----	----	----	----	----	----	----	----	----
Rhithropanopeus harrisi	----	4	10	----	----	5	----	----	----	----	----	----
Amathia vidovici	----	----	----	----	----	----	----	1	----	----		
Anadara ovalis	----	----	----						----	----		
Neomysis sp.	----	----	----						----	----		
Limnodrilus sp.	-----	5	3						----	----		
Modiolus sp.	----	----	----						----	----		
Chryptochirohomus	----	----	----						----	----		
Helobdella stagnalis	---	1	----						----	----		
Total animals per station	2	414	1034	16	22	40	75	298	----	----	.12	246

Table XIII - Summary Benthic Data - March 1972

Station No.	1	2	3	4	6	7	8	9	10	11	12	13	
Date	3/6	3/6	3/8	3/8	3/8	3/8	3/8	3/7		3/7	3/7		
Time	10:15	11:50	13:40	1015	09:40	11:20		12:20		1415	1250		
Tide	east 1.5k	flood	east 2k	ebb 1k	ebb 1k	ebb 1k	ebb 1k	flood		flood	flood		
Water Temp(^{o}C)	4.4^{o}c	4.4	3.7		5.5		6	6.1		5.9	---		
Salinity(^{o}/00)	0.288	0.283	0.136	---	0.244		0.156	0.235		0.165	0.152		
Dissolved O_2(^{m3}/2)			No Oxygen Data										
pH			No PH Data										
Secchi Disc(cm.)	40cm	40cm	20cm	---	30cm	---	35cm	30cm		30cm	---		
Grab(%Full)	100%	50%	74%	45%	52%	52%	45%	84		62	85		
Bottom type	sandy silt	clay gravel	sand	sand& gravel	sand silt	sandy silt	black silt	sandy silt		sandy silt	sandy silt		
Species													
Garveia franciscana				4				10					
Nereis(Neanthes)s succinea													
Scolecolepides viridis	6	1											
Rangia cuneata	2	1 shell 1 juv clam	18	12							6		
Chiridotea almyra	1		1										
Cyathura polita	6				6	11	3			17			
Corophium lacustre	1					1							
Gammarus daiberi	1			1	3		1						
Leptocheirus pinguis													
Rhithropanopeus harrisi	2					1							
Amathia vidovici													
Anadara ovalis													
Limnodrilus sp.		3			1		3	4		36	21		
Monoculodes edwardsi							1						
Helobdella stagnalis											2		
Total Animals Per Station	19	6	19	17	10	13	8	14		53	29		

Table XIII Summary Benthic Data - March 1972

Station No.	14	15	17	19	21				Total Animals
Date	3/7	3/7	3/6	3/6	3/6				
Time	12:12	11:30	15:15	1330	1430				
Tide	flood .5-1k	flood 1.5k	flood .5k	flood 1k	flood 1k				
Water Temp(^{o}C)	5.7	5.7	4.8	---	40				
Salinity($^{o}/00$)	0.164	0.155	0.567		0.326				
Dissolved O_2($^{m3}/2$)									
pH									
Secchi Disc(cm.)	35cm	40cm	30	---	30				
Grab(%Full)	62	44	100	54					
Bottom type	silt & fine sand	gravel detritus	silty sand oily	silty sand	silty &sand				
Species									
Garveia franciscana		45			61				120
Nereis (neanthes) succinea									
Scolecolepides viridis	1	4	2	1	2				17
Rangia cuneata		1	1	1	4				47
Chiridotea almyra				1					4
Cyathura polita		7		23	5				78
Corophium lacustre		1		10					13
Gammarus daiberi	1	1	1	3					12
Leptocheirus pinguis									
Rhithropanopeus harrisi	2			2					17
Amathia vidovici									
Anadara ovalis									
Limnodrilus sp.	9		1						78
Monoculodes edwardsi				1					2
Helobdella stagnalis									2
Total Animals Per Station	13	59	5	52	73				390

Table XIV - Summary Benthic Data - June 1972

Station No.	1	2	3	4	6	7	8	9	10	11	12	13
Date	6/6	6/6	6/5	6/5	6/5	6/6	6/6	6/6		6/6	6/6	
Time	15:50	1500	15:50	10:56	11:35	09:10	10:05	10:45	11:20	11:20	12:00	
Tide	east 1k	east 1.5	east 1.5k	ebb	ebb	ebb 1k		ebb .5k		ebb .5k	ebb .5k	
Water Temp(^{o}C)		21.8	21.7	21.1		21.6		21.9				
Salinity(^{o}/00)												
Dissolved O_2(^{m3}/2)												
pH												
Secchi Disc(cm.)		40	50	40	---	50		60				
Grab(%Full)	80	100	89	89		75	90	100			84	
Bottom type	sand clean detritus	sandy silt	sand detritus	sand & gravel		hard silty clay	silty clay	soft silt		silt	silty sand	
Species												
Garveia franciscana	1	50		5	1						105	
Nereis(Neanthes) succinea												
Scolecolepides viridis	112		4	2						6	10	
Rangia cuneata	4	1	24	2		1					1	
Chiridotea almyra	83		44			1					5	
Cyathura polita						22	3			24	4	
Corophium lacustre						1						
Gammarus daiberi	42	6	42	12		28	33	1		18	31	
Leptocheirus pinguis												
Rhithropanopeus harrisi	1					8						
Amathia vidovici	1											
Anadara ovalis												
Barnacle(Balanus)			1									
Modiolus sp.											1	
Neomysis americana												
Chryptochironomus sp.												
Limnodrilus sp.								64		297	10	
Total Animals Per Station	243	57	115	21	1	61	36	65		265	167	

Table XIV - Summary Benthic Data - June 1972

Station No.	14	15	17	19	21				Total Animals
Date	6/6	6/6	6/5	6/5	6/5				
Time	13:08	13:35	15:10	13:25	1210				
Tide	ebb .5k	ebb .5k	flood .5k	ebb .5k	ebb 1.k				
Water Temp(^{o}C)		22.0	21.8		24.1				
Salinity(^{o}/00)									
Dissolved O_2(^{m3}/2)									
pH									
Secchi Disc(cm.)		50			47				
Grab(%Full)	88		80	73	47				
Bottom type	oily silt	silty sand & gravel	silt clay sandy gravel	silty clay	sand & silt				
Species									
Garveia franciscana		2885	4		21				3172
Nereis(Neanthes) succinea									3
Scolecolepides viridis		18	6		19				181
Rangia cuneata			5		23				63
Chiridotea almyra			47		5				560
Cyathura polita		32		3	2				220
Corophium lacustre		1		5					70
Gammarus daiberi	1	1096	6	29	58				24261
Leptocheirus pinguis									
Rhithropanopeus harrisi		6	1	11					224
Amathia vidovici									1
Anadara ovalis									
Barnacle(*Balanus*)									8
Modiolus sp.									3
Neomysis americana		1							4
Chryptochironomus sp.		2							4
Limnodrilus sp.	165	32							506
Total Animals Per Station	166	4073	69	48	128				29,280

Table XV - Summary Benthic Data - September 1972

Station No.	1	2	3	4	6	7	8	9	10	11	12	13
Date	9/11	9/11	9/11	9/11	9/12	9/12	9/12	9/12		9/12	9/12	
Time	1000	1550	1100	14:50	15:10	10:05	0940	11:10		12:35	1345	
Tide	east	west	east	flood	flood	---	ebb	early		flood 0.5		
Water Temp(^{o}C)	23.1	23.2	22.9	22.8	22.5	---	22.8	21.0		23.2		
Salinity(^{o}/00)	5.5925	5.739	5.874	6.881	6.8315		3.481	2.607		2.119		
Dissolved O_2(^{m3}/2)	4.6818	5.2736	5.8844	4.9109			5.7434	3.7941		3.9707		
pH												
Secchi Disc(cm.)	35	70	40	40	---	---	50	50		55	---	
Grab(%Full)	84	100	64	80	---	70	87	100		90	76	
Bottom type	sand	soft silt	sand	silt & sand sulfide odor	clay & silt	silty clay	black oily silt	soft silty clay oily		black oily silt	silty sand	
Species												
Garveia franciscana												
Nereis(neanthes) succinea												
Scolecolepides viridis	94		9			20	2				5	
Rangia cuneata	2	1	8	7			1				1	
Chiridotea almyra	4		97	23	1		1			1	135	
Cyathura polita						13	1	2			4	
Corophium lacustre	6				2	15		1				
Gammarus daiberi	1		5	1	3	9	6	8		2	1	
Leptocheirus pinguis												
Rhithropanopeus harrisi	1					14		1				
Amathia vidovici	1											
Anadara ovalis												
Limnodrilus sp.								29		64	2	
Neomysis americana	8	5	4	1	14	1	1					
Crangon septemspinosa						2	1					
Total Animals Per Station	116	6	123	32	20	74	13	41		67	148	

Table XV - Summary Benthic Date - September 1972

Station No.	14	15	17	19	21			Total Animals	
Date	9/12	9/12	9/11	9/11	9/11				
Time	1935	1420	1155	1300	1345				
Tide	flood 1.5	flood 2k	flood 2k	flood 2k	flood 2k				
Water Temp(^{o}C)	22.6	---	22.9	21.0	---				
Salinity($^{o}/00$)	4.3545	4.7405	5.276	7.421					
Dissolved O_2($^{m3}/2$)	3.7607	.6028	5.789	5.0827					
pH									
Secchi Disc(cm.)	40	25	40	40					
Grab(%Full)	70	66	80	64	54				
Bottom type	sandy silt	silty clay sand	sand silt	hard clay silt	silty clay				
Species									
Garveia franciscana				11				11	
Nereis(Neanthes) succinea	---	---	---	---	---			---	
Scolecolepides viridis		---	40	1	27			198	
Rangia cuneata	---	---	2		11			33	
Chiridotea almyra	---	1	3					266	
Cyathura polita	---		1	13	1			35	
Corophium lacustre		1	---	53	3			81	
Gammarus daiberi		26	---	17	---			79	
Leptocheirus pinguis		---	---	---	---			---	
Rhithropanopeus harrisi				6				21	
Amathia vidovici									
Anadara ovalis									
Limnodrilus sp.								95	
Neomysis americana		4		4				42	
Crangon septemspinosa			1	1				5	
Total Animals Per Station	---	32	47	106	42			867	

Table XV I Summary Benthic Data - December 1972

Station No.	1	2	3	4	6	7	8	9	10	11	12	13
Date	12/11/72	12/12/72	12/11/72	12/13/72	12/11/72	12/11/72	12/11/72	12/12/72		12/12/72	12/12/72	
Time	1015	0850	1105	0900	1530	1205	1445	1415		1330	1140	
Tide	2.5 E	Flood 1st < 0.5K	E 2K	1.5 K West	Last Flood <0.5K	Flood 2K	Flood 0.5K	Flood 2K		Flood 1.5K	Flood 0.75K	
Water Temp(^{o}C)										6.3	6.2	
Salinity(^{o}/00)	.310	.2353	.3065	.1655	.1755	.283				.1235		
Dissolved O_2(^{m3}/2)	13.520	9.0699	13.5147	10.2488	10.2876	9.6558				10.8163	13.0979	
pH												
Secchi Disc(cm.)	25	25	30	35	35	--	--	--		35	--	
Grab(%Full)	80	100	64	50	80	100	54	95		74	84	
Bottom type	Sand & Clay	Silt	Sand & Silt	Sand & Gravel	Hard Silt	Black Oily Mud	Hard Silt Clay & Sand	Black Silt		Oily Black Silt	Silt w/ some Sand	
Species												
Garveia franciscana	--		--	--	--	--	--	--		2	--	
Nereis (Neanthes) succinea	--		--	--	--	--	--	--		--	--	
Scolecolepides viridis	5	2	10	1	5	20	--	--		--	13	
Rangia cuneata	--		--	--		--	--	1		--	1	
Chiridotea almyra	2	2	1	2		8	--	--		1	2	
Cyathura polita	1		1	--	10	--	1	6		17	5	
Corophium lacustre	--	--	--	--	1	--	--			--	--	
Gammarus daiberi	73	6	--	6	315	8	6	3		--	--	
Leptocheirus pinguis	--		--	--		--	--	--		--	--	
Rhithropanopeus harrisi	--	--	--	--	3	--	--	--		--	--	
Amathia vidovici	--	--	--	--	--	--	--	--		--	--	
Anadara ovalis	--	--	--	--	--	--	--	1		--	--	
Limnodrilus sp.	--	1	1	--	--	2	--	--		32	--	
Neomysis americana	--	--	2	--	--	--	--	--		--	--	
Balanus balanoides	--	--	--	--	31	--	--	--		--	--	
Total Animals Per Station	81	11	15	9	365	38	7	11		52	21	

Table XVI - Summary Benthic Data - December 1972

Station No.	14	15	17	19	21				
Date	12/12/72	12/12/72	12/13/72	12/13/72	12/13/72				
Time	1100	1015	1015	1132	1050				
Tide	Slack	Ebb .5K	Ebb 1 K	Slack	Ebb 1.5K				
Water Temp(^{o}C)	6.0	6.1	6.3						
Salinity(^{o}/00)					--				
Dissolved O_2(^{m3}/2)	10.9402	10.3205	10.1121	13.5373	--				
pH					--				
Secchi Disc(cm.)	--	--	--	35	--				
Grab(%Full)	100	64	97	65	47				
Bottom type	Oily Black Mud Detritus	Silt & Gravel some Stones	Silty Sand	Silt & Clay	Silty Sand				
Species						TOTAL			
<u>Garveia franciscana</u>		504	--		8	514			
<u>Nereis (Neanthes) succinea</u>	--	--	--	--	--	--			
<u>Scolecolepides viridis</u>	--	1	31	1	36	125			
<u>Rangia cuneata</u>	--	--	6	--	--	8			
<u>Chiridotea almyra</u>	--	--	12	1	5	36			
<u>Cyathura polita</u>	--	20	2	2	2	69			
<u>Corophium lacustre</u>	--	--	--	--		1			
<u>Gammarus daiberi</u>	2	99	12	8	81	619			
<u>Leptocheirus pinguis</u>	--	--	--	--					
<u>Rhithropanopeus harrisi</u>	--	14	--	--		17			
<u>Amathia vidovici</u>	--	--	--	--					
<u>Anadara ovalis</u>	--	--	--	--		1			
<u>Limnodrilus</u> sp.	--	1	--	--	2	39			
<u>Neomysis americana</u>	--	--	--	--		2			
<u>Balanus balanoides</u>	--	1		--		32			
		(uni-dent.)							
						TOTAL			
Total Animals Per Station	2	640	63	12	136	1463			

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Table XVII - Summary Benthic Data - June 1972 Dredge

Station No.	2	3	7	11	19		2,7,11,19 Total		Total
Date	6/6	6/5	6/6	6/6	6/5				
Time	15:10	16:15	.0925	11:30	13:40				
Tide	E.1.5k	E. 1.5k	Ebb .5k	Ebb 1.k	Ebb slight				
Water Temp(^{o}C)									
Salinity($^{o}/00$)									
Dissolved O_2($^{m3}/2$)									
pH									
Secchi Disc(cm.)									
Grab(%Full)	60(?)								
Bottom type				Rocky Detritus	Silty Clay				
Species									
Garveia franciscana		4		75	21		96		100
Nereis(Neanthes) succinea					3		3		3
Scolecolepides viridis		1		1	2		3		4
Rangia cuneata		2					0		2
Chiridotea almyra	4	33	324	7	7		342		375
Cyathura polita	5		29	57	39		130		130
Corophium lacustre			1		62		63		63
Gammarus daiberi	531	767	3300	16,100	2170		22,101		22,868
Leptocheirus pinguis									
Rhithropanopeus harrisi			9	4	185		198		198
Amathia vidovici									
Anadara ovalis									
Palaemonetes vulgarus					7		7		7
Monoculodes edwardsi				1			1		1
Rond Snail (Shell only)				2			2		2
Helobdella stagnalis				2			2		2
Limnodrilus sp.	3			15			18		18
Total Animals Per Station	543	807	3663	16,254	2496		22956		23,763

Table XVIII Summary Benthic Data - September 1972 Dredge

Station No.	2	7	11	19	Total Animals
Date	9/11	9/12	9/12	9/11	
	1615	10:20	12:10	13:30	
Tide	west 1k	ebb 1k	flood 0.5	flood 2k	
Water Temp(^{o}C)			23.4	---	
Salinity(^{o}/00)					
Dissolved O_2(^{m3}/2)					
pH					
Secchi Disc(cm.)					
Grab(%Full)	50	25	---	50	
Bottom type	silt	silty clay	---	silt clay	
Species					
Garveia franciscana		20	8	5000	5028
Nereis(Neanthes) succinea	---	---			
Scolecolepides viridis	1	---	1	1	3
Rangia cuneata	---	---			
Chiridotea almyra	5		19	1	25
Cyathura polita	2	---	23	6	31
Corophium lacustre				1	1
Gammarus daiberi	26	175	1166	363	1730
Leptocheirus pinguis	---	---			
Rhithropanopeus harrisi	1	1	8	28	37
Amathia vidovici	---	---			
Anadara ovalis					
Limnodrilus sp.	---	---	1000	71	1071
Neomysis americana	328	100	701	401	1530
Crangon septemspinosa		50	255	62	367
Callinectes sapidis	---	---	1		1
Monoculodes edwardsi	---	---	220		221
Total Animals Per Station	362	345	3402	5935	10,045

Table XIX - Summary Benthic Data - December 1972 Dredge

Station No.	2	7	11	19					Total Animals
Date	12/11	12/11	12/12	12/12					
Time	0900	1345	1345	1230					
Tide	0.5k flood	2k flood	2k flood	1k flood					
Water Temp(^oC)									
Salinity($^o/00$)									
Dissolved O_2($^{m3}/2$)									
pH									
Secchi Disc(cm.)									
Grab(%Full)	80%	70%	70%	70%					
Bottom type	silt	silt	silt	silt & detritus					
Species									
Garveia franciscana			400	35					4035
Nereis(Neanthes) succinea	---	---	---	---					---
Scolecolepides viridis	10	---	----	4					14
Rangia cuneata			12						12
Chiridotea almyra	15	5	2	15					37
Cyathura polita	---	9	46	6					61
Corophium lacustre	---		16	1					17
Gammarus daiberi	93	363	107	607					1170
Leptocheirus pinguis	---								
Rhithropanopeus harrisii		3	5	12					20
Amathia vidovici	---		----						
Anadara ovalis	---		---						
Limnodrilus sp.		3	7						10
Barnacle(unident.) (Balanus)			1						1
Total Animals Per Station	118	383	4196	680					5377

Table XX - Summary Benthic Data - December 1972 Grab Comparison

Station No.	2P	7P	12P			Total Animals			
Date	12/12	12/12	12/12						
Time	0823	1325	1245						
Tide	slack	flood 2k	flood 0.75k						
Water Temp(^{o}C)	---	---	---						
Salinity(^{o}/00)									
Dissolved O_2(^{m3}/2)									
pH									
Secchi Disc(cm.)									
Grab(%Full)	100%	70%	100%						
Bottom type	sand	silt	sand						
Species									
Garveia franciscana			10			10			
Nereis(Neanthes) succinea	---	----	----			- ---			
Scolecolepides viridis		---	6			6			
Rangia cuneata	---	----	---			--			
Chiridotea almyra	---	---	3			3			
Cyathura polita	---	4	4			8			
Corophium lacustre	---	4	----			4			
Gammarus daiberi	1	11	---			12			
Leptocheirus pinguis	---	---	----						
Rhithropanopeus harrisi	-	2	---			2			
Amathia vidovici									
Anadara ovalis									
Limnodrilus sp.	9					9			
Callinectes sapidis		1				1			
Total Animals Per Station	10	22	23			55			

Table XXI

BENTHIC STATION DESCRIPTION FOR C & D CANAL SURVEY

Stations in the Canal are located at mid-channel and those in the River predominately on 18 ft. contour. Use C & G.S chart #570 in Canal and 294 in the Delaware River.

1. Second light east of overhead pipeline; approximately .75 mile east of Summit bridge in canal.

2. West of St. Georges Bridge approximately .75 of a mile, second light past pier in canal.

3. Approximately .5 miles west of Delaware City Branch Channel, 1st light in water after rock pile starts south side (off Ice House Point) in Canal.

4. A beam, quick flashing R "2" at Canal entrance.

6. C & D Canal entrance Range-Move east to 28 ft. depth beyond shipping Channel.

7. Place most southerly storage tank at Getty terminal in line with front range light of Delaware City range. Sample at western edge of channel.

8. Located on same east-west range as 7, at intersection with range formed by Spar bouy R "8" and buoy "1" at entrance to Branch Canal.

9. East-west range Fl "B" on bulkhead bar (Pea Patch) and "F14 sec 30 ft. 7M" on western point of Killicohook National Wildlife Refuge, N.J. Move west across deep slough to western edge, use 18 ft. depth.

10. Same East-west range as "9". At intersection with north south range formed by beacon "A" on Bulkhead Bar Jetty and buoy "1" at entrance to Delaware City branch canal.

11. Bulkhead bar range at intersection with range formed by beacon "E" on Bulkhead Bar and bouy "40" (Deep water point Range)

12. Approximately 75-100 ft. southeast of beacon "E" on Bulkhead Bar.

13. North-south range, buoy "2B" on Bulkhead Bar Range and "Fl G 2½ sec" on Pea Patch Island. Sample at intersection with range formed by beacon "B" on Bulkhead Bar and "1D" on Deepwater point range.

14. Range formed by beacon on Killicohook Refuge, N.J. and buoy "1D" on Deepwater Point range, 75-100 ft. northwest of beacon.

15. Range formed by monument on Killicohook Refuge and tank to east-northeast (65°), approximately 100 ft. from small sand island located 1500 yards north west of "Fl G" on Pea Patch Island.

16. Same range as "15" at intersection with range formed by "2B" on Bulkhead Bar and "Fl 2 sec B" at spoil pumping site.

17. North-south range formed by "C 27" in anchorage 3 and "R 2" on Canal jetty. Sample 0.3 mile south of "C 27".

18. Northwest-southeast range formed by "C 27" and fork 0.3 miles east of Delaware City Branch Canal. North-south range, "IN" (QK Fl) and "8R".

19. East-west range "5R" and spire at Port Penn. approximately 100 feet from Dolphins on East side of Reedy Island.

20. East-west range formed by "5R" and spire at Port Penn. and North-south, "WR10R" Reedy Island Range and "2R" (QK Fl)

21. Same range as "20" at intersection with range formed by North-south "WR10R" and anchorage white nun "B"

22. East West range "C27" and "IN" (QK Fl). Sample at .5 mile, 265° "C27"

23. Same range as "22" intersection "1" (Qk Fl) south jetty C & D anal and "3" Delaware City ship canal.

24. North-south range "C29" and "IC" (Qk Fl) and intersection formed by East-west standpipe and tank .5 mile north of New Castle.

25. North-south range, army maintained structure (Fl. 2 sec) .5 mile south Delaware Memorial Bridge and front range light deep water range and intersection of standpipe and tank .5 mile North of New Castle.

C&D CANAL ECOLOGICAL SURVEY

Biological Survey of the Canal

and its Approaches

Appendix IV - Delaware Benthos

Part B - Sediment Analyses

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METHODS

Grain size analysis was performed on a representative portion of the sediment obtained at each benthic sampling station. Sieve analysis was used on the coarse grained, sand and gravel portion and pipette analysis was used on the fine grained, silt and clay material. The results of these analyses were examined for both geographic and seasonal variations in the sediment composition.

The coarse and fine grained portions of the sediment were separated by wet sieving the entire sample through a 62 micron sieve. The sand-gravel fraction was then oven dried and weighed. Using a sample splitter, a thirty to seventy gram sample was obtained. This sample was poured into a stack of sieves graded in 1/2ϕ intervals, in order, coarsest sieve at the top, pan at the bottom. The sieves were placed in a Ro-Tap machine and shaken for fifteen minutes. The sand trapped by each sieve was then weighed on a Mettler top-loading balance to 0.01 gm.

The silt-clay portion of the sample was poured into a liter cylinder. One gram of dispersant was added along with enough distilled water to fill the cylinder to exactly 1000 ml. The cylinder was then vigorously shaken to distribute the sediment uniformly throughout the column. When the shaking was stopped, a timer was started; and after fifteen seconds on pipette was inserted into the suspension to a depth of twenty centimeters and exactly twenty milliliters of suspension was withdrawn. Additional pipette withdrawals (20 ml each) were made at specified time intervals and depths. The suspension removed was expelled into a pre-weighed fifty milliliter beaker. The pipette was then rinsed with distilled water, and the rinse water expelled into the same beaker. The beakers were placed in an oven and evaporated to dryness. They were then removed from the oven, cooled and weighed to 0.001 gm. The weight of the sediment in each twenty milliliter withdrawal was determined, then multiplied by fifty and the weight of the dispersant subtracted.

Knowing the weight of the sediment removed from the suspension at each withdrawal time, the grain size distribution of the sediment can be determined. Since the silt-clay material was uniformly distributed throughout the 1000 ml cylinder, the twenty milliliter withdrawal represents 1/50 of the total amount of sediment remaining in suspension at the time and at the depth of withdrawal. All particles larger than a given diameter have settled past the point of withdrawal after a given time, according to Stokes Law. With each successive withdrawal, the diameter of the largest particle removed by the pipette becomes smaller and smaller. Based on time and withdrawal depth, the maximum particle size present in each withdrawal can be calculated. Therefore, the difference in weight of two successive withdrawals represents the weight of a particular size fraction. By making pipette withdrawals at the proper times and depths, a complete grain size distribution is obtained. These distributions combined with the data from the sieve analysis were obtained for all the sampling stations.

RESULTS

Reviewing the grain size distribution data for the sampling stations within the Canal, some interesting differences before and after dredging are revealed. In June 1971, Station 2, just west of St. Georges Bridge, was a well-sorted, medium sand. After dredging, in December 1971, a fine, moderately-sorted sand was obtained at that location. By March 1972, a coarse, poorly-sorted silt was discovered and subsequent sampling revealed the same material (December 1972 is typical).

At Station 3, in the area where the Delaware City Branch Channel intersects the Canal, a similar shift in bottom sediment type occurred. September 1972 is typical of the pre-dredging grain size distribution, revealing a well-sorted, medium sand. Just after dredging, in October 1972, a slightly finer but still well-sorted sand was observed. By July 1973, with dredging completed in the area, the appearance of a coarse silt was noted at this station also.

The introduction of the coarse silt at both Stations 2 and 3 is probably the result of silt washing out of the dredged bottom material, becoming suspended in the canal waters, and finally settling out in the quieter waters of the deeper canal sections. It is quite possible that this coarse silt will be washed away when the canal deepening has been completed. The bottom sediment will probably return to being a well-sorted sand.

Comparisons are possible with the canal sediments and with bottom deposits found in the Delaware River adjacent to the canal. Station 12, east of the Pea Patch Island Jetty, and Station 17, in mid-channel south of Reedy Point, are both well-sorted, coarse sands similar to the pre-dredging canal samples. All the Stations west of Pea Patch Island (Station 11 provides the best match) and Station 19, south of Reedy Point, are similar to the poorly-sorted silt sediments observed in the canal after dredging.

FIGURE 1

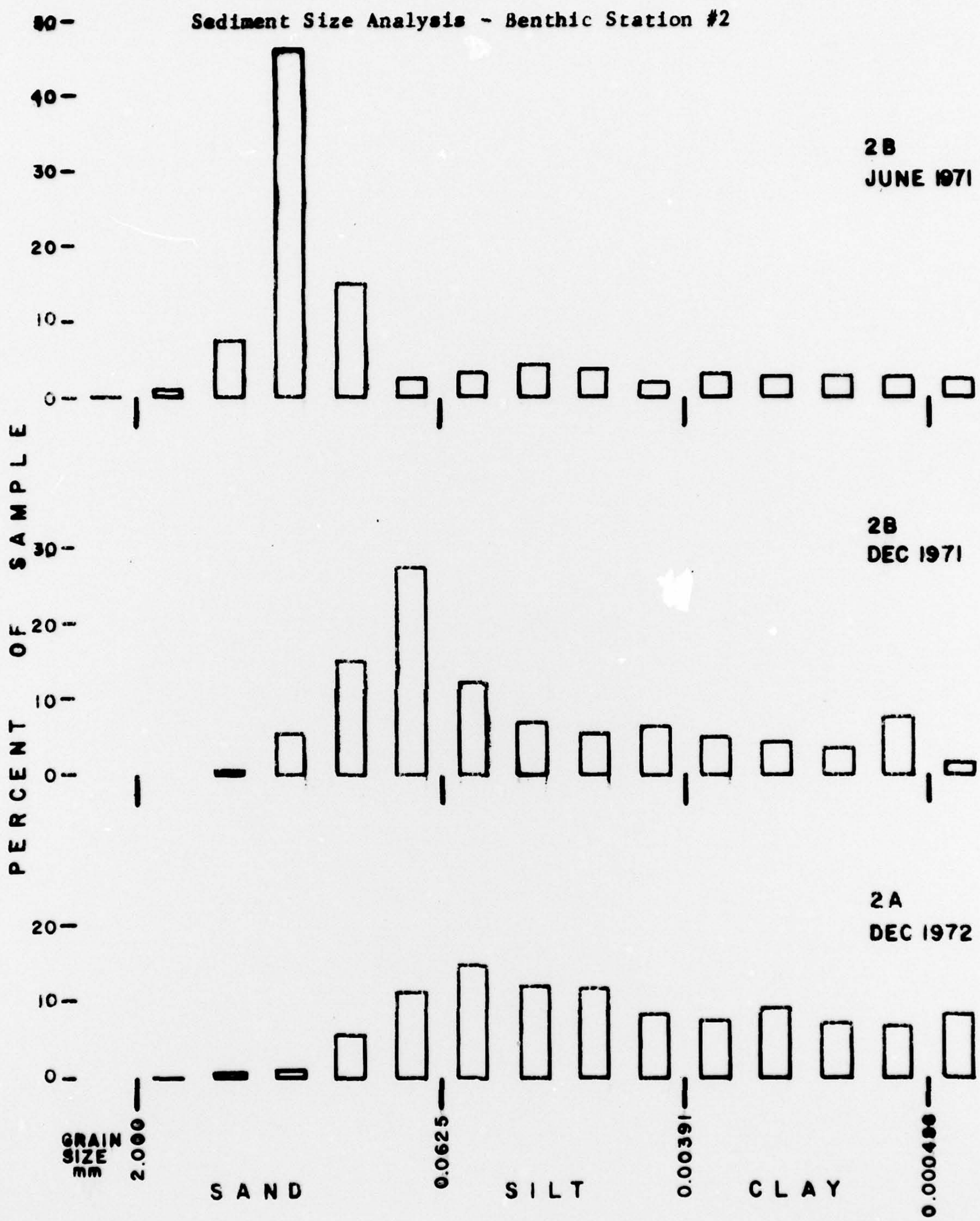
Sediment Size Analysis - Benthic Station #2
PERCENT OF SAMPLE
2B
JUNE 1971
2B
DEC 1971
2A
DEC 1972
GRAIN SIZE mm
2.000
0.0625
0.00391
SAND
SILT
CLAY

FIGURE 2

Sediment Size Analysis - Benthic Station #3

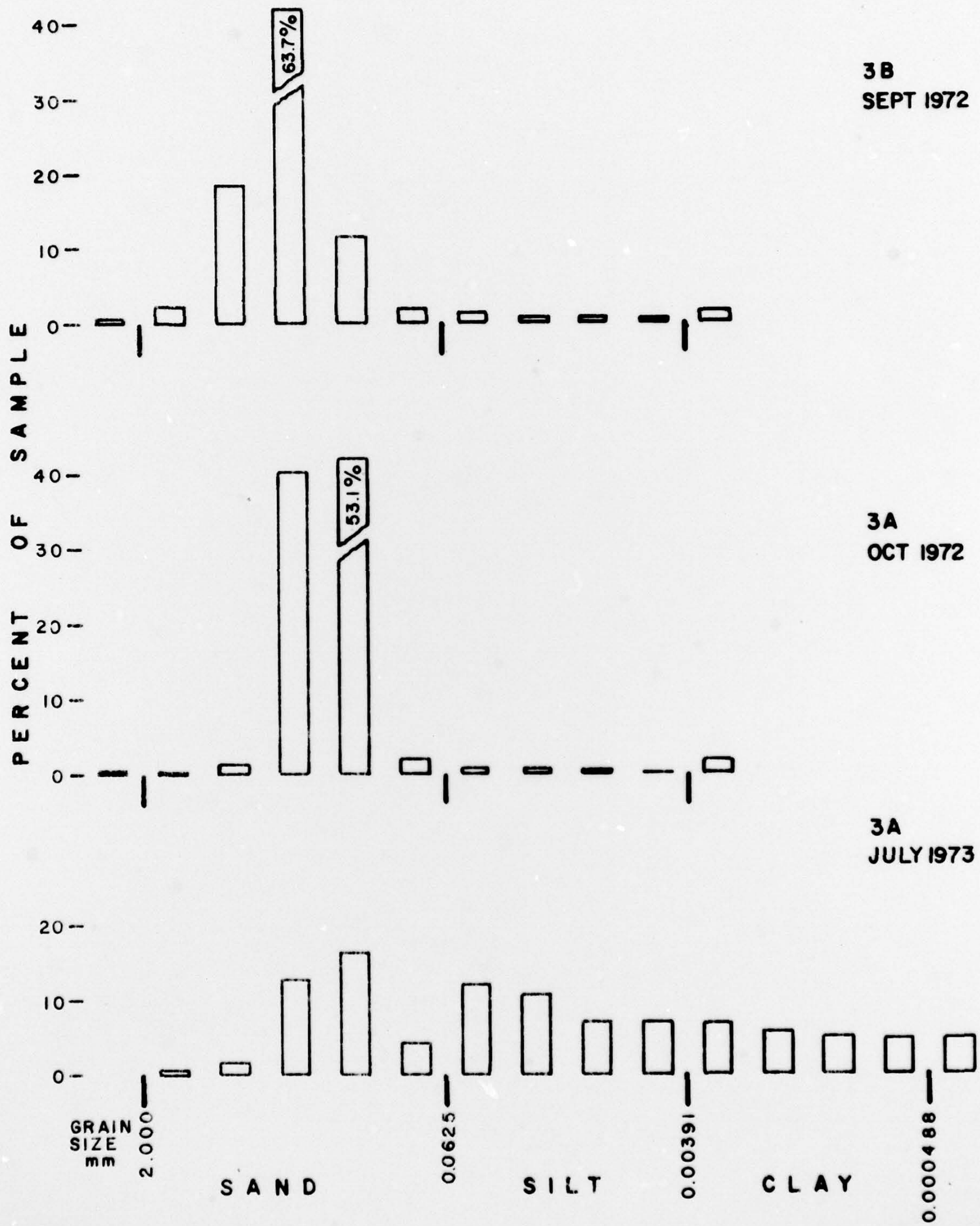

FIGURE 3

Sediment Size Analysis - Benthic Stations 12, 11, 19