FINAL REPORT

CONTAMINANT BODY BURDENS IN MESOPELAGIC FISH (*MYCTOPHIDAE*) COLLECTED NEAR THE 106-MILE SITE

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U.S. ENVIRONMENTAL PROTECTION AGENCY
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1.0 INTRODUCTION

1.1 BACKGROUND

The United States Environmental Protection Agency (EPA), under the Marine Protection, Research, and Sanctuaries Act of 1972, is responsible for regulating disposal of sewage sludge in U.S. territorial waters. This responsibility includes developing and implementing effective monitoring programs to assess compliance with permit conditions and to evaluate potential impacts on the marine environment. A monitoring program has been designed for the 106-Mile Deepwater Municipal Sludge Site (106-Mile Site), which was designated in 1984 for disposal of municipal sludges (EPA , 1992a). The program is being implemented according to a tiered approach (EPA 1992b), whereby data generated in one tier are used in making management decisions about continued site designation, awarding of dumping permits, and the design and implementation of future surveys.

In March 1989, EPA, the National Oceanic and Atmospheric Administration (NOAA), and the U.S. Coast Guard jointly sponsored a workshop to address management issues on sewage sludge dumping at the 106-Mile Site (EPA, in press). Many recommendations were made (EPA, 1989), including a priority placed on assessing possible impacts on indigenous fish populations at the site. Criteria for selection of the fish species included residency at and near the 106-Mile Site and residence in the near surface water (epipelagic zone). The latter criterion is important because contaminants are concentrated on the finer-grained particles in the sewage sludge (Boehm,

1983), and these particles appear to have a long residence time in the epipelagic zone (EPA , 1992c). This could result in long-term exposure of indigenous organisms to contaminants in the sludge. The workshop also strongly recommended enhanced cooperation among the government agencies interested in sewage-sludge disposal at the 106-Mile Site.

Prior to the workshop, NOAA planned a June 1989 survey of the 106-Mile Site and areas up to 100 miles north, south, and east of the 106-Mile Site to collect and analyze mesopelagic fish for mercury content. In part because of the workshop recommendations, NOAA increased the number of metals to be analyzed from 1 to 13. NOAA also offered EPA the opportunity to participate in this survey, and EPA responded by funding the analysis of organic contaminants in fish collected in the survey. This analysis was completed by Battelle Ocean Sciences (Battelle) under Work Assignment 38 (WA 38). NOAA concurrently performed metal analysis of replicated fish collected in the survey.

1.2 OBJECTIVES AND SCOPE OF WORK

Mesopelagic fish indigenous to the 106-Mile Site were analyzed for organic contaminants to provide chemical data for an initial assessment of the impact of sewage-sludge dumping on fish residing at and near the 106-Mile Site. Although not originally part of the 106-Mile Site Implementation Plan (EPA 1992b), results from this survey can be used to support the evaluation of long-term effects (Tier 4 of the monitoring program). This is made possible by comparing contaminant body burdens in fish resident at

the 106-Mile Site with those collected upstream and downstream from the site and with those collected in the Sargasso Sea (control site). Site selection and field operations were performed by NOAA aboard the R/V *Delaware II*. Battelle provided assistance in the collection of fish at the 106-Mile Site and conducted whole-body analyses of organic contaminants.

This report provides a description of the NOAA survey, the results of the organic contaminant analysis, and an interpretive discussion of these data to evaluate the impact of sewage sludge dumping at the 106-Mile Site on indigenous fish. Additional tasks provided under WA38 included assistance on a second NOAA survey (*Atlantis II* - Alvin) in September 1989 to collect benthic and other fish and shellfish species at the 106-Mile Site and a similar survey in September 1989 conducted by the National Undersea Research Program (NURP) at the University of Connecticut. Battelle has received and archived 15 fish tissue samples collected in the Alvin survey and 15 sediment samples collected in the NURP survey. Additional sampling in the NURP survey has been delayed until May or June of 1990 because of structural problems with the submersible sphere. These other surveys are not discussed further in this report.

1.3 SELECTION OF ORGANIC CONTAMINANTS

Several studies have been performed to characterize the chemical composition of sewage sludges originating from the Metropolitan New York area and dumped at the 106-Mile Site (Boehm, 1983; MacLeod, 1981; Ecological Analysts, 1983;). Both organic and inorganic chemical

contaminants are enriched in sewage sludge, but their concentrations can be highly variable both within and between particular sludge sources. There are considerably more data on the levels of inorganic contaminants (e.g., metals) than there are for individual organic compounds. Data from recent sludge-characterization studies (Boehm, 1983; MacLeod, 1981; Ecological Analysts, 1983; Eganhouse *et al.*, 1988) indicate that polychlorinated biphenyls (PCB), chlorinated pesticides including DDT and its metabolites, polynuclear aromatic hydrocarbons (PAH), and linear alkyl benzenes (LAB) are all enriched in sewage sludge (relative to background particles in the ocean). These contaminants also can persist for many years in the marine environment, and, because of their lipophilicity, can accumulate in the lipid tissues of fish that reside in and near the 106-Mile Site.

In addition, PCB, PAH, and pesticides are potentially toxic, mutagenic, carcinogenic, and/or teratogenic to marine organisms and, consequently, pose a significant ecological threat at high exposure levels. The body burdens of PCB, PAH, and pesticides are potential chemical indicators of the impact of sewage-sludge dumping on resident fish. LAB do not themselves pose a significant ecological problem, but they have been used as markers of the hydrocarbon component of sewage sludge and other domestic wastes (Eganhouse *et al.*, 1983, 1988).

Although coprostanol is a more common tracer for sewage sludge and has been measured in water and particulate samples in previous surveys at the 106-Mile Site, it was not measured in this study because the high level of other sterols in the fish was expected to interfere with the analysis.

Trace-metal contaminants will be measured by NOAA in replicated fish samples and are not discussed in this report.

1.4 SELECTION OF INDICATOR ORGANISM

To evaluate the biological effects of sewage-sludge disposal at the 106-Mile Site, an appropriate indicator organism is required. The criteria for selecting an indicator organism in this study were

(1) Full- or part-time residency in epipelagic zone at the 106-Mile Site and Sargasso Sea (control site),

(2) Sufficient biomass for analysis of metals and organic contaminants,

(3) Restricted horizontal migration.

Myctophidae is one of the most abundant families of fish in the Mesopelagic zone. Commonly called lanternfish because of the rows of photophores on the body and head, they live primarily between 100 and 1000 m. A drawing of a myctophid (*Myctophum*) is presented in Figure 1. Myctophids do not migrate horizontally to any great extent, although they will move with the surrounding water mass. Myctophids do migrate vertically each night to the epipelagic zone, where they feed on zooplankton and fish. Thus, as part-time residents above the pycnocline, the myctophids meet the three selection criteria given above.

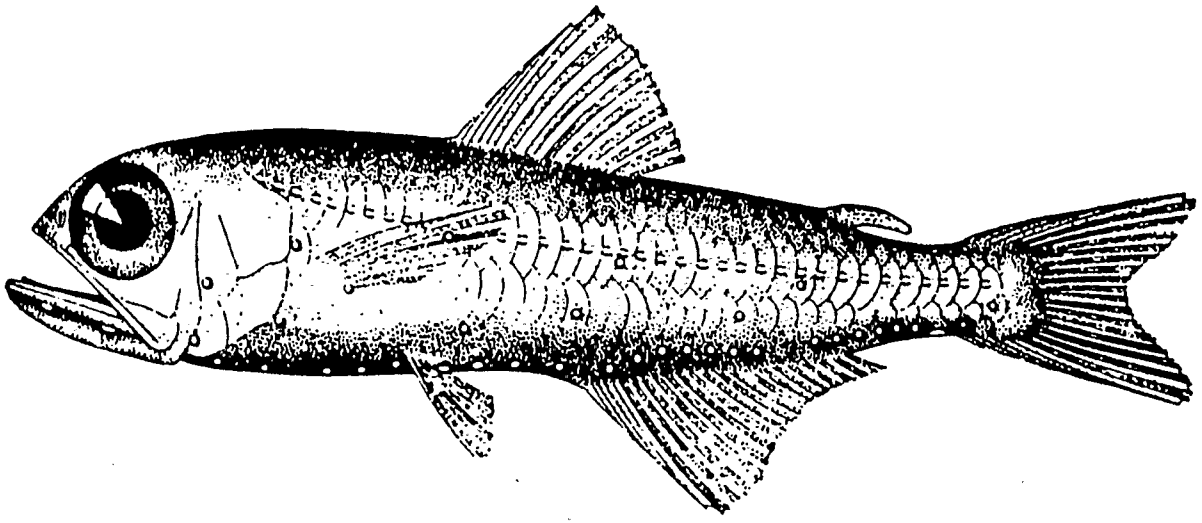


FIGURE 1. DRAWING OF A MYCTOPHIDAE *MYCTOPHUM* (FROM MOYLE AND CECH, 1987).

2.0 SURVEY DESCRIPTION

2.1 STATION LOCATIONS

During June 6-18, 1989 NOAA conducted a survey of the 106-Mile Site, aboard the R/V *Delaware II*, to collect mesopelagic fish at four stations:

Station 1 - 106-Mile Site

Station 2 - 100 miles southwest of the 106-Mile Site

Station 3 - Sargasso Sea

Station 4 - 80 miles northeast of the 106-Mile Site

The location of each station (Figure 2) was determined by using the LORAN-C electronic navigation system aboard the R/V *Delaware II*. Each tow's start and end points and duration, as well as tow depth, bottom depth, mean wire out, and the approximate number of myctophids per sample were recorded in Trawl Location Logs, which are presented in Appendix B.

2.2 SAMPLING METHODS

An Isaacs-Kid Mid-Water Trawl was deployed for sample collection. The net and cod-end catch bag of the trawl were constructed of polypropylene mesh. The cod-end catch bag was secured with rope and cable ties. The trawl was towed for approximately 1 hour at each station. The depth of the tow was dictated by the time of day samples were being collected. Stations 1 and 2 were sampled at nighttime, with the tows conducted primarily at <50 m depths. Stations 3 and 4 were sampled at daytime, with tows conducted at depths of 400 to 800 m.

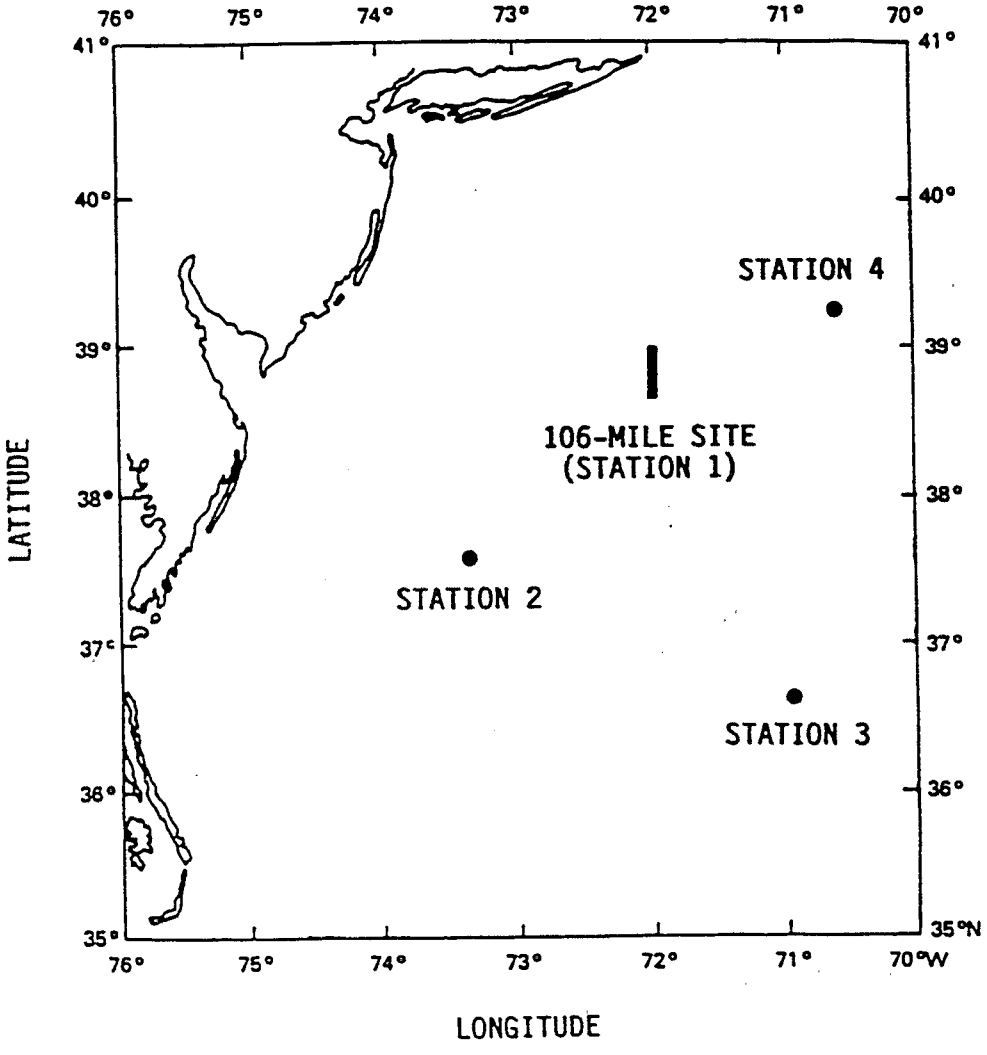


FIGURE 2. LOCATION OF THE 106-MILE SITE AND SAMPLING STATIONS FOR JUNE NOAA/EPA MYCTOPHID SURVEY.

Upon retrieval of the trawl, the cod end was hoisted via the boom directly from the water to a stainless steel collection tray that had been prewashed with soap and water, distilled water, methanol, and methylene chloride. The contents of the trawl were emptied onto the collection tray where the dominant myctophid and/or other mesopelagic species were sorted, identified, and split for organic and trace metal subsamples.

The subsamples were transferred to fiberglass trays lined with solvent-rinsed foil and were taken into the laboratory for processing. Teflon forceps were used to transfer the subsamples from the fiberglass tray into prewashed (as described above) 500-mL Teflon jars. Each sample jar was appropriately labeled from the myctophid sampling log and the label was secured with clear plastic tape. Each sample-jar lid was further secured with tape to ensure sample integrity. The species and the number of animals were recorded in the myctophid sampling log. Samples were maintained at - 20°C in the vessel's freezer until June 19, 1989, at which time samples for organic analyses were transferred by truck to Battelle and stored at - 20°C. Samples for metal analyses were transferred to the NOAA, National Marine Fisheries Service (NMFS) Sandy Hook, NJ laboratory (Mr. Vincent Zdanowicz).

At each of the four stations, an attempt was made to collect three replications, each containing four myctophidae species. At all four stations, multiple tows were required to attain sufficient biomass. Each organic sample replication corresponds to a unique tow. However, time constraints and a lack of species diversity and biomass precluded the

collection of four myctophidae species per station as originally proposed in the Work Plan.

The Isaacs-Kid Mid-Water Trawl required deployment and retrieval at an angle. On one occasion this caused the side arms of the depressor foot to bend, rendering the trawl inoperable. The trawl type and the tow duration (1 hour) often caused severe trauma rendering many of the fish unidentifiable as to genus and species. These samples were identified as Myctophidae Composites. The most severely traumatized samples were not used for organic analysis.

3.0 ANALYTICAL METHODS

Tissue samples were prepared and analyzed for PAH, LAB, and pesticide/PCB analysis following methods established for the NOAA National Status and Trends Mussel Watch Program (Battelle, 1988), with minor modifications made to those methods for the analysis of LAB. Additional modifications to the sample-preparation procedures were necessary because of the unusually high lipid content of myctophids. The excess lipid was removed with an additional cleanup procedure to minimize potential interferences in the instrumental analysis. A brief description of the sample preparation and analyses, including all modifications to the Mussel Watch Program, is given below.

3.1 SAMPLE PREPARATION

A 10 - 15 g aliquot of fish tissue was homogenized with a Tekmar Inc. Tissumizer. The homogenate was spiked with the appropriate PAH, LAB, and pesticide/PCB quantitation internal standards. The compound dibromooctafluororobiphenyl (DBOFB) was used for the pesticide/PCB internal standard, a mixture of d8-naphthalene, d10-acenaphthene, d12-perylene, and d12-benzo[a]pyrene (except one batch, 1A) was used for the PAH internal standard, and the compound 1-phenyl nonane was used for the LAB internal standard.

The spiked homogenate was mixed with 40 g sodium sulfate, and extracted for 5 minutes with methylene chloride. The mixture was centrifuged, the methylene chloride was decanted and reserved, and the extraction was procedure repeated twice more. The combined solvent extract was passed through an alumina column for lipid removal. The extract was concentrated to approximately 1 mL, using Kuderna-Danish techniques. Additional cleanup was necessary because of the high lipid content of the fish and was performed by using a high performance liquid chromatographic (HPLC) gel permeation technique (Krahn *et al.*, 1988). Extracts were diluted to 4 mL, and 1-mL fractions were separately loaded onto a Phenomonex 100 A gel permeation column and isocratically eluted with methylene chloride. The eluted fractions were combined and the volume reduced by gentle nitrogen gas evaporation to approximately 500 μL.

Just prior to instrumental analysis, the samples were spiked with PAH/LAB and pesticide/PCB recovery internal standards, which are used to measure the recovery of the quantitation internal standards. The compound tetrachloro-m-xylene (TCMX) was used as the recovery internal standard for pesticide/PCB analysis, and the compound d12-chrysene was used as the PAH/LAB recovery internal standard.

Sample dry weight was determined by removing a 1 - 5g aliquot of macerated tissue and weighing after drying overnight at 105°C. Sample percent moisture values ranged from 70 - 80 %.

3.2 INSTRUMENTAL ANALYSIS

Sample extracts were analyzed by capillary gas chromatography with mass spectrometry (GC/MS) for PAH and LAB contamination. GC/MS analysis conditions for LAB were derived from those of Eganhouse *et al.* (1983). Because the levels of PAH and LAB in fish tissue were in the very low ng/g range, the mass spectrometer was operated in the selected ion monitoring (SIM) mode to achieve the lowest possible detection limits. Any PAH and LAB compounds identified in the samples were quantified by using the method of internal standards. Results are reported in ng/g of tissue, on a dry-weight basis. Limits of detection (LOD) were calculated as the concentration of the analyte in the sample producing a signal three times the standard deviation of the backround signal for the procedural blank.

Tissue extracts were analyzed by capillary gas chromatography with electron capture detection (GC/ECD) for pesticide/PCB content. Any pesticide or PCB identified in the samples were quantified by using the method of internal standards. Results are reported in ng/g of tissue, on a dry-weight basis.

Data quality requirements and objectives and the results of quality control sample analyses are given in the Appendix A.

4.0 RESULTS AND DISCUSSION

The mesopelagic species collected during the NOAA June 1989 survey are listed in Table 1. Although, 35 samples were obtained for organic analysis, available funds allowed the analyses of only 12 samples. The criteria used to select samples for analysis were

(1) Station and species commonality with NOAA selections

(2) Adequate spatial coverage and control samples

(3) Replicated samples (where available).

Based on these criteria, 14 samples were initially identified for analysis. However, upon close inspection of the samples, it was found that the second replication for myctophidae composite for Stations 2 and 4 was highly traumatized as a result of the trawl and only unidentifiable tissue pieces remained. Organic analysis was not performed on the two highly traumatized samples because of the loss of sample integrity. All other samples remained sufficiently intact and whole-body organic analysis was performed. A list of the 12 samples analyzed is given in Table 2. Results of the

TABLE 1. SAMPLE SUMMARY BY SPECIES, STATION, AND REPLICATION OF SAMPLES COLLECTED FOR ORGANIC CONTAMINANT ANALYSIS DURING THE NOAA 106-MILE SITE SURVEY, JUNE 6-18, 1989[a,b]

Species Collected	Station 1 Replications			Station 2 Replications			Station 3 Replications			Station 4 Replications		
	1	2	3	1	2	3	1	2	3	1	2	3
Myctophidae Composite		X	X(2)	X(2)			X			X	X	
Benthosema glaciale		X	X							X	X	X(3)
Bolinichthys indicus							X					
Ceratoscopelus maderensis			X		X							
Diaphus spp.							X					
Diaphus rafinesqui	X	X										
Gonostoma spp.	X	X		X								X
Hygophum hygomi	X				X(2)	X						
Lampanyctus spp.					X	X						
Melamphaidae				X								
Royal Red Shrimp	X	X								X	X	
Total Identified	59	67-77	>197	>16	68	36	27			>92	83-93	182
Sample Identification Number	AAL092	AAL093	AAL094	AAL088	AAL089	AAL090	AAL091	NT	NT	AAL095	AAL096	AAL097

a) Number in parenthesis represents the replications within a single trawl.
b) NT indicates that no trawl was performed.

TABLE 2. MYCTOPHID SAMPLES ANALYZED FOR ORGANIC CONTAMINANTS.

Species Identification	Station-Replicate-Species Code[a]	Depth (m)	Date (M/D/Y)	Sample Identification
Hygophum hygomi	1-1-HH	600	6/13/89	AAL092A2
Benthosema glaciale	1-2-BG	362	6/13/89	AAL093A2
Benthosema glaciale	1-3-BG	29	6/13/89	AAL094A2
Myctophidae Composite	1-3-MC(1)	29	6/13/89	AAL094A4
Myctophidae Composite	1-3-MC(2)	29	6/13/89	AAL094A5
Myctophidae Composite	2-1-MC	step	6/12/89	AAL088A2
Hygophum hygomi	2-2-HH	40	6/12/89	AAL089A2
Hygophum hygomi	2-3-HH	35	6/12/89	AAL090A2
Myctophidae Composite	3-1,4-MC	step	6/12/89	AAL091A2
Benthosema glaciale	4-1-BG	600	6/14/89	AAL095A2
Benthosema glaciale	4-2-BG	800	6/14/89	AAL096A2
Myctophidae Composite	4-2-MC	800	6/14/89	AAL096A4

a) Code definition: Station number-Replicate number-First letter of genus and species. Number in parenthesis indicates replication within a single trawl.

analyses for organic contaminants in the 12 myctophid samples collected during the June 1989 survey are presented and discussed below.

4.1 POLYCHLORINATED BIPHENYLS (PCB)

Worldwide usage of PCB has decreased dramatically in recent years, but the input of PCB into the marine environment continues because of its resistance to chemical and biological degradation and its numerous transport mechanisms, including ocean dumping of sewage sludge. Also, marine organisms, such as myctophids, are slow to metabolize PCB and they can accumulate these contaminants in lipid tissues. Thus, PCB body burdens in myctophids can provide a useful indicator of PCB exposure.

The results of 12 analyses for PCB in myctophids are given in Table 3. The data are for individual congeners, level of chlorination, and total PCB. The individual isomer determinations and level of chlorination allow molecular distributions of PCB to be plotted for each sample. Compositional variations between the samples can reveal possible sources of PCB at each sampling site and, therefore, are useful in assessing the impact of a particular source (e.g., sewage sludge) at each site. Comparison of these data to Aroclor formulations is presented below, but is not necessarily justified for fish because of the probability of selective uptake and metabolism of PCB congeners (favoring the accumulation of highly chlorinated PCB). In addition, the sample stations are located far from their original source, allowing weathering and partitioning processes to become a significant factor in the PCB distributions. Although laboratory experiments on the uptake and metabolism of PCB in myctophids have not been

TABLE 3. WHOLE-BODY PCB CONCENTRATIONS IN MYCTOPHID (Dry Weight, ng/g)

PCB	1-1-HH	1-2-BG	1-3-MC(2)	1-3-BG	1-3-MC(1)	2-1-MC	2-2-HH	2-3-HH	3-1,4-MC	4-1-BG	4-2-BG	4-2-MC
INDIVIDUAL CONGENERS												
CL2(08)	ND*	ND*	ND*	ND*	ND*	ND	ND	ND*	ND	ND*	ND*	ND*
CL3(18)	ND*	ND	ND*	ND	ND	ND*	ND*	ND*	ND	ND*	ND*	ND*
CL3(28)	ND	ND	ND	3.593	3.029	0.489	0.427	3.163	ND	ND	ND	ND
CL4(52)	4.368	5.894	2.491	3.080	2.988	1.780	1.037	4.517	ND	11.338	6.822	ND
CL4(44)	2.630	2.063	1.531	2.335	1.534	3.642	1.265	2.075	1.474	8.077	ND	6.750
CL4(66)	4.067	6.479	0.961	1.942	2.264	1.502	1.312	4.279	0.685	6.143	7.750	6.156
CL5(101)	3.872	4.717	2.049	2.692	2.679	1.732	1.505	1.202	0.794	7.245	8.095	8.090
CL5(118)	1.840	2.336	1.077	0.938	1.136	2.021	1.658	0.789	0.653	2.563	3.546	3.375
CL5(105)	1.017	1.648	0.423	0.019	ND	0.402	0.597	0.397	0.215	1.594	3.333	1.606
CL6(128)	ND	ND	ND	ND	0.628	0.156	0.891	ND	ND	2.124	6.729	3.437
CL6(153)	3.978	6.748	3.361	2.201	2.153	4.556	3.820	1.927	2.111	8.527	12.324	7.885
CL6(138)	1.900	2.733	1.466	1.669	1.856	1.931	2.900	0.000	0.753	3.736	3.998	3.658
CL7(180)	0.586	1.302	1.254	1.145	1.893	1.933	2.066	0.303	1.406	2.988	3.492	2.013
CL7(187)	1.038	2.345	1.126	1.240	1.354	1.438	1.911	1.363	0.920	4.881	5.943	2.612
CL7(170)	3.065	4.826	ND*	3.599	ND*	4.146	0.739	12.111	19.449	ND*	ND*	15.411
CL8(195)	ND	ND	ND	ND	ND	ND	ND	3.407	12.130	ND	ND	ND
CL9(206)	ND	ND	ND	ND	ND	ND	0.041	ND	ND	ND	ND	ND
CL10(209)	ND	0.298	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
LEVEL OF CHLORINATION												
TOTAL CL2	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
CL3	ND	ND	ND	3.593	3.029	.489	.427	3.163	ND	ND	ND	ND
CL4	11.066	14.436	4.984	7.356	6.786	6.924	3.614	10.871	2.159	25.558	14.572	12.906
CL5	6.729	8.701	3.549	3.648	3.815	4.154	3.760	2.388	1.661	11.402	14.974	13.071
CL6	5.878	9.482	4.827	3.871	4.636	6.643	7.611	1.927	2.863	14.387	23.051	14.979
CL7	4.688	8.473	2.380	5.984	3.247	7.518	4.717	13.777	21.775	7.870	9.435	20.035
CL8	ND	ND	ND	ND	ND	ND	ND	3.407	12.130	ND	ND	ND
CL9	ND	ND	ND	ND	ND	ND	0.041	ND	ND	ND	ND	ND
CL10	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TOTAL PCB	28.4	41.4	15.8	24.5	21.5	25.7	20.2	35.5	40.6	59.2	62.0	61.0

ND : Below limit of detection (LOD).
* : Interfering peaks created uncertainty in value; data were treated as ND.

reported, it is likely that these processes are consistent within the myctophidae family. Thus, the relative abundance of PCB congeners may not be indicative of exposure to particular Aroclors, but differences in the distribution patterns between stations are indicative of different sources of PCB.

The mean total PCB concentrations at each station are listed in Table 4. The intrastation variability was very low at all sites, and the range of mean values between stations was small. There is no statistical difference between the mean total PCB concentrations at Stations 1 and 2. However, Station 4 (upstream), had PCB body burdens significantly higher (a factor of 2) than those of Stations 1 and 2, with PCB concentrations at Station 3 falling within this range. This is particularly interesting because Station 4 was chosen to represent a possible "reference" site that is not impacted by sewage-sludge dumping at the 106-Mile Site.

The mean PCB and pesticide body burdens for 21 mesopelagic fish collected from 20 different sites (all east of latitude 50°W) in the North Atlantic in 1972 (Harvey *et al.* 1974) are listed in Table 4. These data represent several different species, including *Benthosema glaciale, Myctophum punctatum, Protomyctophum articulum, Ceratoscopelus warmingi, Ceratoscopelus maderenisis, and Hygophum hygomi.* Comparison of these earlier data with those reported here indicates that there has been no statistically significant change in the PCB body burdens over the last 17 years, assuming that the fish collected near the 106-Mile Site can be compared to those collected throughout the North Atlantic. In addition, it

TABLE 4. MEAN PCB AND PESTICIDE CONCENTRATIONS (DRY WEIGHT) IN MYCTOPHID COLLECTED NEAR THE 106-MILE SITE.[1]

	Station 1 (ng/g)	Station 2 (ng/g)	Station 3 (ng/g)	Station 4 (ng/g)	Atlantic[2] (ng/g)
PCB (Total)	26.3±8.6	27.1±6.3	40.6	60.7±1.2	57±49
Pesticide (Total)	50.5±18.5	31.1±3.3	12.5	166±32	NA
DDT (Total)[3]	26.1±11.2	16.4±3.2	8.7	74.7±9.6	8.0±6.3

[1] Mean valve plus or minus standard deviation.
[2] Data from Harvey et al. (1974). NA: Data not available.
[3] Includes p,p' -DDE, p,p' -DDD, and p,p'-DDT only.

is apparent from these data that mesopelagic fish residing at the 106-Mile Site are not accumulating PCB to any greater extent than those fish from the other stations or elsewhere in the Atlantic. In all samples analyzed from this survey, the total PCB concentrations were low relative to PCB levels found in coastal fish near urban harbors, 0.5 to 300 ug/g (Weaver, 1984), and the current FDA action limit, 2 ug/g.

The level of chlorination in each sample is plotted in Figures 3 - 6 as a function of the percentage of total PCB. The tetrachlorobiphenyl dominates the molecular distribution of samples collected at the 106-Mile Site (Figure 3), but there is a significant contribution from the penta-, hexa-, and hepta-chlorobiphenyls. This corresponds to a mixture of Aroclors, with 1248 and 1254 containing the tetra- and penta-chlorobiphenyls and Aroclor 1260 and possibly 1262 contributing the hexa- and hepta-chlorobiphenyls. Aroclors 1254 and 1260 are the most abundant PCB formulations in the sewage sludge dumped at the 106-Mile Site (Ecological Analysts, 1983). A more distinct bimodal distribution is found for samples collected at Station 2, 100 miles southwest (downstream) of the 106-Mile Site (Figure 4), but it is shifted toward higher chlorination (Figure 4). This indicates possible enrichment of Aroclor 1260 in these samples. The distribution of PCB in the Sargasso Sea sample (Station 3) is enriched in the hepta- and octa-chlorobiphenyls as shown in Figure 5. This pattern is unique among the samples collected in this survey and indicates exposure of myctophids to only highly chlorinated PCB (e.g., Aroclor 1262). At Station 4, 80 miles northeast (upstream) of the 106-Mile Site, a bimodal distribution exists

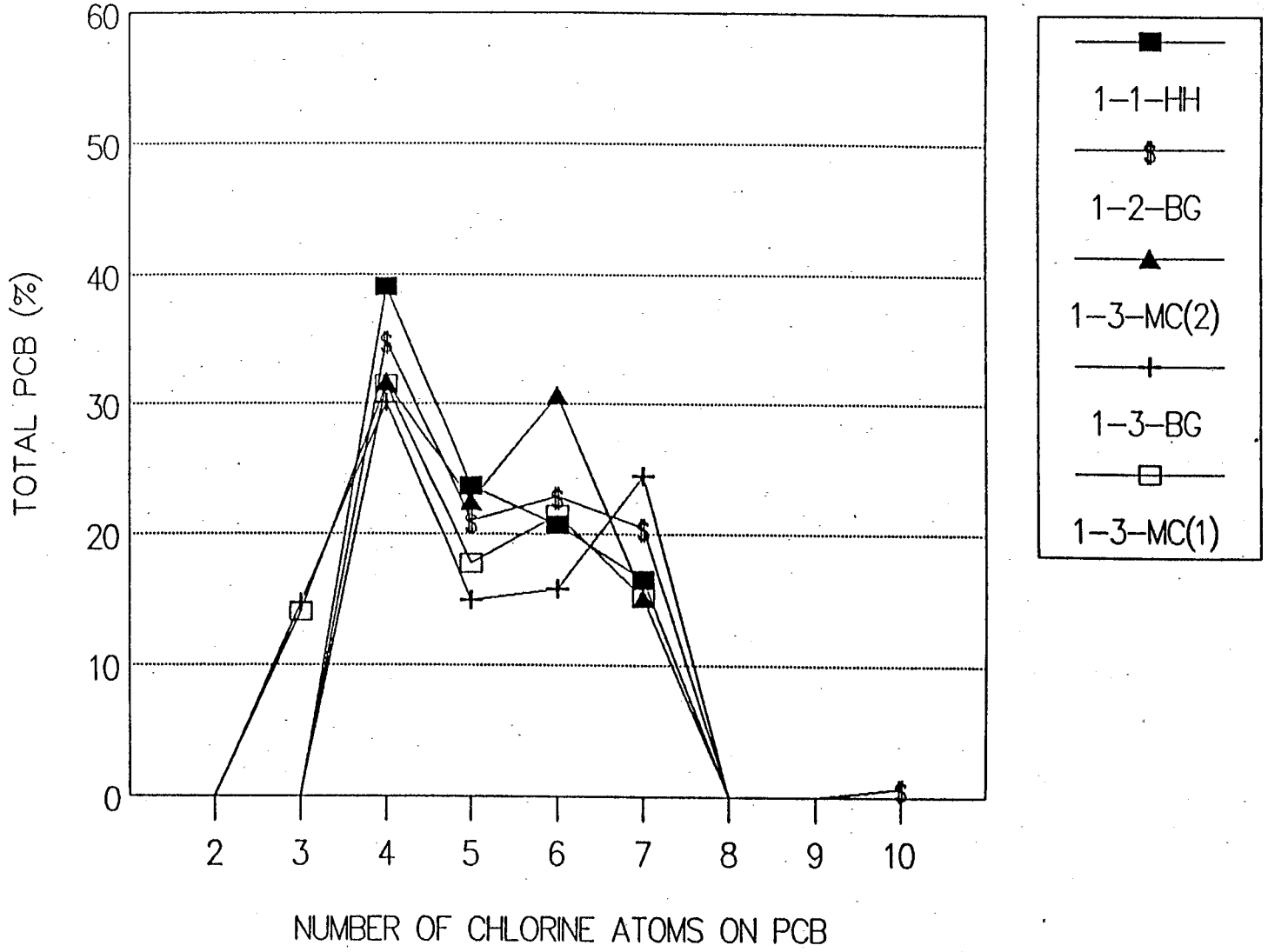


FIGURE 3. DISTRIBUTION OF PCB IN MYCTOPHID COLLECTED AT THE 106-MILE SITE (STATION 1).

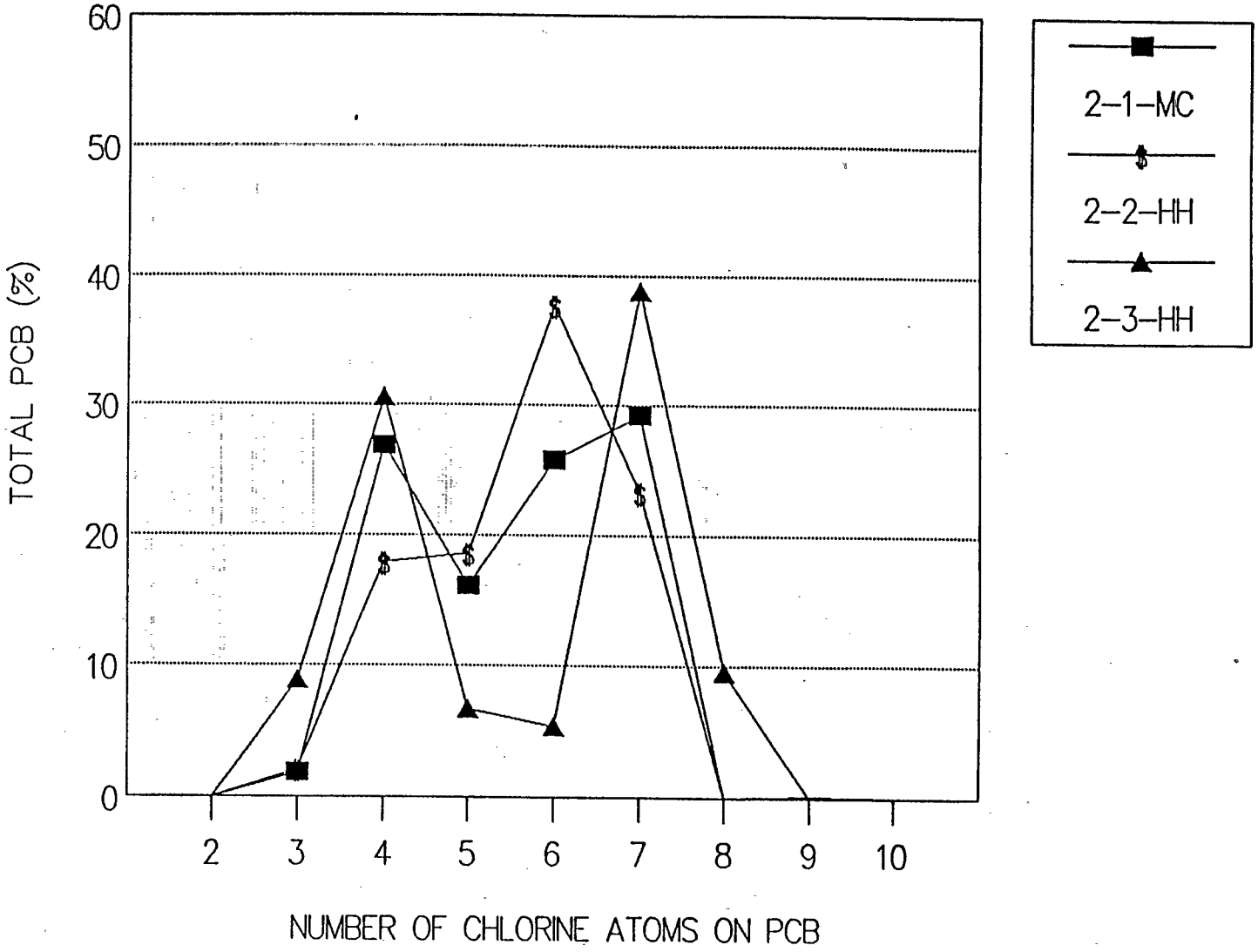


FIGURE 4. DISTRIBUTION OF PCB IN MYCTOPHID COLLECTED 100 MILES SOUTHWEST OF THE 106-MILE SITE (STATION 2).

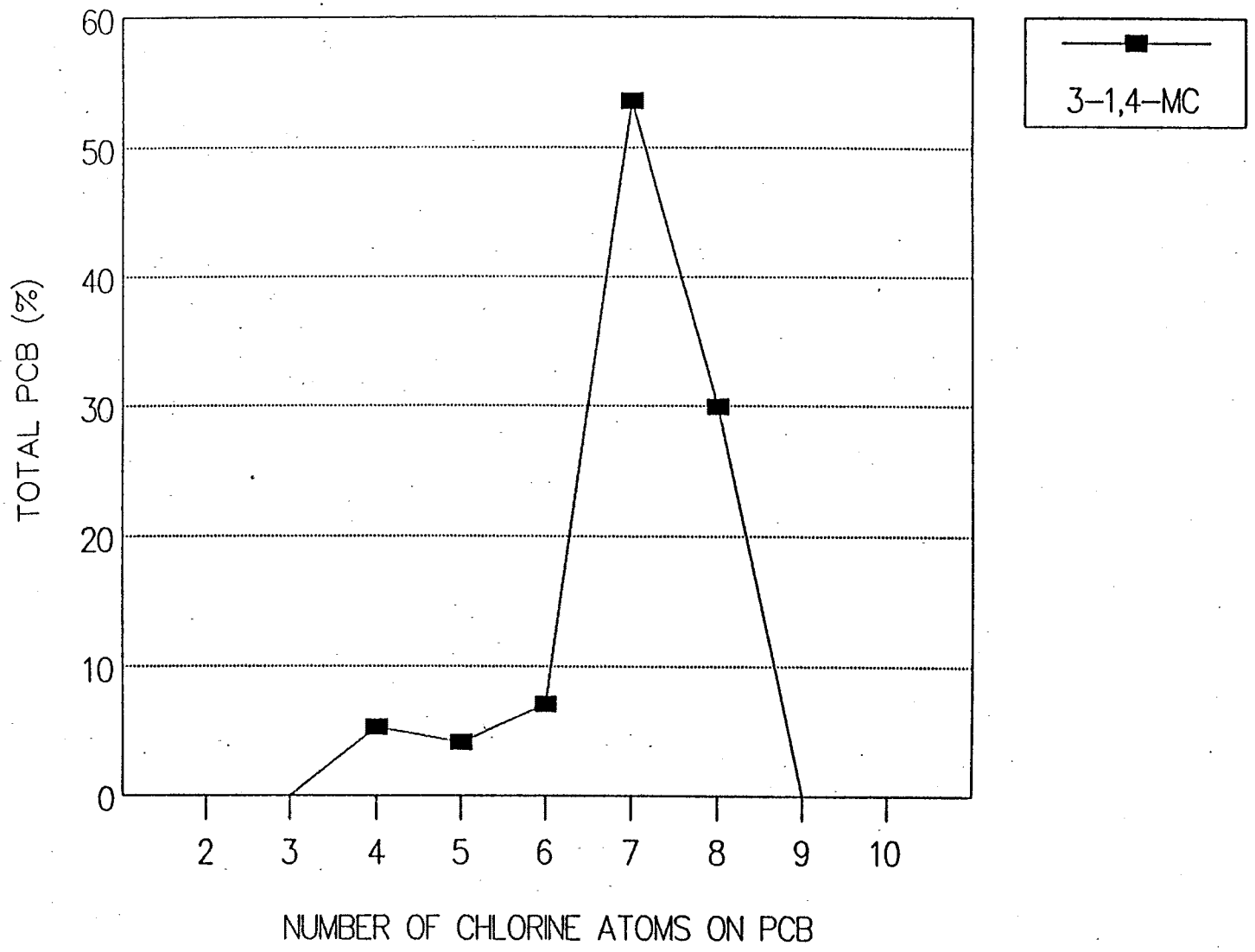


FIGURE 5. DISTRIBUTION OF PCB IN MYCTOPHID COLLECTED IN THE SARGASSO SEA (STATION 3).

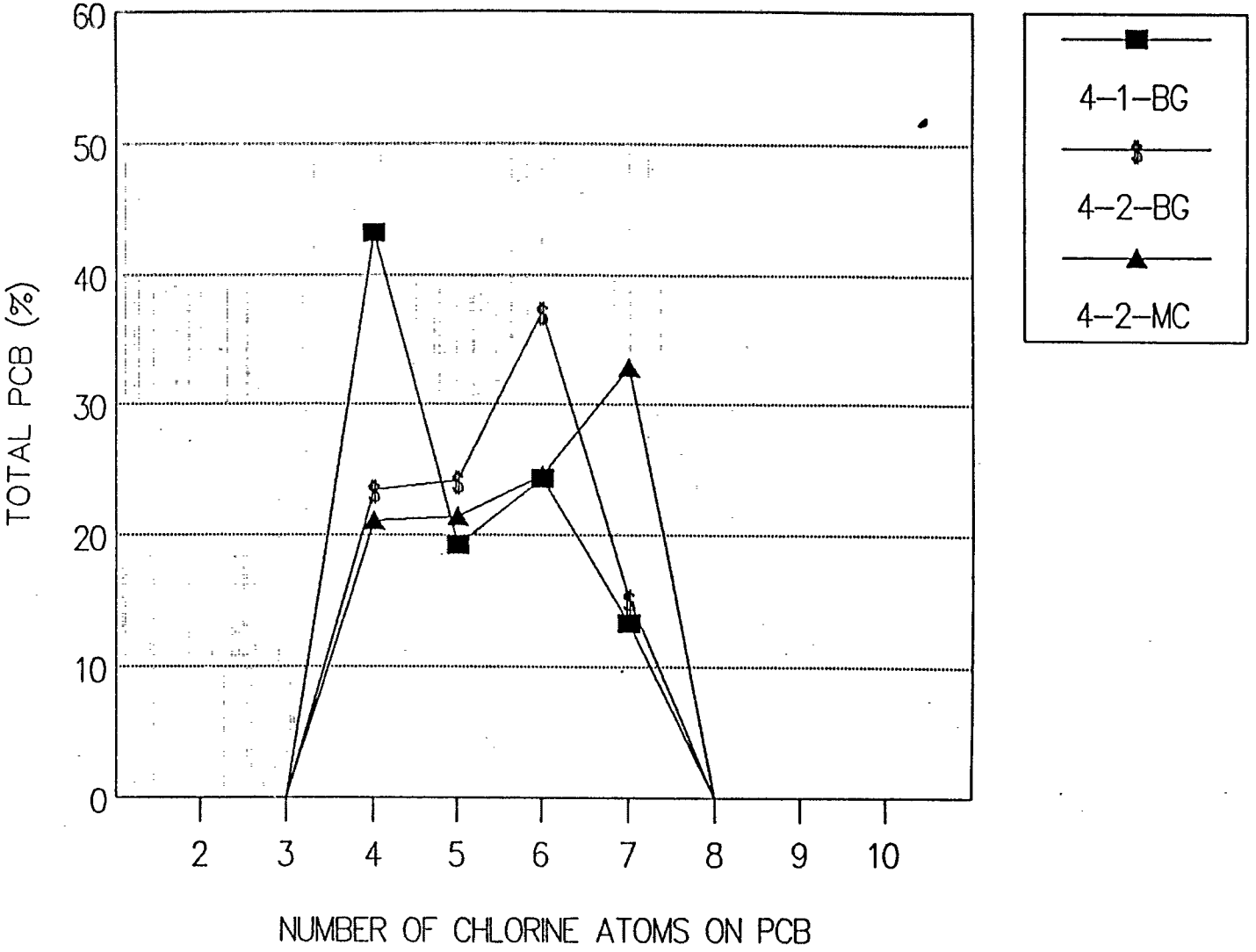


FIGURE 6. DISTRIBUTION OF PCB IN MYCTOPHID COLLECTED 80 MILES NORTHEAST OF THE 106-MILE SITE (STATION 4).

(Figure 6); the pattern is similar to that found for Station 1. Station 4 also contained the highest absolute concentrations of PCB (Table 4).

4.2 PESTICIDES

The results of 12 analyses for pesticides in myctophids are given in Table 5. The majority of the values are very low, but pesticides were detected in all samples and aldrin was the only compound not detected. The mean total pesticide values for each station are listed in Table 4. Within-station variability was low, but there are significant differences among the pesticide body burdens at the stations. The pesticide levels in the fish from the Sargasso Sea (Station 3) were significantly lower than those at the other stations. A gradient was found along Stations 1, 2 and 4; with concentrations decreasing from north to south. The pesticide body burdens were 4 times higher at the 106-Mile Site (Station 1) than the Sargasso Sea (Station 3), 2.5 times higher downstream (Station 2), and more than an order of magnitude higher upstream (Station 4). The enrichment of pesticides in the tissues of mesopelagic fish upstream from the 106-Mile Site is consistent with, but more dramatic than, that seen for PCB body burdens. Harvey et al. (1974) measured total DDT (PPDDE, PPDDD, and PPDDT) in North Atlantic myctophids (20 different sites) and the mean value is comparable to that of Station 3 (Table 4).

TABLE 5. PESTICIDE BODY BURDENS IN MYCTOPHID (Dry Weight, ng/g)

Pesticide	1-1-HH	1-2-BG	1-3-MC(2)	1-3-BG	1-3-MC(1)	2-1-MC	2-2-HH	2-3-HH	3-1,4-MC	4-1-BG	4-2-BG	4-2-MC
HCB	0.330	ND	2.856	3.427	2.983	1.851	1.520	2.243	0.306	2.711*	9.382*	1.321*
LINDANE	2.288	ND	1.063	ND	0.668	ND	ND	3.517	0.035	27.355	31.597	ND
HEPTACHLOR	ND	ND	0.544	ND	ND	0.827	0.078	ND	ND	1.779	2.262	0.202
ALDRIN	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
HEPTACHLOREPOXID	0.442	0.826	0.686	0.637	0.568	ND	ND	0.159	ND	1.409	1.480	3.014
OPDDE	1.005	1.426	0.442	ND	ND	0.936	0.319	ND	0.061	1.867	0.491	1.921
A CH	4.061	7.430	4.275	4.103	4.303	2.123	1.961	1.025	0.470	12.399	16.551	11.992
TRANSNONACHLOR	5.467	9.516	3.803	3.970	3.304	3.649	2.457	2.999	0.877	14.739	17.764	13.582
DIELDRIN	5.922	8.169	0.942	6.004	5.325	1.325	2.744	2.858	ND	15.458	18.901	16.158
PPDDE	10.723	18.486	8.392	8.117	7.830	6.978	6.882	7.040	3.300	33.310	37.621	30.412
OPDDD	0.288	1.080	0.254	ND	ND	0.361	0.439	ND	0.251	1.082	1.420	1.573
PPDDD	5.722	16.523	6.801	3.276	2.478	3.483	3.841	1.868	1.198	20.171	28.135	16.506
OPDDT	3.508	7.837	3.297	ND	ND	3.103	3.312	1.215	1.259	9.773	14.983	9.739
PPDDT	6.097	13.266	6.224	7.785	8.583	7.328	8.833	3.027	4.216	19.614	21.477	16.871
MIREX	1.318	2.430	0.392	2.483	2.404	1.022	1.552	0.534	0.473	2.835	4.658	3.846
TOTAL PESTICIDE	47.17	86.99	39.97	39.80	38.45	32.99	33.94	26.49	12.45	164.50	206.72	127.14

ND: Value below limit of Detection (LOD).

* : Interfering peak occurred; value may be artificially high.

4.3 POLYNUCLEAR AROMATIC HYDROCARBONS (PAH)

The PAH body burden data for the myctophids are given in Table 6. Most of the data are below the detection limit, and all of the measured values are trace levels. The few elevated naphthalene values are probably the result of laboratory contamination. These low values are consistent with previous studies of PAH body burdens in fish tissue. PAH levels in fish tissue are usually very low or not detectable even in heavily polluted waters because PAH are easily metabolized by most fish. Assessing the exposure of fish to PAH would require analysis of the PAH metabolites.

4.4 LINEAR ALKYL BENZENES (LAB)

The LAB are a group of phenyl alkanes having a benzene ring with a straight alkyl chain of between 9 and 15 carbons. LAB are precursors used in the production of linear alkyl benzenesulphonate surfactants (LAS), which are common in domestic detergents. Unreacted LAB remain in the detergent product as impurities; they may also result from desulfonation of LAS. Eventually LAB can appear in domestic wastes and sewage sludge. Although the initial concentrations of LAS are higher than those of LAB, LAS are easily oxidized (both photochemically and microbially); therefore they do not persist in the environment. Conversely, LAB are more resistent to oxidation than are LAS and may be preserved in sediments for decades (Eganhouse *et al.*, 1988). This stability has led to the use of LAB as a geochronological marker and as a chemical tracer for domestic wastes and

TABLE 6.PAH AND LAB BODY BURDENS IN MYCTOPHID (Dry Weight, ng/g)

PAH	1-1-HH	1-2-BG	1-3-MC	1-3-BG	1-3-MC	2-1-MC	2-2-HH	2-3-HH	3-1,4-MC	4-1-BG	4-2-BG	4-2-MC
naphthalene	15.00	15.48	16.62	12.2	13.19	23.87	7.28	12.90	19.52	10.62	11.70	11.2
2-methylnaphthalene	10.84	7.80	ND	5.97	9.97	16.89	5.20	9.15	13.46	6.93	6.94	8.05
1-methylnaphthalene	6.50	5.23	ND	ND	4.61	10.19	3.35	ND	10.02	4.24	4.43	5.31
biphenyl	ND	ND	ND	ND	4.21	5.93	2.42	4.19	5.32	ND	ND	ND
2,6-dimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	4.07	ND	1.52	3.66
acenaphthylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
acenaphthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
2,3,5-trimethylnaphthalene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	4.21
fluorene	ND	ND	ND	2.25	ND	4.19	1.76	1.98	2.49	0.69	1.22	1.96
phenanthrene	ND	ND	ND	ND	ND	12.54	4.03	ND	7.52	ND	ND	ND
anthracene	ND	ND	ND	ND	ND	ND	0.58	ND	ND	ND	ND	ND
1-methylphenanthrene	ND	ND	ND	ND	ND	ND	ND	ND	2.00	ND	ND	ND
fluoranthene	1.73	8.80	ND	ND	ND	9.35	1.71	ND	4.56	ND	ND	2.23
pyrene	2.18	8.62	ND	ND	ND	7.66	ND	ND	3.82	0.93	1.42	2.08
benz[a]anthracene	ND	ND	ND	ND	ND	0.85	ND	ND	ND	ND	ND	ND
chrysene	ND	ND	ND	ND	ND	3.61	2.04	ND	11.89	4.80	7.42	14.47
benzo[b]fluoranthene	ND	ND	ND	ND	ND	1.42	0.83	ND	ND	ND	ND	ND
benzo[k]fluoranthene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
benzo(e)pyrene	ND	ND	ND	ND	ND	ND	0.75	ND	ND	ND	ND	ND
benzo(a)pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
indeno[1,2,3-c,d]pyrene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
dibenz[a,h]anthracene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
benzo[g,h,i]perylene	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
TOTAL PAH	36.25	45.93	16.62	20.42	31.98	96.5	29.87	28.22	102.76	28.21	34.65	53.17
1-phenyl decane	ND	15.78	ND	2.13	2.31	25.75	11.89	6.76	17.32	ND	ND	ND
1-phenyl undecane	ND	ND	ND	ND	ND	2.45	4.76	ND	2.11	ND	ND	ND
1-phenyl dodecane	ND	ND	ND	ND	ND	ND	ND	ND	4.03	ND	ND	ND
1-phenyl tridecane	ND	29.49	ND	ND	2.49	29.22	11.08	6.50	20.66	ND	ND	3.99
n-tetradecylbenzene	27.50	157.54	23.25	ND	ND	105.80	42.11	232.37	57.34	142.04	61.02	ND
TOTAL LAB	27.5	202.81	23.25	2.13	4.8	163.22	69.84	245.63	101.46	142.04	61.02	3.99

ND: Value is below limit of detection (LOD).

sewage sludge. Although there are several reports of LAB measurements in sediments and particulate matter, very little work has been reported on measuring LAB in tissues of organisms that have been exposed to sewage. Murray *et al.* (1987) found LAB in a single mussel sample collected near Port Phillip Bay (Australia) sediments enriched in LAB, and some studies have been performed on the microbial oxidation of LAB in cultures (Bayona *et al.*, 1986). This study provides the first field evaluation of LAB as a chemical indicator of biological exposure to sewage sludge at the 106-Mile Site.

Results obtained from the LAB body-burden analyses are listed in Table 6, with essentially all of the data near or below the detection limit. Extremely low levels of LAB in fish tissue could result from either limited exposure to sludge particles or rapid metabolism of the aliphatic chains. In addition, laboratory and/or field contamination from detergents (containing high levels of LAB) could introduce measurable LAB to the sample, and may account for the high n-tetradecyl-benzene values. All of the LAB compounds were detected in the sample from the Sargasso Sea (Station 3), giving further indication of contamination.

4.5 PHYSICAL OCEANOGRAPHIC DATA

The satellite thermal imagery data for June 11, 1989 is shown in Figure 7. These data were prepared by Margaret Sano of the Marine Climatology Investigation of the National Marine Fisheries Service. This low-resolution analysis provides a composite view of the Gulf Stream position,

JUNE 11, 1989 NOAA-11 AVHRR IMAGE AND MYCTOPHID TRAWL STATIONS

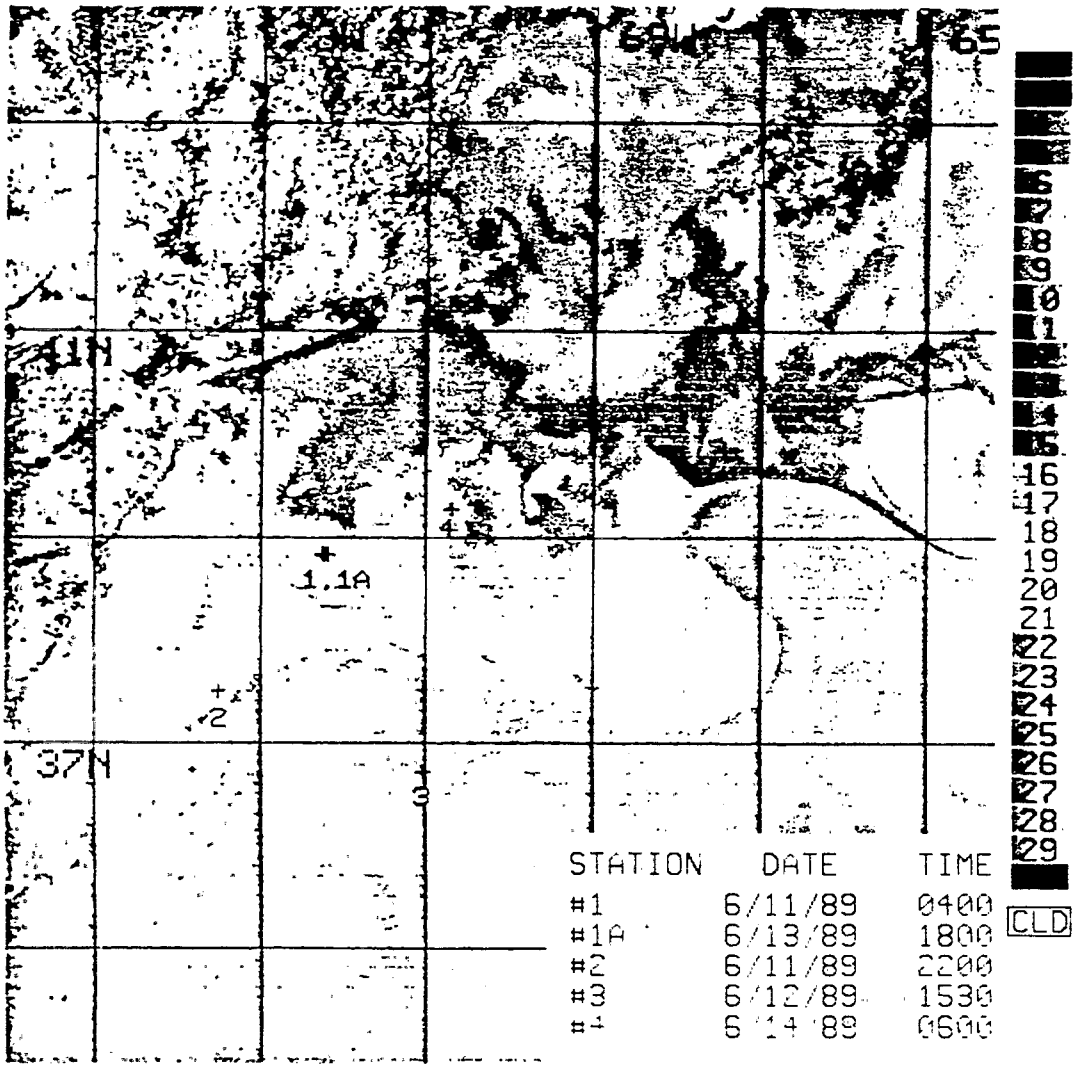
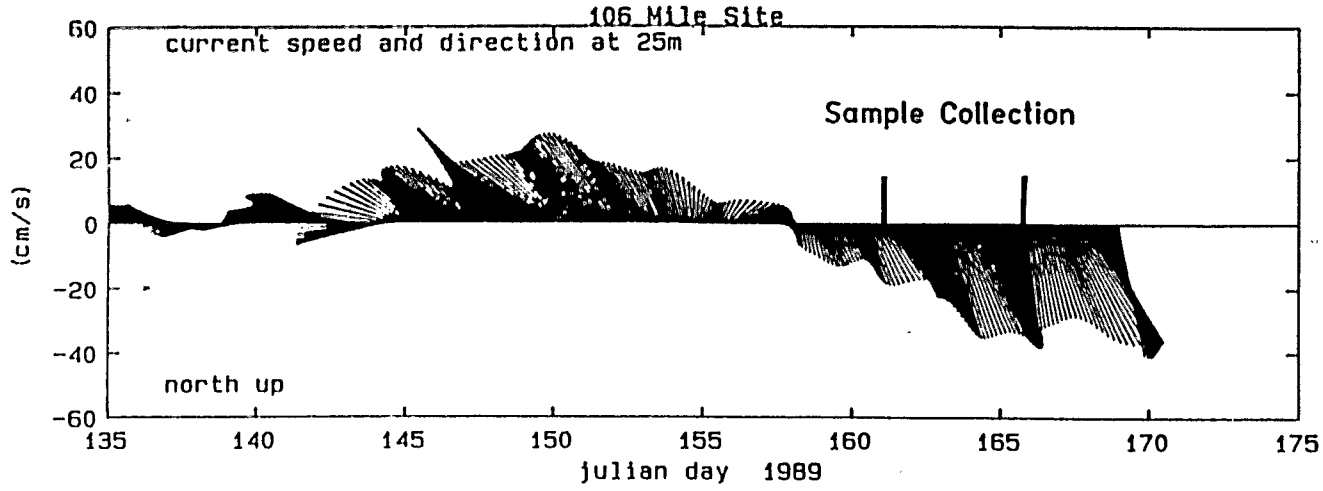


FIGURE 7. SATELLITE THERMAL IMAGERY DATA FROM JUNE 11, 1989.

the location of the shelf water/slope water front, and the positions of warm-core and cold-core eddies formed by Gulf Stream meanders. However, surface warming reduces the thermal contrast between these water masses during the summer. The data show that during the sampling period Station 3 was in the Sargasso Sea, about 20 miles southeast of the Gulf Stream. Station 2 was located in slope water, but was very close to the Gulf Stream. Stations 1 and 4 were located in slope water, over 10 miles north of the Gulf Stream. These data alone are not sufficient to attempt correlations between water masses and contaminant body burdens.

Near-surface current velocity and direction at the 106-Mile Site were monitored with the moored current meters in place at 25 m and 100 m depths. Vector profiles for the time period 15 May to 18 June, 1989 are shown in Figure 8. For the three weeks prior to sampling, current velocities were moderately weak (<30 cm/s) and the prevailing current direction was toward the northeast. Around 8 June, 1989 the current direction shifted toward the south and remained that way throughout the survey. The maximum current velocity was about 40 cm/s. There is no evidence of water movement (or contaminant transport) from Station 1 (106-Mile Site) toward Station 4 over this 1 month period.

Hydrographic profiles of temperature, salinity and sigma-t are given in Appendix C.



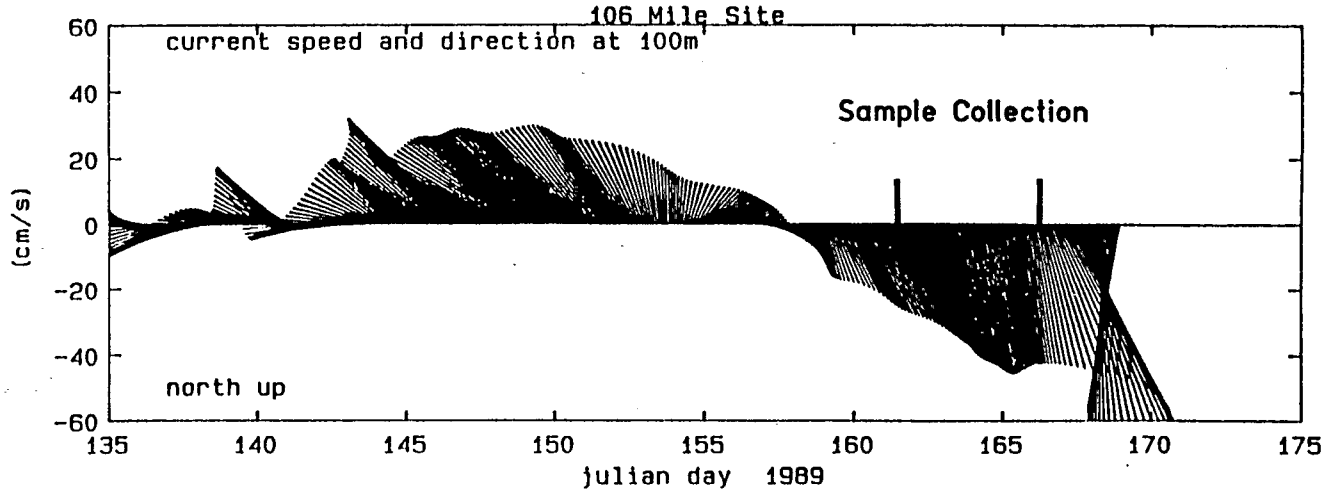


FIGURE 8. CURRENT VECTORS FOR 25 AND 100 METERS AT THE 106-MILE SITE (15 MAY TO 18 JUNE, 1989).

5.0 CONCLUDING REMARKS

5.1 SUMMARY AND CONCLUSIONS

The objectives of this work assignment were to conduct an initial assessment of the impact of sewage-sludge disposal on indigenous fish in the vicinity of the 106-Mile Site and evaluate the feasibility of monitoring the bioaccumulation of sludge-related contaminants in mesopelagic fish. Myctophids were collected at four stations: the 106-Mile Site, 100 miles southwest and 80 miles northeast of the 106-Mile Site, and the Sargasso Sea.

Contaminant body burdens in these fish provided a good indication of low level exposure to PCB and pesticides at all four stations, but the data were not sufficient to determine the source of the contaminants. Concentrations of almost all PAH and LAB were near or below the detection limit for all of the samples. Both PAH and LAB are readily metabolized by fish, so the low levels reported here are not necessarily a result of low exposure.

Trace levels of PCB and pesticides were found in fish at all stations. The highest concentrations were found at Station 4, 80 miles northeast of the 106-Mile Site. Very little difference was found in the levels of PCB and pesticide at Stations 1 and 2 and only small differences were found in the distribution of PCB in fish at Stations 1, 2, and 4. However, Station 3 exhibited a unique PCB distribution (higher level of chlorination),

indicating either a unique source of PCB or the PCB was more weathered. There were no apparent interspecies differences in the amount or distribution of PCB and pesticides in myctophids.

To gain more insight into possible PCB and pesticide sources, diagnostic ratios of total pesticide/total PCB, total DDT/total PCB, total DDT/total pesticide are plotted in Figure 9. These diagnostic ratios show a clear similarity between Stations 1 and 4, while Station 3 again exhibits a unique pattern. Diagnostic ratios for Station 2 fall within this range and are closest to those of Stations 1 and 4. Pesticide/PCB ratios found in this study are simialr to those of fish collected in areas without direct contamination (Amico *et al.*, 1979), whereas much lower ratios have been found for marine organisms in areas with more direct contaminant inputs (Albaiges et al., 1987, Contardi et al., 1979, Fossato and Craboledda, 1980).

Based on these data, it appears that mesopelagic fish at the 106-Mile Site have organic-contaminant body burdens less than or similar to those found in fish from other continental slope waters and much less than fish of coastal waters. Sewage-sludge disposal at the 106-Mile Site is only one of several sources of PCB and pesticides and has not caused greater contaminant body burdens in resident fish than those found at reference stations. McVicar *et al.* (1988) recently found a similar no-effects relationship between sewage-sludge dumping in the North Sea and the prevalence of fish diseases. More definitive conclusions on the biological impact of sewage-sludge disposal at the 106-Mile Site might be made after

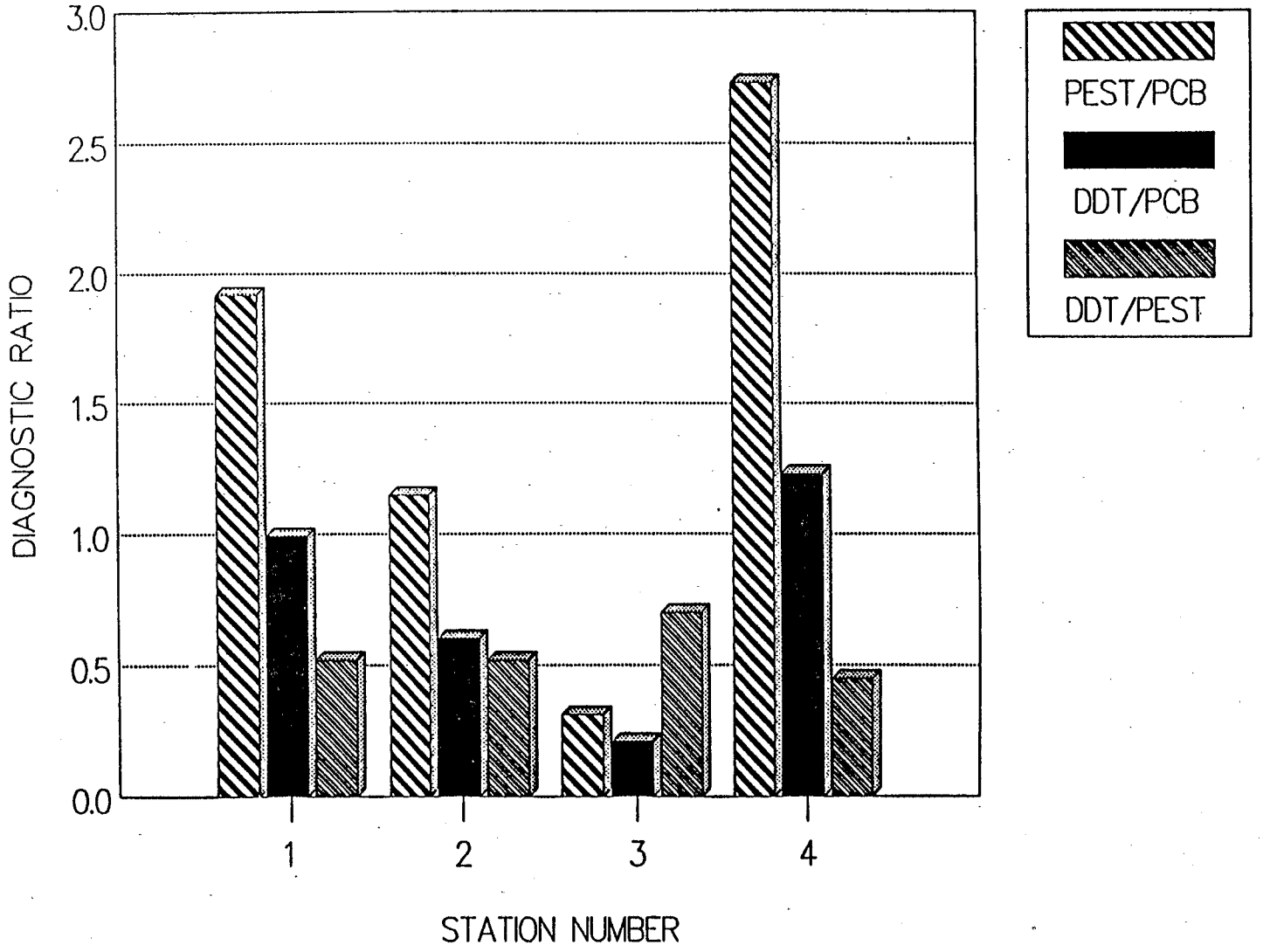


FIGURE 9. PCB AND PESTICIDE DIAGNOSTIC RATIOS IN MYCTOPHID: TOTAL PCB (PCB), TOTAL PESTICIDE (PEST), AND TOTAL DDT (DDT).

the complimentary trace-metal data become available and after additional surveys are conducted.

5.2 RECOMMENDATIONS

Based on the results of this study, myctophids appear to be good indicators of exposure to chlorinated hydrocarbons and, therefore, myctophids should be considered as potential biomarkers of long-term biological affects resulting from sludge dumping at the 106-Mile Site. However, before myctophids can be used to assess the effects of sewage-sludge dumping at the 106-Mile Site, more information is needed on the body burdens in fish not impacted by dumping at the 106-Mile Site. This requires a more thorough understanding of the distribution of contaminant body burdens in waters outside the influence of the 106-Mile Site (i.e., background body burdens) and the identification of contaminant gradients. These background data would also provide critical information on the long-range transport and fate of chlorinated hydrocarbons in open ocean waters. Several recommendations are listed below regarding future studies of myctophids as indicators of organic-contaminant exposure and effects.

- The use of myctophids as an indicator of long-term biological effects of sewage-sludge dumping should be included in any future monitoring plan for the 106-Mile Site.
- Any future field collections of myctophids should have complimentary contaminant distribution data from whole water, particulate, microlayer, and plankton samples. The additional information would enhance our ability to relate contaminant body burdens to contaminant transport and fate, and routes of exposure to the organism.

- The list of organic contaminants should include PCB and chlorinated pesticides, and possibly PAH metabolites. Consideration should be given to PCB/pesticide analysis by negative ion GC/MS, a method that would increase sensitivity over conventional GC/ECD analyses, and would also provide positive identification of these analytes.

- The distribution of contaminant body burdens should be determined in myctophids collected at several sites beyond the influence of the 106-Mile Site as determined from physical oceanographic data. Sampling design should include a transect(s) from coastal waters to establish the existence of gradients.

- The background data should be used to estimate the body burdens that would be expected in myctophids at the 106-Mile Site in the absence of sewage-sludge dumping. The background body burdens can be used to establish null hypotheses regarding the effects of sewage-sludge dumping at the 106-Mile Site.

- Future field activity should be guided by advice from recognized experts in the behavior and collection of myctophids to ensure sampling success. The trauma of the fish could be minimized by reducing the tow duration (<20 min.) and speed (2 - 4 knots), and conducting more frequent trawls.

The June 1989 myctophid survey was joint NOAA/EPA monitoring effort. Cooperation between NOAA and EPA will continue to yield comprehensive and cost effective monitoring programs.

6.0. REFERENCES

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APPENDIX A. DATA QUALITY REQUIREMENTS AND QUALITY CONTROL RESULTS

Accuracy of the chemical data and assessment of the quality of the chemical data set are guided by quality control (QC) procedures described in Battelle standard operating procedures (SOPs) listed in the Work Plan for WA 38. Accuracy is ensured by the analysis of procedural blanks and matrix spike samples. Laboratory extraction efficiencies were monitored by tracking the recovery of internal standard and surrogate compounds. Precision was determined by analysis of duplicate extractions.

Matrix spike and matrix spike duplicate extraction recoveries and procedural blanks are listed in Tables A-1 and A-2. Surrogate recoveries are listed in Tables A-3 and A-4.

TABLE A-1. RESULTS OF PROCEDURAL BLANKS (PB), MATRIX SPIKES (MS), AND MATRIX SPIKE DUPLICATES (MSD) FOR PCB AND PESTICIDES.

PCB/Pesticide	HV01 PB (ng)	HV04 PB (ng)	RECOVERY (%) HV05-MS	HV06-MSD	MEAN	%RPD[a]
CL2(08)	ND	ND	467.81[b]	285.15[b]	376	49
HCB	0.039	ND	19.06[b]	9.63[b]	14	66
LINDANE	ND	0.055	108.29	98.33	103	10
CL3(18)	ND	ND	131.54[b]	110.07	121	18
CL3(28)	ND	ND	115.59	95.61	106	19
HEPTACHLOR	ND	ND	120.34[b]	101.30	111	17
CL4(52)	ND	ND	118.73	102.41	111	15
ALDRIN	ND	ND	127.96[b]	121.98[b]	125	5
CL4(44)	2.309	2.752	115.45	95.88	106	19
HEPTACHLOREPOXID	ND	ND	122.04[b]	103.28	113	17
CL4(66)	ND	ND	83.72	72.03	78	15
OPDDE	ND	ND	96.04	77.66	87	21
CL5(101)	ND	ND	77.76	61.50	70	23
A CH	ND	ND	92.26	72.65	82	24
TRANSNONACHLOR	ND	ND	106.32	83.07	95	25
DIELDRIN	ND	ND	89.97	107.12	99	17
PPDDE	ND	ND	123.84[b]	100.34	112	21
OPDDD	ND	0.048	100.95	85.45	93	17
CL5(118)	ND	ND	92.71	77.06	85	18
PPDDD	ND	ND	154.79[b]	92.88	124	50
OPDDT	ND	ND	128.51[b]	105.29	117	20
CL6(153)	ND	ND	73.20	64.06	69	13
CL5(105)	ND	ND	87.11	74.81	81	15
PPDDT	ND	ND	50.84	34.08	42	39
CL6(138)	ND	ND	68.91	55.67	62	21
CL7(187)	ND	ND	66.17	52.31	59	23
CL6(128)	ND	ND	71.15	56.84	64	22
CL7(180)	ND	ND	51.50	36.61	44	34
MIREX	ND	ND	49.06	39.81	44	21
CL7(170)	ND	ND	88.27	92.61	90	5
CL8(195)	ND	11.818	43.29	34.69	39	22
CL9(206)	ND	ND	24.97	21.24	23	16
CL10(209)	ND	ND	25.54	21.42	23	18

[a] RPD = 2 * (MS - MSD)/(MS + MSD)) * 100.

[b] Value is outside acceptable recovery range (20-120%).

TABLE A-2. RESULTS OF PROCEDURAL BLANKS (PB), MATRIX SPIKES (MS), AND MATRIX SPIKE DUPLICATE (MSD) RECOVERY VALUES FOR PAH AND LAB.[a,b]

PAH/LAB	Recovery (%) HV01PB (ng)	HV04PB (ng)	HV05 MS	HV06 MSD	MEAN	%RPD
naphthalene	11.90	18.21	92	95	93	3
2-methylnaphthalene	5.47	6.62	103	109	106	6
1-methylnaphthalene	4.33	ND	101	108	104	7
biphenyl	ND	ND	101	106	104	5
2,6-dimethylnaphthalene	ND	ND	103	109	106	6
acenaphthylene	ND	ND	101	106	103	4
acenaphthene	ND	ND	81	84	83	4
2,3,5-trimethylnaphthalene	ND	ND	78	81	80	3
fluorene	ND	ND	78	79	79	2
phenanthrene	ND	2.9	54	55	54	1
anthracene	ND	ND	42	79	61	61
1-methylphenanthrene	ND	ND	61	61	61	1
fluoranthene	ND	5.61	54	51	52	5
pyrene	3.46	5.26	49	46	48	6
benz[a]anthracene	ND	ND	299[a]	388[a]	344	26
chrysene	5.01	5.54	279[a]	363[a]	321	26
benzo[b]fluoranthene	ND	4.96	0[a]	46	23	100
benzo[k]fluoranthene	ND	2.69	0[a]	0	0	0
benzo(e)pyrene	ND	3.25	132[a]	137[a]	135	4
benzo(a)pyrene	ND	2.49	52	95	74	59
perylene	ND	ND	88	90	89	2
indeno[1,2,3-c,d]pyrene	ND	ND	0[a]	0	0	0
dibenz[a,h]anthracene	ND	ND	0[a]	0	0	0
benzo[g,h,i]perylene	ND	ND	162[a]	172[a]	167	6
1-phenyl decane	21.95	ND	104	105	105	1
1-phenyl undecane	ND	ND	96	95	96	1
1-phenyl dodecane	5.88	ND	79	76	77	4
1-phenyl tridecane	25.60	2.89	87	86	87	1
n-tetradecylbenzene	110.47	34.69	78	77	78	2
d8-naphthalene			394[a]	281[a]	337	33
d10-acenaphthene			494[a]	360[a]	427	31
d12-perylene			32	23	27	34
1-phenyl nonane			439[a]	334[a]	38	27

[a] value is outside acceptable recovery range (20-120%).
[b] %RPD = 2 * (MS - MSD)/(MS + MSD)) * 100

TABLE A-3. SURROGATE (DBOFB) RECOVERIES FOR PCB/PESTICIDE ANALYSIS

Sample ID	Recovery (%)
HV01 PB	105.35
HV04 PB	67.45
AAL088A2	116.86
AAL089A2	101.97
AAL091A2	96.91
AAL090A2	119.96
AAL092A2	82.82
AAL093A2	17.59[a]
AAL094A5	82.91
AAL094A2	86.04
AAL094A4	91.40
AAL095A2	23.11
AAL096A2	23.08
AAL096A4	57.83

[a]Value is outside acceptable recovery range (20-120%).

TABLE A-4. SURROGATE RECOVERIES (%) FOR PAH AND LAB[a,b,c].

Sample ID	Sample Dry Weight (g)	d8-N	d10-A	d12-B(a)P	d12-P	1-PN
HV01 PB	1.000	91	93	96	99	101
AAL088A2	1.141	86	93	92	92	104
AAL089A2	3.572	83	94	79	76	102
AAL090A2	3.507	320[b]	414[b]	32	26	525[b]
AAL091A2	1.582	77	83	85	84	93
AAL092A2	2.820	285[b]	400[b]	28	21	464[b]
AAL093A2	4.575	35	38	3[b]	4[b]	50
AAL094A5	3.681	457[b]	629[b]	0[b]	104	578[b]
HV04 PB	1.000	61	74	NS	94	64
AAL094A2	2.868	89	134[b]	NS	34	117
AAL094A4	2.585	97	142[b]	NS	39	126[b]
AAL095A2	2.837	247[b]	305[b]	NS	32	107
AAL096A2	2.659	228[b]	288[b]	NS	34	120
AAL096A4	2.523	194[b]	242[b]	NS	28	122[b]

[a]d8-N = d8-naphthalene
d10-A = d10-acenaphthene
d12-B(a)P = d12-benzo(a)pyrene
d12-P = d12-perylene
1-PN = 1-phenyl nonane
[b]value is outside acceptable range (20-120%).
[c]NS = the surrogate was not spiked in the sample.

APPENDIX B. TRAWL LOCATION LOGS

BATTELLE OCEAN SCIENCES
Work Assignment 38
G3811
Trawl Location Log

TATION IDENTIFICATION

Station Number 1 (DUMPSITE) (X or X-XXX) Date 11 (DD) 06 (MM) 89 (YY)

AMPLING LOCATION ①

Start of Tow

TD1 26137.0 (xxxxx.x) TD2 42733.4 (xxxxx.x) Lat 38 (DD) 49 70 (MM.MM) N Lon 72 (DDD) 14 30 (MM.MM) W

End of Tow

TD1 26116.0 (xxxxx.x) TD2 42696.3 (xxxxx.x) Lat 38 (DD) 45 40 (MM.MM) N Lon 72 (DDD) 21 40 (MM.MM) W

Bottom Depth 2536 (xxx) FM Mean Wire Out - (xxx)

Tow Depth STEP Tow (xxx) No. of Myctophids 13 NONE TAKEN FOR ORGANICS (xxx)

Start Time 04 (HH) : 05 (MM) (24 Hour clock) End Time 05 (HH) : 25 (MM) (24 Hour clock

AMPLING LOCATION 2

Start of Tow NO RECORD - TRAWL IS UPSIDE DOWN

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat __ (DD) __ (MM.MM) N Lon ___ (DDD) __ (MM.MM) W

End of Tow NET IS TORN

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat __ (DD) __ (MM.MM) N Lon ___ (DDD) __ (MM.MM) W

Bottom Depth _____ m (xxx) Mean Wire Out _____ (xxx)

Tow Depth _____ m (xxx) No. of Myctophids 0 NET TORN (xxx)

Start Time 06 (HH) : 47 (MM) (24-Hour clock) End Time ___ (HH) : ___ (MM) (24-Hour clock)

RECORDER

Name Nina M Young ID Number 3211.10

(White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

BATTELLE OCEAN SCIENCES
Work Assignment 38
G3811
Trawl Location Log

TATION IDENTIFICATION

Station Number 1 (DUMPSITE) (X or X-XXX) Date 11 (DD) 06 (MM) 89 (YY)

AMPLING LOCATION 3

Start of Tow

TD1 26141.9 (xxxxx.x) TD2 42737.0 (xxxxx.x) Lat 38 (DD) 50 10 (MM.MM) N Lon 72 (DDD) 15 10 (MM.MM) W

End of Tow

TD1 26120.5 (xxxxx.x) TD2 4267.66 (xxxxx.x) Lat 38 (DD) 43 30 (MM.MM) N Lon 72 (DDD) 11 00 (MM.MM) W

Bottom Depth 1504?m (xxx) Mean Wire Out - (xxx)

Tow Depth STEP TRAWL m (xxx) SEE LOG BOOK No. of Myctophids 0 (xxx)

Start Time 09 (HH) : 15 (MM) (24 Hour clock) End Time 11 (HH) : 55 (MM) (24 Hour clock

COD END BECAME UNTIED NO SAMPLE

AMPLING LOCATION _____

Start of Tow

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat ___ (DD) ___ (MM.MM) N Lon ___ (DDD) ___ (MM.MM) W

End of Tow

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat ___ (DD) ___ (MM.MM) N Lon ___ (DDD) ___ (MM.MM) W

Bottom Depth _____ m (xxx) Mean Wire Out _____ (xxx)

Tow Depth _____ m (xxx) No. of Myctophids 0 (xxx)

Start Time ___ (HH) : ___ (MM) (24-Hour clock) End Time ___ (HH) : ___ (MM) (24-Hour clock)

RECORDER

Name Nina M Young ID Number 321.10

(White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

BATTELLE OCEAN SCIENCES
Work Assignment 38
G3811
Trawl Location Log

STATION IDENTIFICATION

Station Number 1 (DUMPSITE) (X or X-XXX) Date 13 (DD) 06 (MM) 89 (YY)

SAMPLING LOCATION (1) REPEAT

Start of Tow

TD1 26124.3 (xxxxx.x) TD2 42741.0 (xxxxx.x) Lat 38 (DD) 50 40 (MM.MM) N Lon 72 (DDD) 12 20 (MM.MM) W

End of Tow

TD1 26100.3 (xxxxx.x) TD2 42749.7 (xxxxx.x) Lat 38 (DD) 51 30 (MM.MM) N Lon 72 (DDD) 08 20 (MM.MM) W

Bottom Depth 2537 m (xxx) Mean Wire Out - (xxx)

Tow Depth 600 m (xxx) No. of Myctophids 18 (xxx)

Start Time 18 (HH) : 00 (MM) (24 Hour clock) End Time 19 (HH) : 00 (MM) (24 Hour clock)

SAMPLING LOCATION 2

Start of Tow

TD1 26080.1 (xxxxx.x) TD2 42754.3 (xxxxx.x) Lat 38 (DD) 51 60 (MM.MM) N Lon 72 (DDD) 04 70 (MM.MM) W

End of Tow

TD1 26085.8 (xxxxx.x) (59 mmy 6-13-89) TD2 42770.3 (xxxxx.x) Lat 38 (DD) 53 30 (MM.MM) N Lon 72 (DDD) 01 50 (MM.MM) W

Bottom Depth 1280 FM 2537 m (xxx) mmy 6-13-89 Mean Wire Out - (xxx)

Tow Depth 362 m (xxx) No. of Myctophids 30 (xxx)

Start Time 20 (HH) : 10 (MM) (24-Hour clock) End Time 21 (HH) : 15 (MM) (24-Hour clock)

RECORDER

Name Mary M Young ID Number 3211.10

White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

BATTELLE OCEAN SCIENCES
Work Assignment 38
G3811
Trawl Location Log

ATION IDENTIFICATION

Station Number 1 (DUMPSITE) (X or X-XXX) Date 13 (DD) 06 (MM) 89 (YY)

MPLING LOCATION 3

Start of Tow

TD1 26056.2 (xxxxx.x) TD2 42772.9 (xxxxx.x) Lat 38 (DD) 53 60 (MM.MM) N Lon 72 (DDD) 00 80 (MM.MM) W

End of Tow

TD1 76034.8 (xxxxx.x) TD2 42792.3 (xxxxx.x) Lat 38 (DD) 55 70 (MM.MM) N Lon 72 (DDD) 57 40 (MM.MM) W 1 mmy 6-13-89

Bottom Depth 1300 Fm (xxx) Mean Wire Out - (xxx)

Tow Depth 29 / 43 m (xxx) mmy 6-13-89 No. of Myctophids 300 (xxx)

Start Time 21 (HH) : 45 (MM) (24 Hour clock) End Time 22 (HH) : 46 (MM) (24 Hour clock)

MPLING LOCATION _____

Start of Tow

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat __ (DD) __ __ (MM.MM) N Lon __ (DDD) __ __ (MM.MM) W

End of Tow

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat __ (DD) __ __ (MM.MM) N Lon __ (DDD) __ __ (MM.MM) W

Bottom Depth _____ m (xxx) Mean Wire Out _____ (xxx)

Tow Depth _____ m (xxx) No. of Myctophids _____ (xxx)

Start Time __ (HH) : __ (MM) (24-Hour clock) End Time __ (HH) : __ (MM) (24-Hour clock)

RECORDER

Name Nina M Young ID Number 3211.6

(White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

BATTELLE OCEAN SCIENCES
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G3811
Trawl Location Log

STATION IDENTIFICATION

Station Number 2 (#73 100 MI SOUTHWEST OF DUMPSITE) (X or X-XXX) Date 11 (DD) 06 (MM) 89 (YY)

SAMPLING LOCATION (1)

Start of Tow

TD1 265260 (xxxxx.x) TD2 41918.7 (xxxxx.x) Lat 37 (DD) 30 50 (MM.MM) N Lon 73 (DDD) 28 10 (MM.MM) W

End of Tow

TD1 26511.5 (xxxxx.x) TD2 41923.8 (xxxxx.x) Lat 37 (DD) 30 60 (MM.MM) N Lon 73 (DDD) 25 10 (MM.MM) W

Bottom Depth 1150 Fm (xxx) Mean Wire Out – (xxx)

Tow Depth STEP TOW (xxx) m No. of Myctophids TOTAL 21 (xxx)
SEE LOG

Start Time 22 (HH) : 42 (MM) (24 Hour clock) End Time 23 (HH) : 43 (MM) (24 Hour clock

SAMPLING LOCATION (2)

Start of Tow

TD1 26508.1 (xxxxx.x) TD2 15398.1 (xxxxx.x) Lat 37 (DD) 30 6 (MM.MM) N Lon 73 (DDD) 24 3 (MM.MM) W

End of Tow

TD1 26526.7 (xxxxx.x) TD2 15413.4 (xxxxx.x) Lat 37 (DD) 30 30 (MM.MM) N Lon 73 (DDD) 28 20 (MM.MM) W

Bottom Depth 1540069 m (xxx) Mean Wire Out – (xxx)

Tow Depth 40 m (xxx) No. of Myctophids _____ (xxx)

Start Time 24 (HH) : 03 (MM) (24-Hour clock) End Time 01 (HH) : 05 (MM) (24-Hour clock)

RECORDER

Name Gina M Young ID Number 3211.10

White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

BATTELLE OCEAN SCIENCES
Work Assignment 38
G3811
Trawl Location Log

TATION IDENTIFICATION

Station Number 2 (#73 100 MI SOUTHWEST OF DUMPSITE) (X or X-XXX) Date 12 (DD) 06 (MM) 89 (YY)

AMPLING LOCATION (3)

Start of Tow

TD1 26523.4 (xxxxx.x) TD2 15410.6 (xxxxx.x) Lat 37 (DD) 30 40 (MM.MM) N Lon 73 (DDD) 27 50 (MM.MM) W

End of Tow

TD1 26507.4 (xxxxx.x) TD2 15397.8 (xxxxx.x) Lat 37 (DD) 30 70 (MM.MM) N Lon 73 (DDD) 24 20 (MM.MM) W

Bottom Depth _____ m (xxx) Mean Wire Out - (xxx)

Tow Depth 35 m (xxx) No. of Myctophids - (xxx)

Start Time 01 (HH) : 33 (MM) (24 Hour clock) End Time 02 (HH) : 33 (MM) (24 Hour clock)

AMPLING LOCATION _____

Start of Tow

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat ___ (DD) ___ (MM.MM) N Lon ___ (DDD) ___ (MM.MM) W

End of Tow

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat ___ (DD) ___ (MM.MM) N Lon ___ (DDD) ___ (MM.MM) W

Bottom Depth _____ m (xxx) Mean Wire Out _____ (xxx)

Tow Depth _____ m (xxx) No. of Myctophids _____ (xxx)

Start Time ___ (HH) : ___ (MM) (24-Hour clock) End Time ___ (HH) : ___ (MM) (24-Hour clock)

RECORDER

Name _____ ID Number _____

(White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

BATTELLE OCEAN SCIENCES
Work Assignment 38
G3811
Trawl Location Log

STATION IDENTIFICATION

Station Number #74 3 SARGASSO SEA (X or X-XXX) Date 12 (DD) 06 (MM) 89 (YY)

SAMPLING LOCATION 1

Start of Tow

TD1 25904.9 (xxxxx.x) TD2 14864.2 (xxxxx.x) Lat 36 (DD) 44 40 (MM.MM) N Lon 71 (DDD) 01 90 (MM.MM) W

End of Tow

TD1 25918.3 (xxxxx.x) TD2 41755.7 (xxxxx.x) Lat 36 (DD) 43 90 (MM.MM) N Lon 71 (DDD) 05 40 (MM.MM) W

Bottom Depth _____ (xxx) m Mean Wire Out 1600m (xxx)

Tow Depth 600 (xxx) m No. of Myctophids 5 (xxx)

Start Time 15 (HH) : 42 (MM) (24 Hour clock) End Time 16 (HH) : 50 (MM) (24 Hour clock)

SAMPLING LOCATION 2

Start of Tow

TD1 25911.0 (xxxxx.x) TD2 41752.5 (xxxxx.x) Lat 36 (DD) 42 90 (MM.MM) N Lon 71 (DDD) 03 20 (MM.MM) W

End of Tow

TD1 25889.3 (xxxxx.x) TD2 41756.5 (xxxxx.x) Lat 36 (DD) 42 00 (MM.MM) N Lon 71 (DDD) 57 00 (MM.MM) W

Bottom Depth _____ (xxx) m Mean Wire Out 1400m (xxx)

Tow Depth 600 STEP TOW (xxx) m No. of Myctophids 8 (xxx)

Start Time 17 (HH) : 53 (MM) (24-Hour clock) End Time 19 (HH) : 15 (MM) (24-Hour clock)

RECORDER

Name Yma M Young ID Number 3211.10

White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

BATTELLE OCEAN SCIENCES
Work Assignment 38
G3811
Trawl Location Log

ATION IDENTIFICATION

Station Number 3 #74 SARGASSO SEA (X or X-XXX) Date 12 (DD) 06 (MM) 89 (YY)

MPLING LOCATION 3

Start of Tow

TD1 25880.3 (xxxxx.x) TD2 41755.3 (xxxxx.x) Lat 36 (DD) 41 20 (MM.MM) N Lon 70 (DDD) 54 20 (MM.MM) W

End of Tow

TD1 25872.2 (xxxxx.x) TD2 41738.7 (xxxxx.x) Lat 36 (DD) ~~38~~ 39 20 (MM.MM) N Lon 70 (DDD) 51 10 (MM.MM) W

Bottom Depth 2250 FM (xxx) Mean Wire Out 600m (xxx)

Tow Depth STEP Tow m (xxx) No. of Myctophids 3 (xxx)

Start Time 20 (HH) : 18 (MM) (24 Hour clock) End Time 21 (HH) : 19 (MM) (24 Hour clock)

MPLING LOCATION 4

Start of Tow

TD1 25868.1 (xxxxx.x) TD2 41734.7 (xxxxx.x) Lat 36 (DD) 37 00 (MM.MM) N Lon 70 (DDD) 49 50 (MM.MM) W

End of Tow

TD1 25858.5 (xxxxx.x) TD2 41813.9 (xxxxx.x) Lat 36 (DD) 34 60 (MM.MM) N Lon 70 (DDD) 45 90 (MM.MM) W

Bottom Depth 2250 FM (xxx) Mean Wire Out 400m (xxx)

Tow Depth 20 m (xxx) No. of Myctophids 1 (xxx)

Start Time 23 (HH) : 52 (MM) (24-Hour clock) End Time 23 (HH) : 52 (MM) (24-Hour clock)

RECORDER

Name Nina M Young ID Number 3211.10

(White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

BATTELLE OCEAN SCIENCES
Work Assignment 38
G3811
Trawl Location Log

STATION IDENTIFICATION

Station Number 4 (80 MI NE DUMPSITE) (X or X-XXX) Date 14 (DD) 06 (MM) 89 (YY)

SAMPLING LOCATION (1)

Start of Tow

TD1 25586.4 (xxxxx.x) TD2 42976.0 (xxxxx.x) Lat 39 (DD) 17 (MM.MM) 40 N Lon 70 (DDD) 42 (MM.MM) 10 W

End of Tow

TD1 25607.1 (xxxxx.x) TD2 42966.2 (xxxxx.x) Lat 39 (DD) 16 (MM.MM) 10 N Lon 70 (DDD) 45 (MM.MM) 60 W

Bottom Depth 14547.0 m (xxx) Mean Wire Out 800 FM (xxx)

Tow Depth 600 m (xxx) No. of Myctophids 30 (xxx)

Start Time 05 (HH) : 55 (MM) (24 Hour clock) End Time 07 (HH) : 25 (MM) (24 Hour clock)

SAMPLING LOCATION (2)

Start of Tow

TD1 25620.3 (xxxxx.x) TD2 42952.7 (xxxxx.x) Lat 39 (DD) 14 (MM.MM) 40 N Lon 70 (DDD) 47 (MM.MM) 50 W

End of Tow

TD1 25623.6 (xxxxx.x) TD2 42935.2 (xxxxx.x) Lat 39 (DD) 12 (MM.MM) 10 N Lon 70 (DDD) 47 (MM.MM) 30 W

Bottom Depth 14580.3 m (xxx) Mean Wire Out 800 FM (xxx)

Tow Depth 800m m (xxx) No. of Myctophids 24 (xxx)

Start Time 09 (HH) : 02 (MM) (24-Hour clock) End Time 10 (HH) : 01 (MM) (24-Hour clock)

RECORDER

Name Nina M Young ID Number 3211.10

White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

BATTELLE OCEAN SCIENCES
Work Assignment 38
G3811
Trawl Location Log

TATION IDENTIFICATION

Station Number 4 (80MI NE DUMPSITE) (X or X-XXX) Date 14 08 89 (DD MM YY)

AMPLING LOCATION (3)

Start of Tow

TD1 25631.3 (xxxxx.x) TD2 42913.8 (xxxxx.x) Lat 39 09 40 N (DD MM.MM) Lon 70 47 80 W (DDD MM.MM)

End of Tow

TD1 25648.1 (xxxxx.x) TD2 ~~42608.4~~ 14 mm 2-2-89 (xxxxx.x) Lat 39 04 60 N (DD MM.MM) Lon 70 49 20 W (DDD MM.MM)

Bottom Depth 14583.8 m (xxx) Mean Wire Out 800 FM (xxx)

Tow Depth 500 m (xxx) No. of Myctophids 240 (xxx)

Start Time 11 : 21 (HH MM) (24 Hour clock) End Time 12 : 37 (HH MM) (24 Hour clock)

AMPLING LOCATION _____

Start of Tow

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat __ __ __ N (DD MM.MM) Lon ___ __ __ W (DDD MM.MM)

End of Tow

TD1 _____ (xxxxx.x) TD2 _____ (xxxxx.x) Lat __ __ __ N (DD MM.MM) Lon ___ __ __ W (DDD MM.MM)

Bottom Depth _____ m (xxx) Mean Wire Out _____ (xxx)

Tow Depth _____ m (xxx) No. of Myctophids _____ (xxx)

Start Time ___ : ___ (HH MM) (24-Hour clock) End Time ___ : ___ (HH MM) (24-Hour clock)

RECORDER

Name Nina M Young ID Number 3211.10

(White- DATA MGR Yellow- PROGRAM MANAGER Pink- FIELD PARTY)

APPENDIX C. HYDROGRAPHIC PROFILES

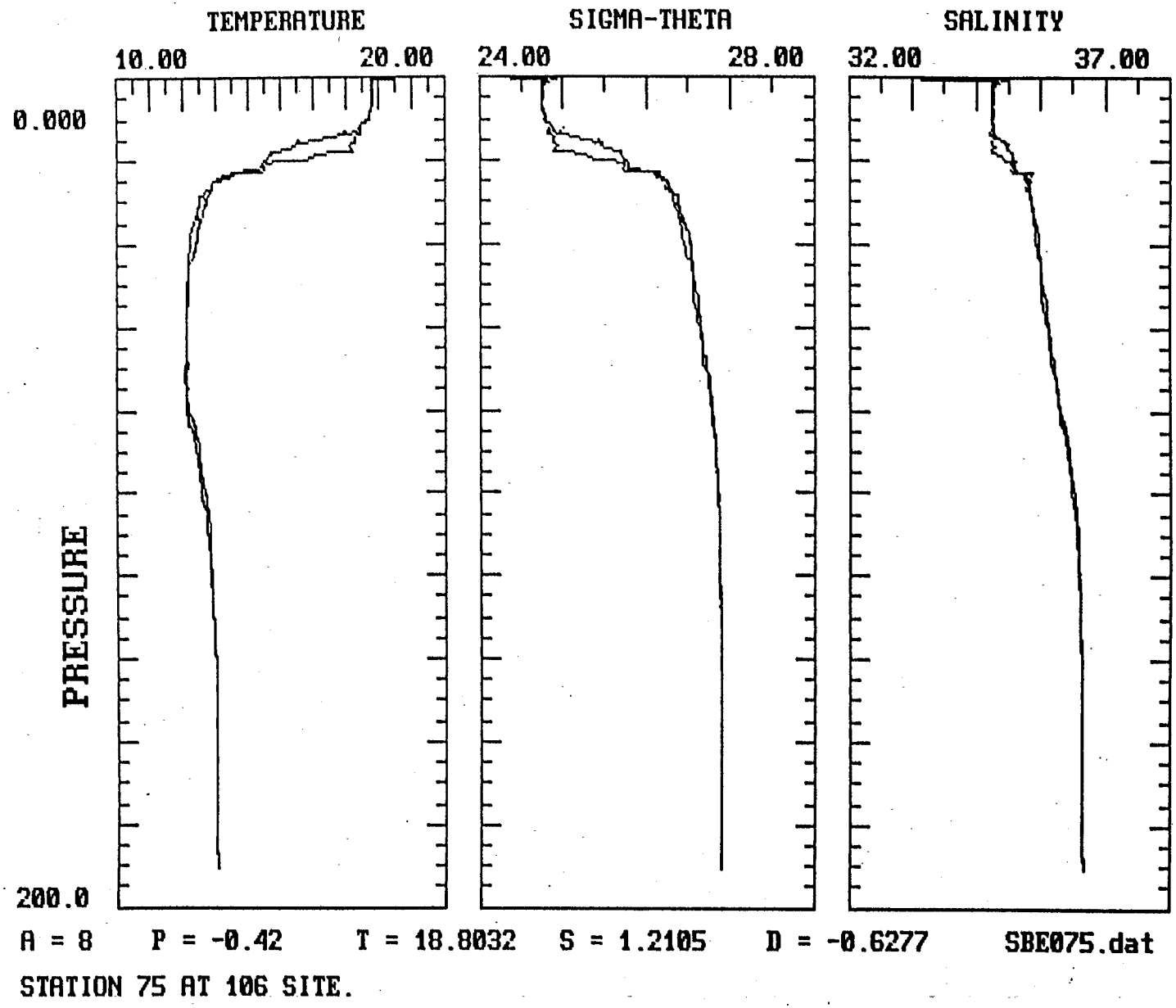

FIGURE A-1. HYDROGRAPHIC PROFILE AT STATION 1 (106-MILE SITE).

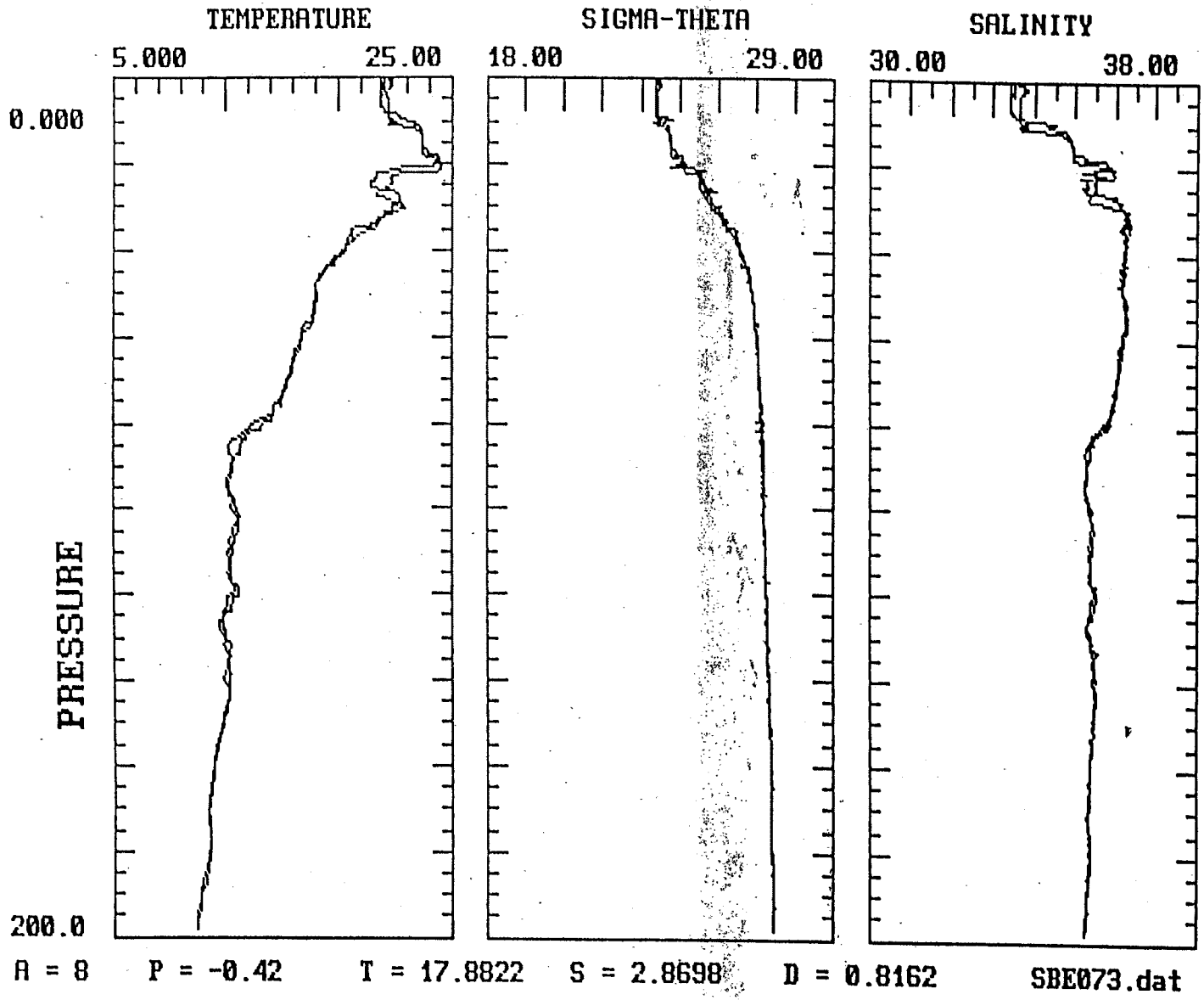

FIGURE A-2. HYDROGRAPHIC PROFILE AT STATION 2 (100 MILES S.W. OF 106-MILE SITE).

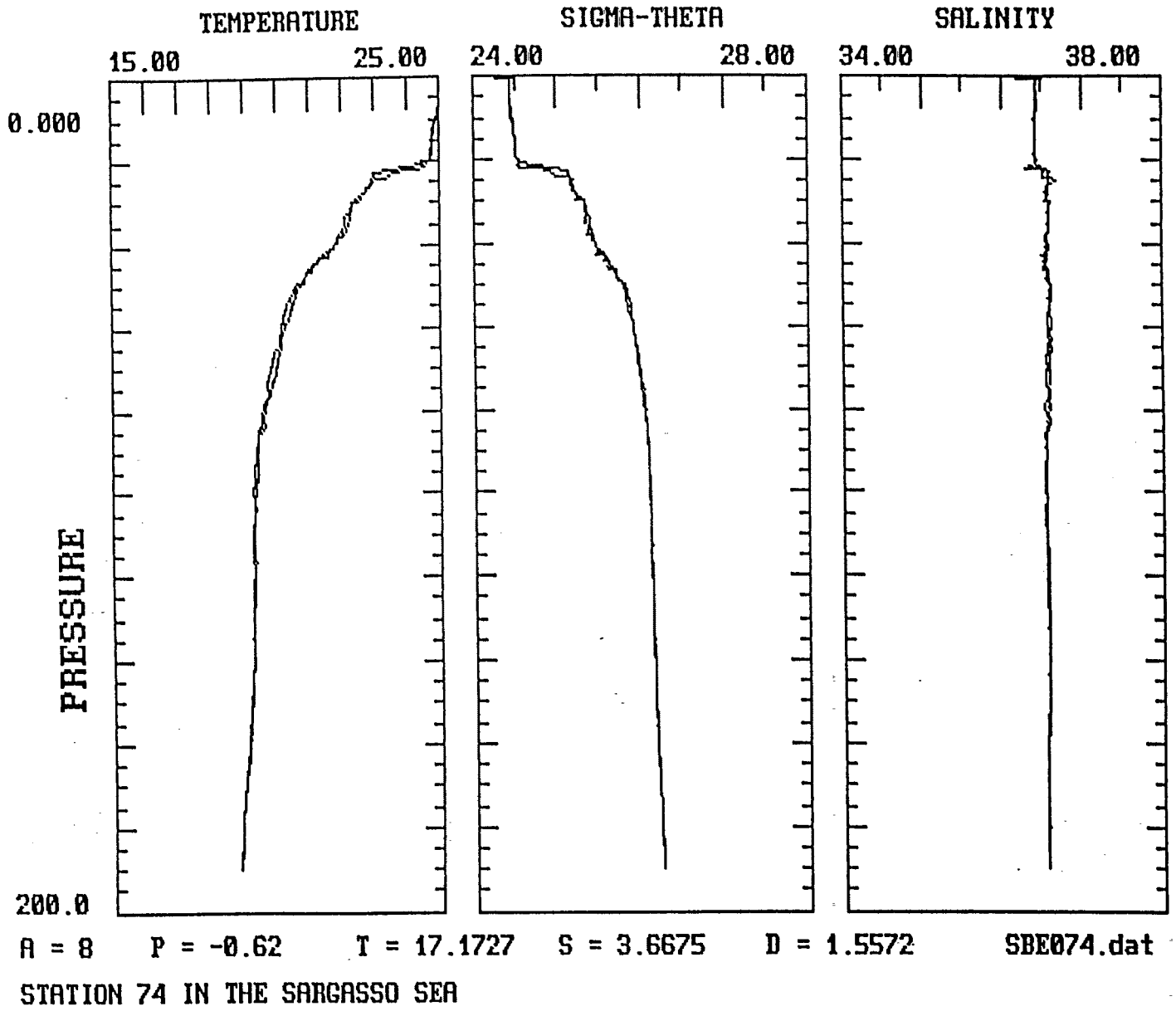

FIGURE A-3. HYDROGRAPHIC PROFILE AT STATION 3 (SARGASSO SEA).

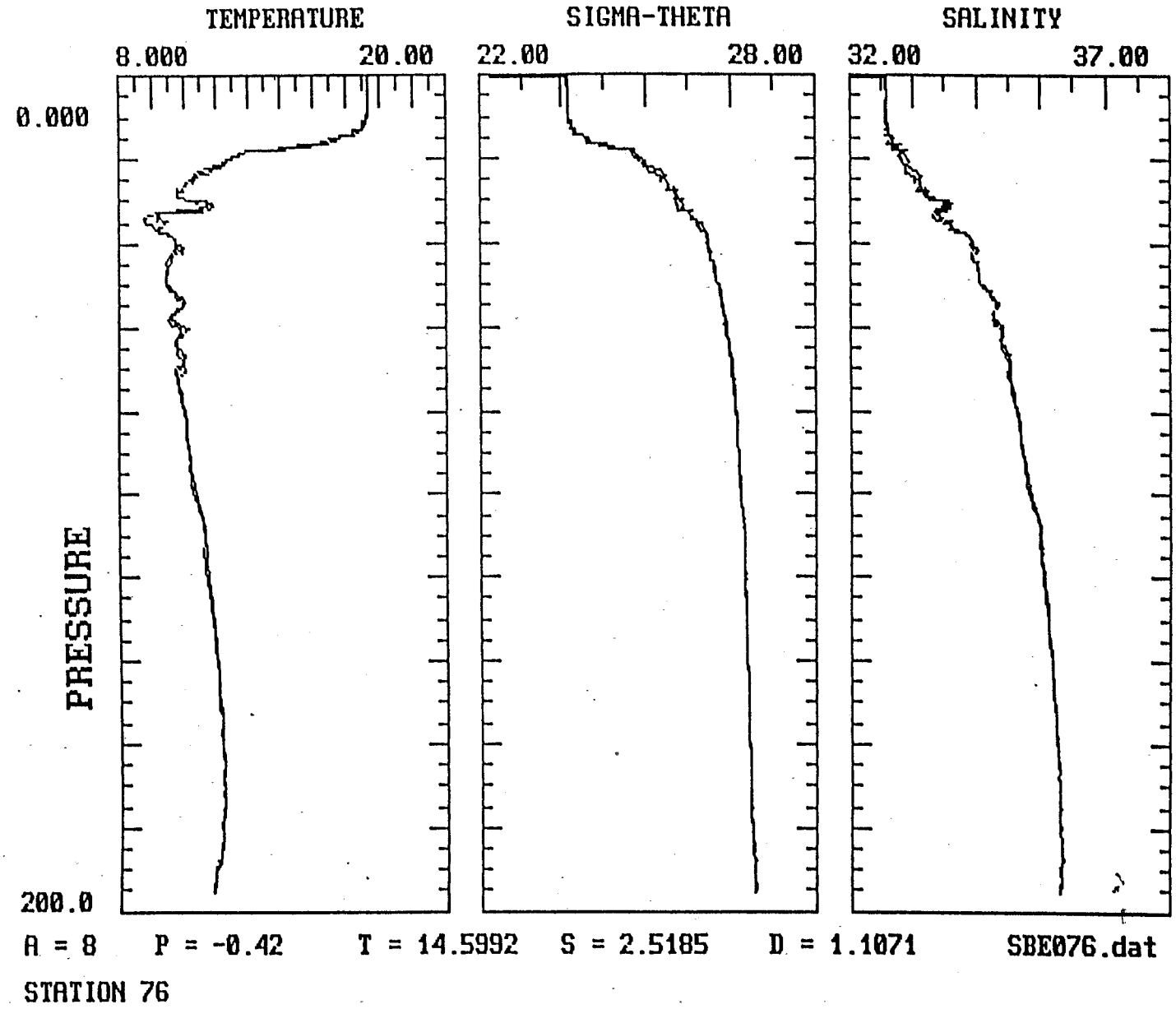

FIGURE A-4. HYDROGRAPHIC PROFILE AT STATION 4 (80 MILES N.E. OF 106-MILE SITE).