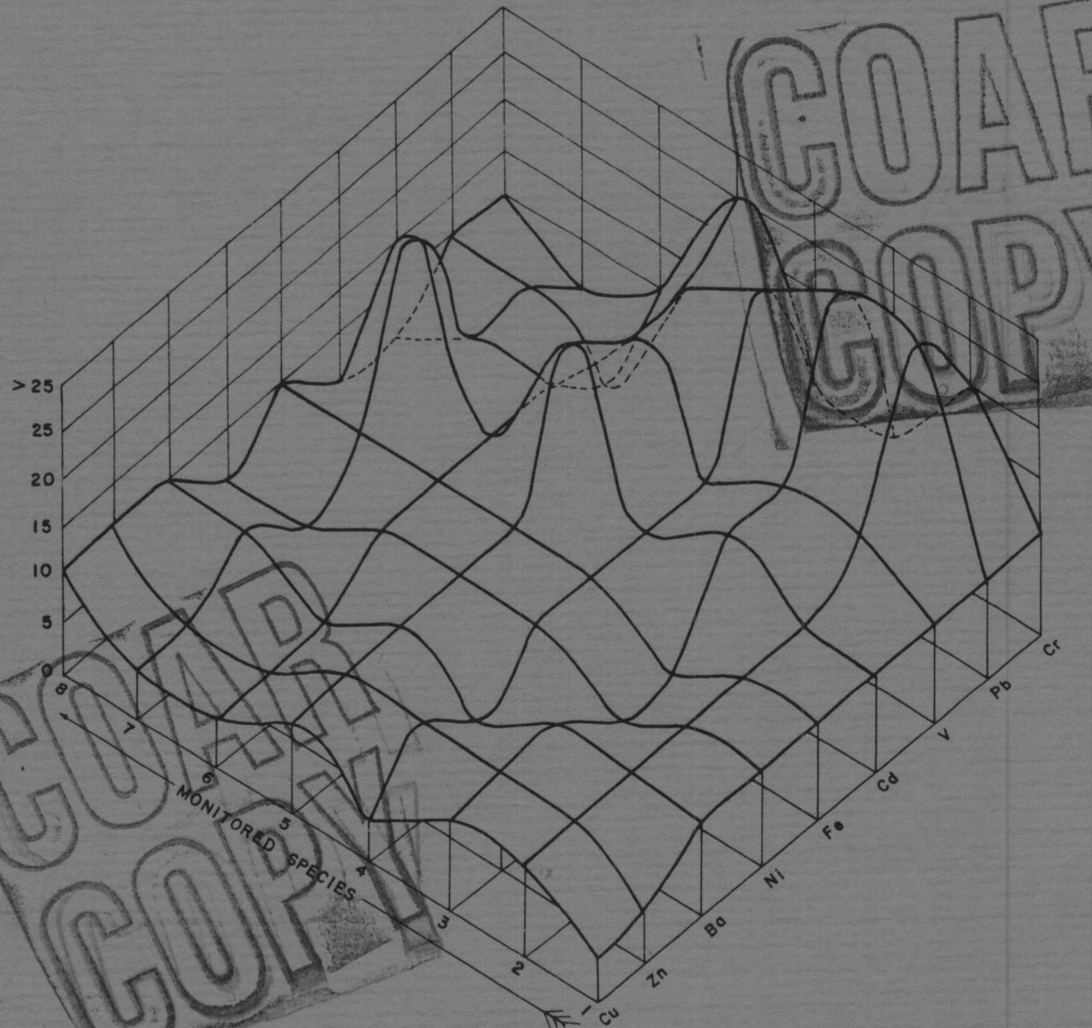
MAFLA
FINAL REPORT

THE MISSISSIPPI, ALABAMA, FLORIDA, OUTER CONTINENTAL SHELF BASELINE ENVIRONMENTAL SURVEY

1977/1978



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VOLUME II

CHAPTER 18

HISTOPATHOLOGY OF EPIFAUNAL INVERTEBRATES OF THE EASTERN GULF OF MEXICO

by

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Report Submitted to
DAMES & MOORE
1977-78 BLM MAFLA Contract Number AA550-CT7-34

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INTRODUCTION

Histopathological studies in the Bureau of Land Management's Outer Continental Shelf Program began in 1974 with the first MAFLA survey. Since then it has been an integral part of all other MAFLA surveys and has been incorporated into other OCS studies.

Histopathology has been shown to be a sensitive ecological tool for bridging the gap between the highly quantitative molecular level of biogeochemistry and the highly qualitative and variable population and community level of ecology. The value of histopathology in marine ecology has only recently been realized and few large scale studies have been undertaken. In no instances has there previously been a histopathological-biogeochemical study before and after the addition of pollutants such as hydrocarbons or trace metals. This study was an attempt to determine the incidence of pathological conditions in reprsentative marine invertebrates in the MAFLA area and to correlate this incidence with hydrocarbon and trace metal concentrations in the animals and their surrounding sediments. The methods employed may be found in the third 1977-78 quarterly report (Dames & Moore, 1978e).

LITERATURE REVIEW

Numerous studies have been conducted on the effects of oil on marine organisms, especially commercially important fish and shellfish, as well as other invertebrates. Moore and Dwyer (1974) noted that these effects may be categorized as direct lethal toxicity by ingestion, sublethal disruption of physiological behavioral activities, coating of the organism, incorporation of hydrocarbons which may be carcinogenic and can be passed along in marine food chains, and alteration of habitats. In reviewing previous studies, they found that exposures of 1 - 10 ppm soluble aromatic derivative hydrocarbons caused lethal effects in many adult marine organisms, with sublethal effects in the 10 - 100 ppb range. Few studies on the sublethal effects of oil have traced changes in normal behavioral and physiological responses to damage at the cellular and tissue levels, which may be revealed by histopathological examinations even when there is no outward evidence of injury or disease.

Harshbarger (1967) suggested that although early studies were inconclusive, vertebrate carcinogens generally stimulated the regenerative cells in invertebrates. Goldacre (1968) noted that the plasma membrane of amoeba would double in area, separate from the cytoplasm and burst when the concentration of oil in the water increased. He speculated that hydrocarbon carcinogens could cause permanent changes in the cell membrane leading to a breakdown in cell to cell communication and to cancer. Couch et al.(1974) discussed possible neoplasms in neurosensory and reproductive tissues of filter-feeding molluscs exposed to oil hydrocarbons. *Mya arenaria* from two oil spill sites in Maine showed either gonadal neoplasms or hematopietic (connective tissue) neoplasms with extensive metastasis throughout the tissue, although no gross changes in the morphology of the clams were observed (Dow et al., 1975; Yevich and Barszcz, 1977).

TABLE 86

BLM MAFLA 1977-1978 SPECIES COLLECTED BY STATION

STATION	SUMMER	FALL	WINTER
0001	*Portunus spinicarpus* *Sicyonia brevirostris*	*Portunus spinimanus* *Solenocera atlantidis*	*Callista eucymata* *Circumphalus strigillinus*
0002	*Murex beauii* *Parapenaeus longirostris*	*Murex beauii* *Solenocera atlantidis*	*Acanthocarpus alexandri* *Murex beauii* *Parapenaeus longirostris* *Portunus spinicarpus* *Portunus spinimanus*
0003	*Portunus spinicarpus*	*Bebryce cinerea* *Portunus spinicarpus* *Psuedoceratina crassa* *Scleracis guadalupensis*	*Bebryce cinerea* *Sicyonia brevirostris*
0004		*Aequipecten glyptus*	*Aequipecten glyptus* *Murex beauii* *Parapenaeus longirostris* *Solenocera atlantidis*
0005		*Chama macerophylla* *Portunus spinicarpus* *Psuedoceratina crassa* *Sicyonia brevirostris* *Spondylus americanus*	*Chama macerophylla* *Chama* sp. *Eunicea calyculata* *Muricea laxa* *Portunus spinimanus* *Sicyonia brevirostris* *Solenocera atlantidis* *Spondylus americanus*
2103	*Oculina* cf. *diffusa* *Psuedoceratina crassa* *Stenorynchus seticornis*	*Aequipecten muscosus* *Chama macerophylla* *Chama* sp.	*Chama macerophylla* *Oculina* cf. *diffusa* *Psuedoceratina crassa*

TABLE 86 (Cont.)

STATION	SUMMER	FALL	WINTER
2103 (Cont.)		Cladocora arbuscula Oculina cf. diffusa Pseudoceratina crassa Sicyonia brevirostris Spondylus americanus Stenorynchus seticornis	Spondylus americanus Stenorynchus seticornis
2105	Iliacantha subglobosa Portunus spinicarpus Sicyonia brevirostris Stenorynchus seticornis	Iliacantha subglobosa Murex beauii Portunus spinicarpus Stenorynchus seticornis	Iliacantha subglobosa Portunus spinicarpus
2106	Murex beauii Portunus spinicarpus		
2209	Penaeus duorarum Portunus spinicarpus Sicyonia brevirostris	Portunus spinimanus Oculina cf. diffusa Aequipecten muscosus Cladocora arbuscula Pecten raveneli Phyllangia americana Siderastrea radians Solenastrea hyades Spondylus americanus Stephanocoenia michellini	Penaeus duorarum Portunus gibbesi Portunus spinicarpus Portunus spinimanus Sicyonia brevirostris Solenocera atlantidis
2313	Portunus spinicarpus	Aequipecten glyptus	Aequipecten glyptus Acanthocarpus alexandri Parapenaeus longirostris Portunus spinicarpus Solenocera atlantidis

TABLE 86 (Cont.)

STATION	SUMMER	FALL	WINTER
2315	*Chama macerophylla* *Dichocoenia stellaris* *Eunicea calyculata* *Lophogorgia cardinalis* *Muricea elongata* *Porites porites forma divaricata* *Pteria colymbus* *Scolymia lacera* *Spondylus americanus* *Spondylus ictericus* *Stephanocoenia michellini*		
2426	*Bebryce cinerea* *Nicella guadalupensis* *Oculina* cf. *diffusa* *Sicyonia brevirostris* *Swiftia casta*	*Balanophyllia floridana* *Portunus spinicarpus*	*Portunus spinicarpus* *Sicyonia brevirostris* *Stenorynchus seticornis*
2427	*Mesopanaeus tropicalis* *Solenocera atlantidis*	*Ananthocarpus alexandri* *Aequipecten glyptus* *Portunus spinicarpus*	*Aequipecten glyptus* *Parapenaeus longirostris*
2529	*Sicyonia brevirostris* *Stenorynchus seticornis*	*Aequipecten muscosus*	*Aequipecten muscosus* *Pecten raveneli* *Metaenaeopsis goodei* *Sicyonia brevirostris* *Solenocera atlantidis*
2534		*Pecten raveneli* *Stenorynchus seticornis*	
2536	*Mesopenaeus tropicalis* *Parapenaeus longrostris*	*Aequipecten glyptus* *Iliacantha subglobosa*	*Acanthocarpus alexandri* *Aequipecten glyptus* *Anadara* sp. *Parapenaeus longirostris* *Solenocera atlantidis*

TABLE 86 (Cont.)

STATION	SUMMER	FALL	WINTER
2641	*Argopecten gibbus* *Pecten raveneli* *Portunus spinicarpus* *Sicyonia brevirostris*	*Argopecten gibbus* *Portunus gibbesi* *Portunus spinicarpus*	*Aequipecten muscosus* *Penaeus duorarum*
2643			*Parthenope pourtalesii* *Portunus spinicarpus* *Sicyonia brevirostris*
2645	*Mesopenaeus tropicalis* *Paracyathus pulchellus* *Sicyonia brevirostris* *Stenorynchus seticornis* *Villogorgia negrescens*		*Aequipecten muscosus* *Hymenopenaeus tropicalis* *Portunus spinicarpus* *Stenorynchus seticornis*
2747	*Sicyonia brevirostris*	*Placogorgia* n.sp. *Portunus spinicarpus* *Sicyonia breverostris* *Stenorynchus seticornis*	*Ellisella barbadensis* *Portunus spinicarpus* *Sicyonia brevirostris* *Stenorynchus seticornis*
2748	*Sicyonia brevirostris* *Stenorynchus seticornis*	*Aequipecten muscosus* *Oculina tenella* *Murex cabritii*	*Oculina tenella* *Portunus spinimanus* *Sicyonia brevirostris* *Solenocera atlantidis*
2749		*Aequipecten muscosus* *Cladocora arbuscula* *Penaeus duorarum* *Portunus spinicarpus* *Phyllangia americana* *Sicyonia brevirostris* *Solenastrea hyades*	

Sublethal exposures to oil may also affect tissues without causing neoplasms. In studies on two marine bivalves, Renzoni (1975) found that water soluble fractions of oil depressed fertilization and caused developmental abnormalities of the zygotes. Sperm were particularly sensitive. Blue mussels which survived the Buzzards Bay oil spill in 1969 developed no eggs or sperm the following season (Blumer et al., 1971). Rinkevich and Loya (1977) observed depression of normal gonad development in one species of coral from a chronically oil-polluted reef in the Gulf of Eilat, Red Sea, which was also noted by Peters (1978) in colonies of a Caribbean coral exposed to sublethal levels of No. 2 fuel oil hydrocarbons during a three month flow-through bioassay.

An increased incidence of thinning, necrosis and sloughing of the epidermis, and decrease in the number and thickness of the zooxanthellae in the gastrodermis appeared in oil-exposed corals in this bioassay. Fries and Tripp (1977) observed that adult clams exposed to varied concentrations of phenol for 24 hr had damaged gills, gut, digestive glands and blood cells with basophilic staining, moderate necrosis and sloughing of ciliated epithelial layers. Electron microscopy revealed cell membrane ruptures. Recent studies by Yevich and Barszcz (1978) of molluscs from the Amoco Cadiz oil spill site showed an increase in mucus secretory cells, hyaline degeneration, necrosis and sloughing of epithelial tissues, accumulations of black particulates and loss of neurons from the ganglions, varying with the species. All of these effects have been observed in laboratory studies of similar organisms (Barszcz et al., 1978; Normal J. Blake, unpublished observations). Although Kittredge (1973) did not examine oil-exposed tissue histologically, his studies on the inhibition of chemoreceptors by water-soluble extracts of crude oils suggested a destruction of the neuronal membranes involved in perceiving chemical signals which affect their behavior and survival.

RESULTS AND DISCUSSION

Since 1975, 14,732 slides have been made and analyzed for pathological conditions. These slides represent 98 epifaunal species, of which 31 were new to the 1977-1978 collections (Table 86).

The results have been extremely surprising. The incidence of pathological conditions which could be expected from hydrocarbons has been completely absent (see literature review). Parasites have been occasionally observed and they were reported in the 1975-76 final report. An atlas containing normal histology of representative tissues from representative species was also supplied in the 1975-76 report.

Thus, the incidence of pathology cannot be correlated with hydrocarbon or trace metal concentrations. Unlike other areas which receive large amounts of natural seepage of hydrocarbons and subsequent bioaccumulations, the eastern Gulf of Mexico appears relativedly free of such contaminants (see final reports on hydrocarbons and trace metals). As a result of the fauna of the shelf of the eastern Gulf of Mexico may be described as healthy and the environment may be described as pristine in comparison to other shelf areas.

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VOLUME II

CHAPTER 19

DEMERSAL FISH

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CONTRACT NO. AA550-CT7-34

CHAPTER 19

DEMERSAL FISHES OF THE MAFLA LEASE AREA

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FINAL REPORT

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ABSTRACT

Demersal fishes from the MAFLA lease area were collected during four sampling periods: summer 1976, summer 1977, fall 1977, winter 1978. All specimens were identified, weighed, measured, and archived. Data were submitted to the data management group of Dames & Moore for analysis, which were then interpreted. Initial indications are of significant range extensions of fishes in the northeastern Gulf of Mexico, especially in the vicinity of the northeast segment of the De Soto Canyon. Several undescribed species were discovered during the effort period. Families containing species of especial concern to the MAFLA goals are discussed. Data analysis techniques are utilized in describing various biological parameters.

In addition, samples collected during 1975-1976 as a component of an earlier MAFLA effort were incorporated into the analysis.

INTRODUCTION

The fundamental purposes of the Bureau of Land Management 1977/78 Benchmark Survey (AA550-CT7-34) are stated in an earlier section of this report and need not be restated here. However, the specific subject of this subunit, demersal fishes, merits purpose and justification as to their inclusion in the work effort.

Demersal, or bottom fishes, are represented by numerous species at the peak of the trophic level. These top carnivores are, therefore, primary candidates for analysis of any sort of biological concentration or magnification of substances passing through the lower trophic levels. In addition, many of the benthic fishes are substrate-specific, and reflect and corroborate distribution of sediment types. Many of the forms exhibit abbreviated larval development, and thus are good indicators of historical zoogeographical patterns. Finally, to the public at large, fishes represent an identifiable unit, recognizable and deserving of study, especially in regard to possible effects by drilling interests.

Surprisingly, until the 1970's, synoptic literature on Gulf of Mexico fishes was sparse, and treated as an afterthought of Atlantic Coast works. Excellent historical accounts of ichthyological literature on the region are available from Hoese and Moore (1977), Nester (1978), and Shipp (1978). These works also include references to virtually all systematic treatments of Gulf of Mexico fishes. A bibliography of selected works is included in this report.

METHODS AND MATERIALS

Ichthyological materials were from two sources. First, samples collected under the previous MAFLA effort, as managed by SUSIO. The second were collected during the present effort, from cruises DM I, DM II, and DM IV. Details of station locations, dates, ship specifications, etc. are located elsewhere in this report.

Materials gathered during the DM cruises were from dredge and trawl sampling. General methodology of these operations are also contained elsewhere in this report. Shipboard operations specific to demersal fish sampling follows.

When trawl contents were released into the ondeck sorting boxes, initial effort was directed toward securing of uncontaminated TM/HC samples. The only species involved from the demersal fish catch was the flatfish Syacium papillosum. A member of the demersal fish contingent, trained in the sight identification of fishes, would point out individuals of S. papillosum to another member of the scientific party who, wearing sterile gloves, removed the specimes to an uncontaminated tray. Eleven specimens were required, and if an inadequate sample was taken, trawling was repeated. Occasionally, the specimens were taken from dredge samples following an identical procedure.

After proper disposition of the TM/HC samples, fishes were removed from the sorting tray and placed in plastic buckets of approximately 12 to

32ℓ capacity (depending on catch volume). When the sorting was completed, all specimens of near 100 mm SL and above were slit on the right side of the abdomen. The slit penetrated the viscera, was approximately 10 mm in length, and was performed with a standard laboratory scalpel.

During the slitting operation a voucher specimen of S. papillosum was removed and photographed. Color notes and an on-board species list was compiled, and these were entered into field notebooks, kept in duplicate. The notebooks contained all supporting data deemed appropriate by the demersal fish personnel, and are available for usage by all interested parties.

Species deemed especially noteworthy by the team were also photographed to better aid subsequent identification. All photographs were taken with Kodak 35 mm slide film, with film type and speed dictated by on-board conditions. Slides are in possession of Dr. Robert L. Shipp, University of South Alabama.

Specimens were then immersed in approximately 1% formalin solution until killing was completed, then full strength formalin was added to make a 10% solution. A label was placed in the container, bearing all pertinent station data; the bucket was then capped and stored.

Stored containers were periodically checked, especially during foul weather, to ensure their quality.

Laboratory analysis involved identification, counting, weighing, measuring, evaluating obvious abnormalities, and archiving all specimens. On arrival at the lab, sample buckets were soaked for 24-48 h in water, with several changes as dictated by size, volume, etc. to remove formalin. They were then transferred to 40% isopropanol solution. Specimens were rough sorted to species and placed into separate containers. Each species group was then carefully scrutinized to verify identification of each individual specimen. All individuals were towel dried and weighed on a standard triple beam balance to the nearest 0.1 g. Each was then measured, standard length (SL), to the nearest 0.1 mm. Sex was taken on 10 mature individuals, or as many as were available if less were taken. Specimens were also examined for obvious pathological/deformity conditoins. These data were then recorded on laboratory worksheets and transferred to data sheets as supplied by Dames & Moore. Each series (consisting of all individuals of a species at a station) were placed together in an appropriate-sized glass container and labeled. Labels of 100% rag paper, lettered by hand with Pelikan India ink, via #1 or #2 Rapidograph pen, were placed in each container. Labels contain taxonomic family number, catalog number, species name, number of individuals in the series, and collection date. Simultaneously with label preparations, the same data were entered into permanent catalogs.

These activities were carried on simultaneously at the University of South Alabama and the University of West Florida. Frequent corroboration was maintained between the two groups to ensure accuracy of data by drawing on the diverse expertise of the personnel involved.

A taxonomic code was compiled and submitted to Dames & Moore to enhance data analysis.

RESULTS AND DISCUSSION

GENERAL COMMENTS

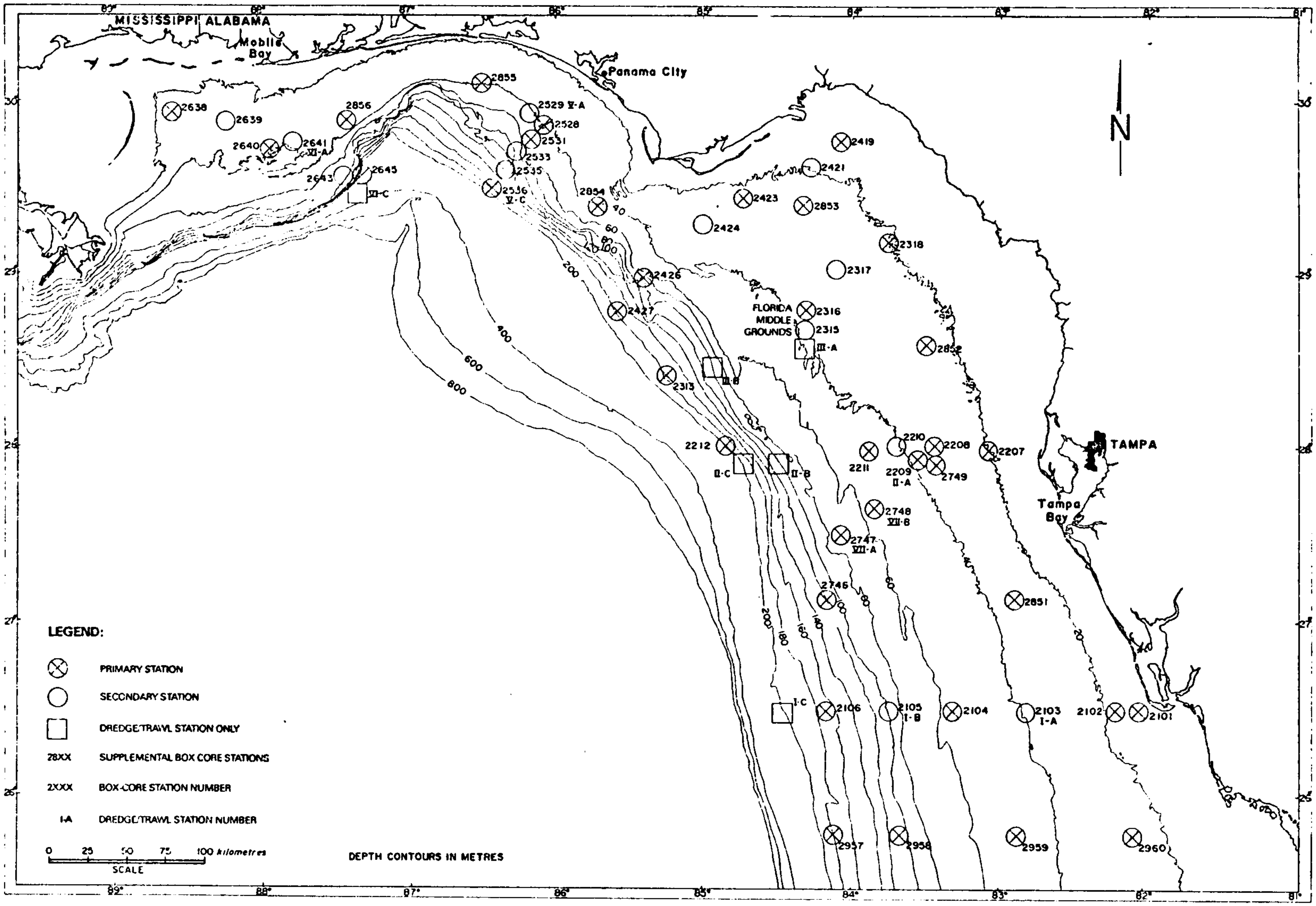
All raw data on demersal fishes were submitted in accordance with contractual obligations. The 292 species collected represent about one-half of the fish species known to the United States coastal/shelf area of the Gulf of Mexico. However, almost all species of demersal fishes known to the area, based on previous literature reports, were taken. A complete species list in tabular for is appended to this chapter of the final report. Most species were captured in all seasons and in significant numbers, representing sufficient size ranges and life history stages and conditions (e.g., mature ovaries, spent ovaries) to provide the most comprehensive data base for demersal fishes of the area ever to be gathered.

In addition to well known species, numerous forms thought to be rare or previously unknown were taken. All raw data as well as analyses on these data are contained in the MAFLA data tapes. Specific station data are restricted to the appendices. An overview of the project findings is presented herein, followed by discussion of pertinent families and exemplary analysis interpretation. Station depth and substrate are the two factors which appear to dictate most strongly the species composition of demersal fish populations. Seasonality, water temperature, salinity, and latitude (except where correlated with sediment size) play minor roles in the composition of the demersal fish fauna. Discussion of data analysis methodology appears later in this subunit.

Specific examples can be selected to illustrate these findings. Catches at stations located west of Ft. Myers, Florida (Stations 2103, 2105) (see Figure 232) indicated hard bottom, with many reef-associated forms. Similar forms were present in the collections in the vicinity of the Florida Middle Grounds (2315), especially those collections able to be taken directly from the high relief areas of this latter region. A sharp change in demersal fish species composition is evident when examining the westernmost stations (e.g., 2641). Here, associated with fine sediment bottom, mud-loving forms characteristic of the north central and western Gulf of Mexico are taken in abundance.

In similar fashion, depth differences of species composition, as indicated by similarity indices, strongly suggest that affinity by depth far overrides affinity by latitude.

Seasonality changes are minimal. Although one would expect stations at the maximum depth stations (200 m) to be little influenced by seasonal changes in physical parameters, such would not be expected of the shallow (40 m) stations. However, composition of the fish fauna showed minimal seasonal change at stations of all depths. In addition, year-to-year comparisons revealed only minor modification of species composition at any given station (see Figure 233 and Table 87).



BLM 77/78 MAFLA SURVEY STATION LOCATIONS

Figure 232 Chart of the MAFLA lease area with stations sampled.

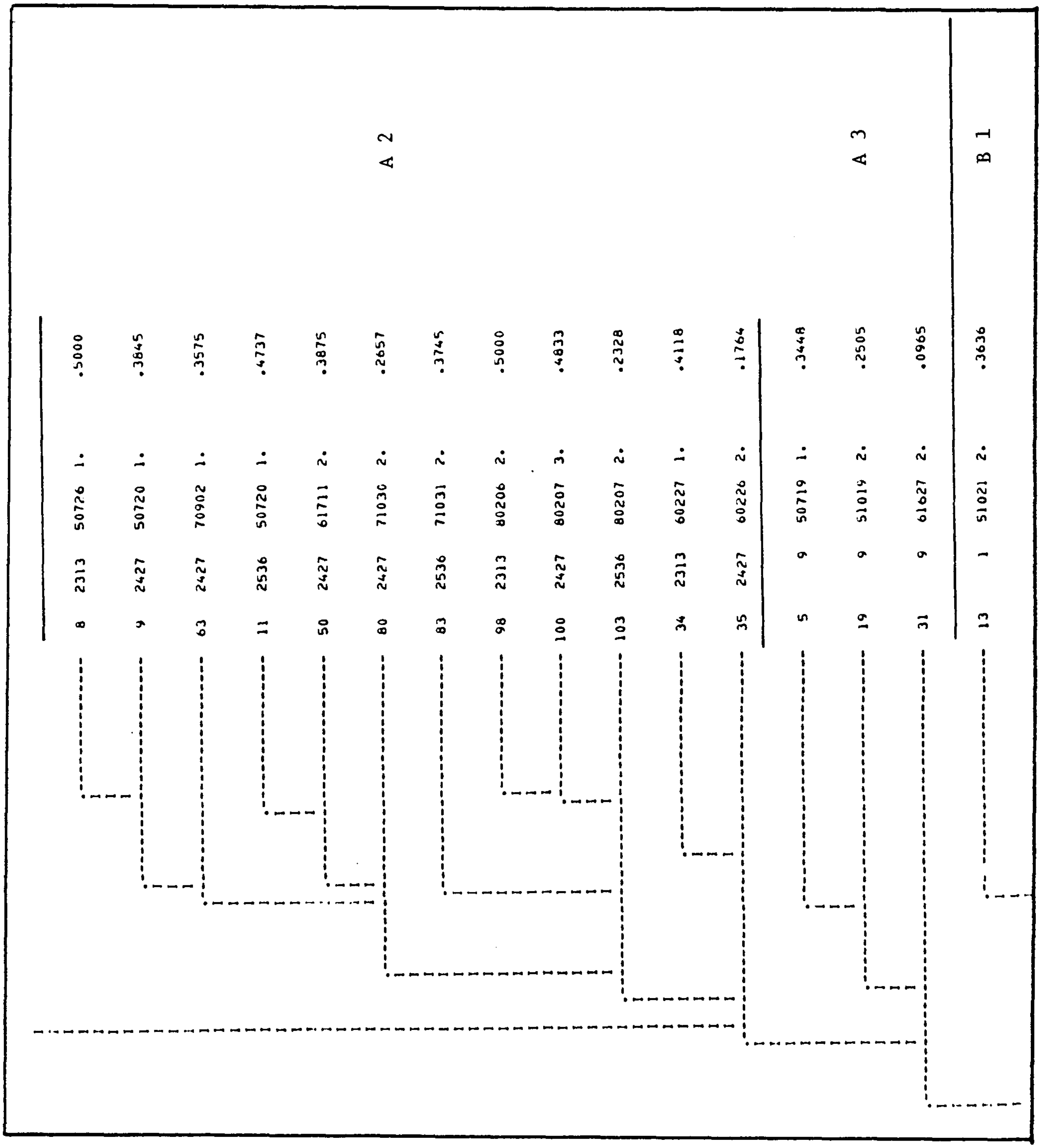


Figure 233 A segment of station clustering analysis using the JACARD methodology. Note for example cluster A-2, where stations are all deep, and at different seasons. Reference appendix for code interpretations.

TABLE 87

LOCATION OF STATION BY SEASON IN CLUSTERS

STATION NUMBER	CLUSTER						
	S-75	F-75	W-76	S-76	S-77	F-77	W-78
0006	C1		C4	C2			
0010 (2209)	C2		C1	C2	C2	C2	C1
2103	C3		C3	C3	C3	C3	C3
2315 & 0005	M		C3	C1	M	C3	C1
2529	C4			C1	C1	C4	C1
2641	C5			C5	C5	C5	C5
2748				C1	C1	C1	C1
2749						C2	M
0001		B1		B4	B2	B1	B2
0003		B2		B2	B2	B2	M
0007 & 2534		B2		B3		B2	B2
0008 & 2643		B1		B3		B3	
2105		B2		B2	B2	B2	B2
2426		B2		B3	B2	B2	B2
2645					M		B1
2747				B2	B2	B2	C1
0002	A1	A1	A1	A1	A1	A1	A1
0004 (2106)	A1	A1	A1	A1	A1	A1	A1
0009	A3	A3		A3			
2313	A2	A1	A2	B4	A1	A1	A2
2427	A2	A1	A2	A2	A2	A2	A2
2536	A2	A1		A1	A1	A2	A2

S-75 = summer 1975, F-75 = Fall 1975, W-76 = winter, 1976, etc.
Based on JACARD. See Figure 233 for graphical interpretation.

ANALYTICAL METHODOLOGY

In comparing station affinities based on faunal similarity, two approaches were taken: a metric distance coefficient (Bray-Curtis) which takes into account species relative abundance per sample at a locality; and a non-metric association coefficient (binary-Jacard) which considers only species presence or absence in comparing localities (Figure 233, Table 87). Essentially the analysis was performed using combined data from all sample periods of both dredge and trawl collections. Attempts to analyze dredge/ trawl data separately proved inappropriate. The results of these analyses which cluster OTU's (the localities of sample sites) on the basis of their character (fish species) similarity (metric and non-metric) proved that fish faunas could be used to compare localities in the MAFLA study area.

Both metric and non-metric coefficients indicated that localities were related to each other. As previously noted in the overview, the localities of similar depth generally had high associations with each other based on this parameter. This implies that, while there may be some species-specific inshore-offshore movement between localities, the majority of the movement based on community type either does not occur or, if it does, it shifts along a depth contour. The possibility remains, of course, that this analysis was insensitive to more subtle community migration.

SPECIES ASSOCIATIONS

Cluster analyses in the R-mode using both metric and non-metric association coefficients were only partially successful in examining species associations. For the purpose of this comparison we have considered species associations significant if two or more species share an association or distance coefficient higher than 0.70. Species associations were notable in the reef community species, the shell-hash community species, and in some shallow sand-dwelling groups.

Dasyatis sayi, Eucinostomus gula, and Micropogon undulatus formed a strongly associated shallow water sand substrate group. Deep reef species associations were high between Holocentrus bullisi and Chaetodon aya. Reef and near-reef species (see the section of Chaetodontidae below) which showed important associations were: Apogon quadrisquamatus with Gobiosoma xanthipora (sponge associates); Hypoplectrus puella with Evermannicthys spongieola, (reef); Epinephelus morio, Rypticus maculatus, and astrapogon stellatus (reef).

A notable dominant sand-community species association was formed by Synodus intermedius, Centropristis ocyurus, Syacium papillosum and Sphocroides dorsalis. This group of species forms a large and highly associated community which dominates much of the MAFLA area.

Many other pair-wise species groups could be recognized by cluster analysis. We feel, however, that they are not biologically meaningful as they reflect more of a sampling bias than real species associations. For example, Histrio histrio and Symphurus pusillosus form a high level association using both metric and non-metric methods; one species is surface dwelling and the other is a bottom dweller.

Care must be exercized in making generalizations based on limited sampling data, but our analyses show that the MAFLA area does have some readily recognized species associations which are biologically significant. Perturbations could disturb these associations, and the result could drastically alter community structure.

COMMENTS ON TAXA OF SPECIAL INTEREST OR CONCERN

Although complete data on the hundreds of species collected are available on the Data Tape, numerous examples are of special interest or concern to individuals or agencies concerned with monitoring or evaluating environmental changes. Such examples include those forms of apparently narrow tolerance to habitat modification, those indicative by their presence of certain habitat parameters, and those of phylogenetic affinities which may indicate important biogeographical tracts. Selected examples are discussed in the following section.

In the Anguilliformes (order of eels) are many very poorly known species. However, the eels are dispersed by a specialized larval form, the leptocephalus, which settles out after extensive transport by ocean currents. Presumably, if settled on habitat favored by the species, successful metamorphosis follows and adults result. Since most eels are fossorial and the number of species high, it would appear that slight changes in composition of the upper centimeters of the shelf surface would be reflected in the composition of eel populations. Unfortunately, present knowledge of eel systematics prevents detailed interpretation of the available eel data. However, the extensive archived material of this group is especially important to future assessments of the MAFLA region.

Although all known eel species are basically carnivorous and thus reflective of top carnivore status in the food web, special emphasis should be given the Nettastomatidae, Congridae, and Ophichthidae in future considerations.

The Ophidiidae (cusk eels) are not true eels at all, but related to the cods. They are of especial importance to the MAFLA program because they are extremely abundant in the shallower (40 m) and middle (100 m) depths sampled. In addition, they are fossorial and nocturnal. Any sudden declind or modification of their population status could be interpreted as a result of modification of upper substrate parameters, especially the upper 25 cm in which they live.

The pearlfishes (Carapidae) are a little understood group, probably best known for the symbiotic relationship of some species with sea cucumbers. One genus of the family, Echiodon, is represented by but three known species, each present in a remote region of the world's oceans. A fourth form was taken in abundance during the MAFLA sampling phase and represents a significant addition to knowledge of biogeographical patterns of this species in the world's oceans. The archived collections of the adults represent the only such material available for this form whose larval distribution has been studies for several years.

The extensive collections of Triglidae provide a significant holding of a group widely recognized for resource partitioning (see Ross, 1977). Slight changes in macroinvertebrate composition would be reflected by changes in the species composition of triglids. As an example of the data available, two typical station collections are presented from the Data Tape, with the triglids indicated (Table 88). Normal variation due to collection methodology, seasonality and inherent cyclical changes can be gathered from the raw data should it ever be desired. This could then be compared with data from future populations as indicators of change.

One of the most characteristic tropical reef groups are the Chaetodontidae or butterfly fishes. These forms are almost exclusively reef dwellers, restricted by stenophagic, stenothermal, and stenohaline requirements. Although cluster analysis is discussed at some length below, identification of reef forms can be inferred by their close statistical association with the chaetodontids. Figure 234 is representative of such a cluster and typifies the type of community association contained in the Data Tapes.

The chaenopsid blennies, family Chaenopsidae, are cryptic forms of special relevance to the MAFLA study for two reasons. First, they had been rarely taken from Gulf waters previously and thus are poorly known. Secondly, they appear to be residents of an extremely specialized and limited environmental area, and thus constitute clear indicator species of environmental change.

Specifically, Emblemaria piratula is now known from hundreds of specimens, less than a dozen of which were collected previous to the MAFLA effort. Collections indicate that this species is endemic to the eastern Gulf of Mexico, but strongly concentrated over shallow to middle depths north and east of the northern postion of the De Soto canyon. The bottom is primarily of sand with small rubble and coarse shell debris.

Chaenopsis sp. is an undescribed form, known from only eight specimens, all of which are from the area north and east of the De Soto canyon of the type described above.

Similar comments to those above are applicable to numerous members of the family Gobiidae. However, collections of most forms were not extensive enough to be significant in regard to their habitat preference.

No other family of fishes is as critical to the MAFLA effort as are the left-eyed flounders, family Bothidae. The family is extremely well represented in nearly all collections from all stations at all seasons. The various species exhibit strong depth and sediment preferences, and this along with the reliability of capturing large series, presents ample opportunity to statistically verify habitat changes of specimens. In illustration, Table 89 is presented of representative catches at three stations along a single transect during the 1978 sampling period. The bothids are indicated.

In addition to their importance in community structure and habitat preference analysis, one species Syacium papillosum, formed the basis of the demersal fish trace metal (TM) and hydrocarbon (HC) analysis. This species

TABLE 88

SAMPLE OF DATA INDICATING EXTENT OF CATCHES OF TRIGLIDAE (SEA ROBINS) AT STATION 2426 (SEE "SAMPLE NUMBERS" COLUMN AND 264) TRIGLID SPECIES ARE UNDERLINED.

NAME	NOAA TAXONOMIC CODE	SAMPLE NUMBER	FIRST SPECIMEN				SECOND SPECIMEN				THIRD SPECIMEN			
			LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE
BROTULA BARBATA														
	8792010701	2426-17-19-80207	56.0	1.4	00	0	55.0	1.4	00	0				
HIPPOCAMPUS ERECTUS														
	8820020201	2426-17-19-80207	151.0	10.5	00	2								
SCORPAENA BRASILIENSIS														
	8826010502	2426-17-19-80207	158.0	30.7	00	1								
PRIONOTUS ROSEUS														
	8826020109	2426-17-19-80207	130.0	38.3	00	1	104.0	23.0	00	1	113.0	29.8	00	2
	8826020109	2426-17-19-80207	124.0	35.5	00	1	110.0	26.6	00	2				
	8826020109	2426-17-19-80207	114.0	30.2	00	1	132.0	36.0	00	1				
	8826020109	2426-17-19-80207	122.0	34.0	00	2	118.0	34.0	00	1	123.0	39.2	00	2
	8826020109	2426-17-19-80207	127.0	42.4	00	1	127.0	40.4	00	1	121.0	36.8	00	2
	8826020109	2426-18-19-80207	120.0	31.6	00	1	115.0	31.6	00	1	110.0	34.0	00	1
	8826020109	2426-19-19-80207	102.0	22.4	00	1								
PRIONOTUS RUBIO														
	8826020110	2426-17-19-80207	112.0	31.5	00	2	117.0	32.7	00	2	118.0	39.4	00	2
	8826020110	2426-17-19-80207	113.0	32.7	00	2	122.0	41.6	00	2	112.0	30.5	00	2
	8826020110	2426-17-19-80207	95.0	19.2	00	1	114.0	33.0	00	1				
	8826020110	2426-17-19-80207	115.0	24.0	00	1	115.0	26.1	00	2	123.0	36.8	00	1
	8826020110	2426-17-19-80207	116.0	30.7	00	1	114.0	36.6	00	2	119.0	37.4	00	1
	8826020110	2426-17-19-80207	115.0	34.6	00	1	118.0	36.2	00	1	105.0	26.0	00	1
	8826020110	2426-17-19-80207	121.0	37.0	00	2	115.0	36.1	00	2	115.0	33.5	00	2
	8826020110	2426-17-19-80207	113.0	30.3	00	1	106.0	25.3	00	1	75.0	11.3	00	0
	8826020110	2426-17-19-80207	89.0	17.6	00	0								
	8826020110	2426-17-19-80207	116.0	32.8	00	2	123.0	35.4	00	2	111.0	30.4	00	1
	8826020110	2426-17-19-80207	118.0	34.5	00	2	118.0	35.0	00	2	117.0	36.6	00	2
	8826020110	2426-17-19-80207	116.0	34.9	00	1	118.0	38.2	00	0	116.0	35.7	00	1
	8826020110	2426-17-19-80207	118.0	41.2	00	2	110.0	30.3	00	1	110.0	34.1	00	2
	8826020110	2426-17-19-80207	113.0	35.4	00	1	114.0	33.4	00	1	94.0	21.4	00	1
	8826020110	2426-17-19-80207	111.0	30.2	00	2	125.0	45.5	00	2	111.0	29.6	00	2
	8826020110	2426-17-19-80207	111.0	34.7	00	1	96.0	22.0	00	2	115.0	35.3	00	2
	8826020110	2426-17-19-80207	90.0	17.3	00	1								
PRIONOTUS SALMONICOLOR														
	8826020111	2426-17-19-80207	161.0	82.7	00	1	165.0	91.2	00	1	150.0	74.4	00	1
PRIONOTUS STEARNSI														
	8826020112	2426-17-19-80207	92.0	14.6	00	2								
	8826020112	2426-17-19-80207	104.0	22.7	00	2	85.0	12.5	00	1	98.0	20.5	00	2
	8626020112	2426-17-19-80207	97.0	20.5	00	2	90.0	17.5	00	1	82.0	11.5	00	2
BELLATOR MILITARIS														
	8826020202	2426-17-19-80207	73.0	17.3	00	2	72.0	15.4	00	2	78.0	17.3	00	2
	8826020202	2426-17-19-80207	76.0	18.8	00	2	68.0	13.4	00	1	73.0	15.5	00	1

TABLE 88 (CONTINUED)

NAME	NOAA TAXONOMIC CODE	SAMPLE NUMBER	FIRST SPECIMEN				SECOND SPECIMEN				THIRD SPECIMEN			
			LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE
	8826020202	2426-17-19-80207	68.0	11.5	00	1	71.0	14.2	00	1	77.0	18.1	00	1
	8826020202	2426-17-19-80207	87.0	20.0	00	1	76.0	17.1	00	1	74.0	16.0	00	1
	8826020202	2426-17-19-80207	74.0	14.9	00	2	78.0	15.0	00	2	82.0	18.1	00	2
	8826020202	2426-17-19-80207	77.0	17.5	00	2	75.0	19.0	00	2	77.0	16.3	00	2
	8826020202	2426-17-19-80207	80.0	20.2	00	2	81.0	15.5	00	2	72.0	12.4	00	2
	8826020202	2426-17-19-80207	78.0	17.8	00	2	90.0	26.1	00	1	80.0	17.6	00	1
	8826020202	2426-17-19-80207	91.0	23.1	00	1	68.0	13.8	00	2	79.0	17.5	00	2
	8826020202	2426-17-19-80207	84.0	20.7	00	1	76.0	15.1	00	2	79.0	17.3	00	1
	8826020202	2426-17-19-80207	80.0	19.2	00	2	78.0	17.5	00	2	82.0	21.2	00	1
	8826020202	2426-17-19-80207	81.0	16.8	00	1	89.0	23.1	00	1	90.0	22.0	00	1
	8826020202	2426-17-19-80207	72.0	13.7	00	2	79.0	15.5	00	1	72.0	14.5	00	2
	8826020202	2426-17-19-80207	73.0	14.5	00	2	86.0	20.2	00	2	73.0	15.4	00	2
	8826020202	2426-17-19-80207	81.0	17.4	00	2	79.0	16.6	00	2	79.0	16.4	00	2
	8826020202	2426-17-19-80207	87.0	20.4	00	1	81.0	21.4	00	1	76.0	17.5	00	2
	8826020202	2426-17-19-80207	67.0	10.4	00	1	78.0	18.3	00	2	77.0	17.5	00	2
	8826020202	2426-17-19-80207	73.0	14.3	00	1	86.0	20.5	00	1	70.0	12.1	00	1
	8826020202	2426-17-19-80207	73.0	13.4	00	1	78.0	19.9	00	2	80.0	16.0	00	2
	8826020202	2426-17-19-80207	80.0	18.0	00	2	82.0	19.0	00	1	70.0	12.1	00	2
	8826020202	2426-17-19-80207	84.0	22.2	00	2	86.0	24.0	00	1	75.0	17.4	00	1
	8826020202	2426-17-19-80207	86.0	22.7	00	1	88.0	21.2	00	2	82.0	18.5	00	1
	8826020202	2426-18-19-80207	75.0	17.0	00	2								
	8826020202	2426-19-19-80207	75.0	15.5	00	1								
CENTROPRISTIS OCYUPUS														
	8835020302	2426-17-19-80207	135.0	75.4	00	2	158.0	101.4	00	1	100.0	29.7	00	2
	8835020302	2426-17-19-80207	127.0	55.1	00	2	95.0	24.4	00	0	117.0	50.2	00	2
	8835020302	2426-17-19-80207	113.0	31.7	00	2	105.0	36.0	00	2	104.0	37.2	00	2
	8835020302	2426-17-19-80207	103.0	35.2	00	2	124.0	49.3	00	1	112.0	35.1	00	2
	8835020302	2426-17-19-80207	106.0	33.1	00	2	95.0	37.7	00	2	105.0	38.5	00	2
	8835020302	2426-17-19-80207	119.0	45.0	00	2	97.0	26.2	00	2	118.0	33.4	00	2
	8835020302	2426-17-19-80207	102.0	32.4	00	2								
	8835020302	2426-17-19-80207	145.0	88.3	00	1	106.0	34.8	00	2	103.0	37.4	00	2
	8835020302	2426-17-19-80207	112.0	40.3	00	2	116.0	46.5	00	2	111.0	44.1	00	2
	8835020302	2426-17-19-80207	106.0	35.2	00	2	116.0	45.2	00	2	118.0	44.8	00	2
	8835020302	2426-17-19-80207	108.0	37.1	00	2	106.0	36.4	00	1	104.0	32.5	00	2
	8835020302	2426-17-19-80207	103.0	33.5	00	2	114.0	43.4	00	2	106.0	36.3	00	2
	8835020302	2426-17-19-80207	99.0	31.1	00	2	102.0	27.1	00	2	104.0	34.4	00	2
	8835020302	2426-17-19-80207	104.0	33.0	00	2	96.0	26.5	00	0	92.0	24.8	00	2
	8835020302	2426-17-19-80207	76.0	13.1	00	0	97.0	30.0	00	2	114.0	43.0	00	2
	8835020302	2426-17-19-80207	107.0	33.2	00	2	105.0	33.2	00	2	102.0	30.0	00	2
	8835020302	2426-17-19-80207	99.0	26.5	00	2	98.0	27.3	00	2	96.0	26.9	00	2
	8835020302	2426-17-19-80207	140.0	77.1	00	1	145.0	92.1	00	1	105.0	40.5	00	1

TABLE 88 (CONTINUED)

NAME	NOAA TAXONOMIC CODE	SAMPLE NUMBER	FIRST SPECIMEN				SECOND SPECIMEN				THIRD SPECIMEN			
			LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE
	8826010503	2641-17-19-80209	60.0	10.5	00	0	60.0	10.5	00	0	59.0	9.2	00	0
PRIONOTUS OPHRYAS														
	8826020107	2641-17-19-80209	146.0	80.8	00	2	98.0	26.5	00	2	96.0	21.7	00	2
	8826020107	2641-17-19-80209	98.0	25.6	00	2	94.0	22.8	00	1	81.0	16.6	00	0
	8826020107	2641-17-19-80209	98.0	24.0	00	1	90.0	18.8	00	2				
PRIONOTUS ROSEUS														
	8826020109	2641-17-19-80209	134.0	52.0	00	1	141.0	53.0	00	1	130.0	48.1	00	1
	8826020109	2641-17-19-80209	104.0	24.9	00	1	120.0	31.2	00	2				
PRIONOTUS RUBIO														
	8826020110	2641-17-19-80209	114.0	34.4	00	1	117.0	41.2	00	1				
PRIONOTUS SALMONICOLOR														
	8826020111	2641-17-19-80209	118.0	35.2	00	1	129.0	52.0	00	1	120.0	38.9	00	1
	8826020111	2641-17-19-80209	150.0	64.2	00	2	108.0	33.2	00	2				
BELLATOR EGRETTA														
	8826020201	2641-17-19-80209	151.0	115.0	00									
BELLATOR MILITARIS														
	8826020202	2641-17-19-80209	64.0	9.8	00	0	60.0	10.5	00	0	61.0	9.0	00	0
	8826020202	2641-17-19-80209	61.0	8.9	00	0	75.0	16.4	00	0	66.0	12.5	00	0
	8826020202	2641-17-19-80209	61.0	9.1	00	0	54.0	7.5	00	0	58.0	8.9	00	0
	8826020202	2641-17-19-80209	67.0	12.0	00	0	64.0	10.4	00	0	56.0	6.8	00	0
	8826020202	2641-17-19-80209	65.0	10.4	00	0	70.0	12.0	00	0	66.0	10.9	00	0
	8826020202	2641-17-19-80209	63.0	10.2	00	0	67.0	8.3	00	0	56.0	7.5	00	0
CENTROPRISTIS OCYURUS														
	8835020302	2641-17-19-80209	187.0	72.6	00	1	172.0	146.0	00	1	184.0	160.3	00	1
	8835020302	2641-17-19-80209	189.0	179.4	00	1	130.0	60.8	00	1	168.0	136.0	00	1
	8835020302	2641-17-19-80209	163.0	113.3	00	2	130.0	63.9	00	2	147.0	93.9	00	2
	8835020302	2641-17-19-80209	127.0	61.0	00	2	94.0	23.9	00	2				
CENTROPRISTIS PHILADELPHICA														
	8835020303	2641-17-19-80209	126.0	46.0	00	2								
DIPLECTRUM BIVITTATUM														
	8835020601	2641-17-19-80209	50.0	2.4	00	0								
DIPLECTRUM FORMOSUM														
	8835020602	2641-17-19-80209	179.0	28.6	00	3								
PRISTIGENYS ALTA														
	8835170201	2641-17-19-80209	134.0	123.2	00	1								
LUTJANUS CAMPECHANUS														
	8835360103	2641-17-19-80209	124.0	63.6	00	0	124.0	57.3	00	0	114.0	45.3	00	0
	8835360103	2641-17-19-80209	92.0	27.4	00	0								
	8835360103	2641-17-19-80209	109.0	43.2	00	0	124.0	64.3	00	0	110.0	45.1	00	0
	8835360103	2641-17-19-80209	114.0	53.9	00	0	117.0	48.7	00	0	88.0	24.3	00	0
	8835360103	2641-17-19-80209	82.0	17.4	00	0	72.0	13.1	00	0				

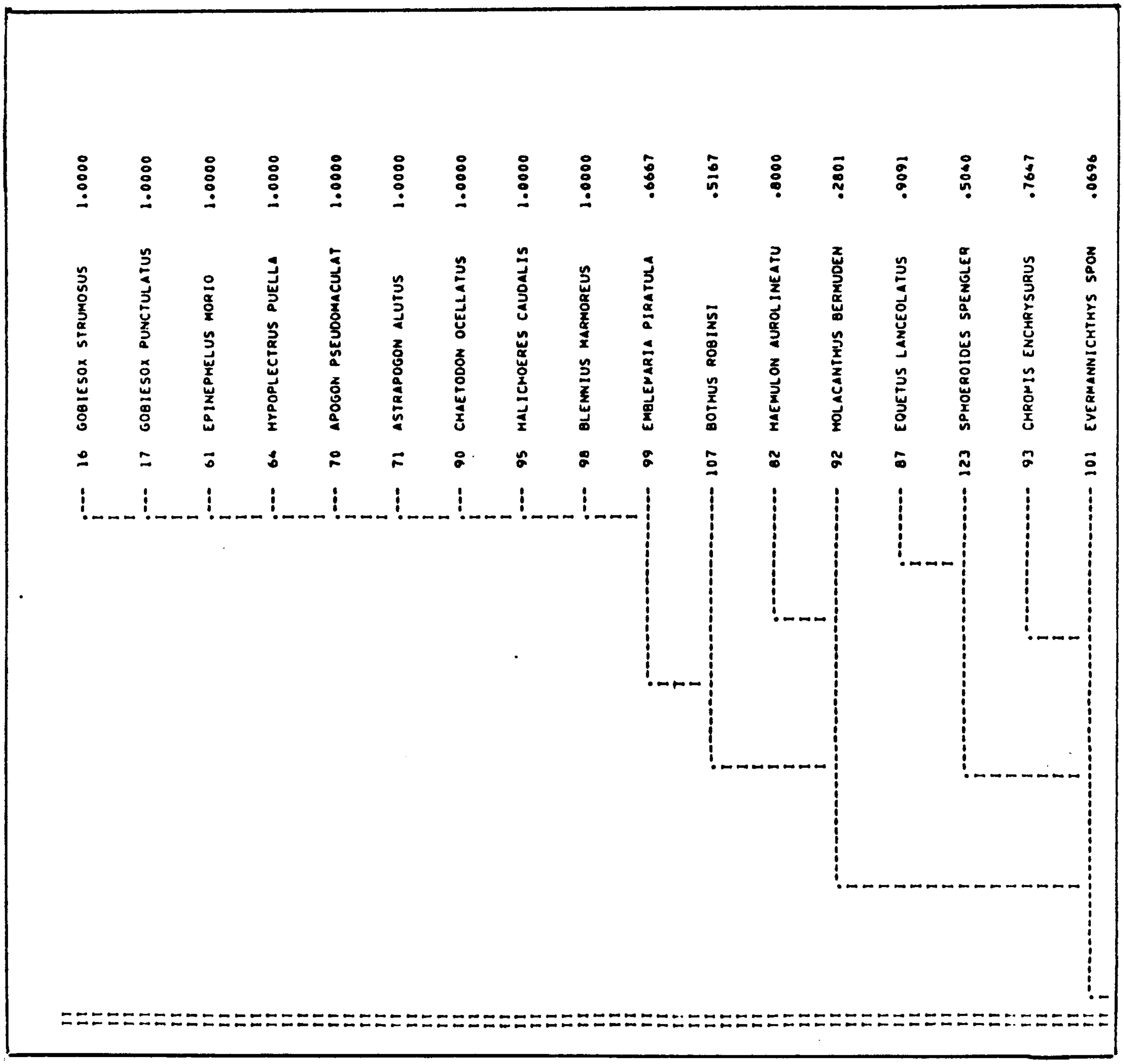


Figure 234 Community analysis by species clustering, exemplified by a cluster of reef associated forms (see text for methodology).

TABLE 89

SAMPLE OF DATA INDICATING DISTINCT MATURE OF BOTHIDAE FAUNA (UNDERLINED) AS RELATED TO DEPTH. THE THREE SELECTED STATIONS ARE 40, 100, and 200 m STATIONS ALONG THE SAME TRANSECT (I) DURING THE SINGLE FEBRUARY 1978 SAMPLING
STATION 2103 (SEE "SAMPLE NUMBER" COLUMN) -40 m; 2105-100 m; 2106-200 m

NAME	NOAA TAXONOMIC CODE	SAMPLE NUMBER	FIRST SPECIMEN				SECOND SPECIMEN				THIRD SPECIMEN			
			LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE
	8835620101	2103-17-19-80201	73.0	20.8		2	74.0	17.1		2	74.0	16.0		1
	8835620101	2103-17-19-80201	69.0	13.8		1	72.0	16.0			65.0	11.5		
	8835620101	2103-17-19-80201	61.0	10.3			55.0	7.0			52.0	5.3		
	8835620101	2103-30-19-80201	71.0	16.2		1	73.0	19.9		1	76.0	17.4		2
	8835620101	2103-30-19-80201	75.0	19.8		2	77.0	20.1		2				
	8835620101	2103-31-19-80202	79.0	20.0		1	78.0	19.5		2	72.0	17.6		2
POMACENTRUS VARIABILIS														
	8835620201	2103-17-19-80201	77.0	22.9		1	65.0	12.1		2				
	8835620201	2103-30-19-80201	91.0	36.6		2								
HALICHOERES CAUDALIS														
	8839010402	2103-30-19-80201	139.0	40.5		2								
	8839010402	2103-31-19-80202	152.0	57.3		1								
HEMIPTERONOTUS NOVACULA														
	8839010501	2103-17-19-80201	128.0	46.4		2								
NICHOLSINA USTA														
	8839030201	2103-30-19-80201	163.0	113.9		1	128.0	45.1		2				
	8839030201	2103-31-19-80202	176.0	110.4		1	166.0	99.6		2	138.0	60.0		
KATHETOSTOMA ALBIGUTTA														
	8840140201	2103-40-19-80201	114.0	48.1		2								
BLENNIUS MARMOREUS														
	8842010101	2103-17-19-80201	67.0	4.4		1								
	8842010101	2103-31-19-80202	30.0	0.4		2								
STARKSIA OCELLATA														
	8842090301	2103-17-19-80201	137.0	0.9		2								
EVERMANNICHTHYS SPONGICOLA														
	8847010901	2103-30-19-80201	23.0	0.1		2	25.0	0.1		2				
	8847010901	2103-31-19-80202	22.0	0.1		2								
ETROPUS RIMOSUS														
	8857030203	2103-30-19-80201	92.0	17.5		1	103.0	21.9		1	90.0	16.1		1
	8857030203	2103-30-19-80201	96.0	20.3		1	80.0	11.2		1	70.0	7.0		1
	8857030203	2103-30-19-80201	69.0	6.5		2	79.0	9.8		2	81.0	11.5		2
	8857030203	2103-30-19-80201	75.0	8.3		2								
ANCYLOPSETTA QUADROCELLATA														
	8857030502	2103-30-19-80201	181.0	111.6		2								
	8857030502	2103-31-19-80202	190.0	131.5		1								
BOTHUS OCELLATUS														
	8857030601	2103-17-19-80201	117.0	31.3		2								
BOTHUS ROBINSI														
	8857030602	2103-17-19-80201	120.0	29.5		2	133.0	46.6		1	135.0	47.0		1
	8857030602	2103-17-19-80201	85.0	10.3		1								
	8857030602	2103-30-19-80201	126.0	36.3		1	122.0	34.7		2	82.0	9.8		1

TABLE 89 (CONTINUED)

NAME	NQAA TAXONOMIC CODE	SAMPLE NUMBER	FIRST SPECIMEN				SECOND SPECIMEN				THIRD SPECIMEN			
			LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE
	8857030602	2103-31-19-80202	122.0	34.9		2								
CYCLOPSETTA FIMBRIATA														
	8857030702	2103-18-19-80201	200.0	98.8		1								
SYACIUM PAPILLOSUM														
	8857031102	2103-17-19-80201	175.0	88.7		2	165.0	65.4		1	115.0	21.8		1
	8857031102	2103-18-19-80201	13.5	31.6		2	151.5	46.5		1	100.0	14.5		1
	8857031102	2103-18-19-80201	85.0	7.0		2								
	8857031102	2103-30-19-80201	152.0	50.4		1	144.0	41.2		1	99.0	15.3		2
	8857031102	2103-30-19-80201	121.0	30.1		1								
	8857031102	2103-40-19-80201	50.0	2.0		1								
MONACANTHUS CILIATUS														
	8860020601	2103-17-19-80201	68.0	8.6		2	42.0	1.4						
	8860020601	2103-18-19-80201	91.0	22.3		2								
	8860020601	2103-30-19-80201	73.0	10.2		2								
MONACANTHUS HISPIDUS														
	8860020602	2103-18-19-80201	98.0	32.0		2								
	8860020602	2103-31-19-80202	132.0	64.8		1	106.0	40.3		2				
SPHOEROIDES DORSALIS														
	8861010203	2103-30-19-80201	88.0	16.1		1								
	8861010203	2103-31-19-80202	61.0	5.6		1								
SPHOEROIDES SPENGLERI														
	8861010207	2103-17-19-80201	67.0	8.3										
	8861010207	2103-17-19-80201	126.0	52.0		1	140.0	80.5		2	138.0	67.5		1
	8861010207	2103-17-19-80201	129.0	56.2		1	124.0	53.5		2	111.0	35.0		1
	8861010207	2103-17-19-80201	115.0	39.6		2	110.0	31.8		1	103.0	24.5		1
	8861010207	2103-17-19-80201	99.0	24.3		1	97.0	22.5			83.0	17.0		
	8861010207	2103-17-19-80201	95.0	22.0			71.0	28.3			75.0	11.1		
	8861010207	2103-30-19-80201	104.0	31.6		2	105.0	30.8		2	116.0	46.7		2
	8861010207	2103-30-19-80201	110.0	38.1		2	113.0	46.6		2	109.0	30.7		1
	8861010207	2103-30-19-80201	85.0	17.5		1								
	8861010207	2103-31-19-80202	126.0	55.5		1	113.0	32.4		2	108.0	36.1		2
	8861010207	2103-31-19-80202	94.0	18.4		1								
	8861010207	2103-40-19-80201	124.0	45.7		2								
GYMNOTHORAX NIGROMARGINATUS														
	8741050102	2105-19-19-80202	375.0	56.4		2								
OPHICHTHUS OCELLATUS														
	8741130402	2105-17-19-80202	562.0	125.2		2								
SYNODUS INTERMEDIUS														
	8762020102	2105-17-19-80202	180.0	60.8		1	165.0	46.6		1	181.0	58.2		1
	8762020102	2105-17-19-80202	187.0	57.6		2	195.0	61.0		2	209.0	78.8		2
	8762020102	2105-17-19-80202	198.0	72.8		2	175.0	52.5		2	176.0	58.6		1

TABLE 89 (CONTINUED)

NAME	NOAA TAXONOMIC CODE	SAMPLE NUMBER	FIRST SPECIMEN LENGTH MM	FIRST SPECIMEN WEIGHT G	FIRST SPECIMEN PATH CODE	FIRST SPECIMEN SEX CODE	SECOND SPECIMEN LENGTH MM	SECOND SPECIMEN WEIGHT G	SECOND SPECIMEN PATH CODE	SECOND SPECIMEN SEX CODE	THIRD SPECIMEN LENGTH MM	THIRD SPECIMEN WEIGHT G	THIRD SPECIMEN PATH CODE	THIRD SPECIMEN SEX CODE
	8826020112	2105-19-19-80202	30.0	0.6			26.0	0.5						
BELLATOR MILITARIS														
	8826020202	2105-17-19-80202	93.0	26.8		1	95.0	24.5		2	94.0	23.3		2
	8826020202	2105-17-19-80202	100.0	31.7		2	102.0	28.2		2	100.0	26.8		2
	8826020202	2105-17-19-80202	97.0	24.2		2	96.0	28.0		2				
	8826020202	2105-19-19-80202	77.0	10.6		2								
SERRANUS NOTOSPILUS														
	8835021203	2105-17-19-80202	44.0	2.4		2	37.0	1.3		2	37.0	1.3		2
MULLUS AURATUS														
	8835450101	2105-17-19-80202	134.0	53.6		1	129.0	50.1		2				
CITHARICHTHYS CORNUTUS														
	8857030103	2105-19-19-80202	33.0	0.4		2								
SYACIUM PAPILLOSUM														
	8857031102	2105-17-19-80202	116.0	19.1		1								
MONACANTHUS CILIATUS														
	8860020601	2105-17-19-80202	97.0	23.5		2								
	8860020601	2105-18-19-80202	94.0	21.6		1								
	8860020601	2105-19-19-80202	90.0	21.4		2								
SPHOEROIDES DORSALIS														
	8861010203	2105-17-19-80202	133.0	55.6		1	127.0	49.4		1	111.0	36.4		1
	8861010203	2105-17-19-80202	129.0	58.1		1	120.0	47.1		1	132.0	60.8		2
	8861010203	2105-17-19-80202	121.0	52.4		2	120.0	48.9		2	128.0	62.5		2
	8861010203	2105-17-19-80202	120.0	49.5		2	130.0	53.8			104.0	31.2		
	8861010203	2105-17-19-80202	118.0	39.2			116.0	40.1						
	8861010203	2105-17-19-80202	122.0	53.7			129.0	50.9			100.0	25.2		
LEPTOCEPHALUS LARVA														
	8741000001	2106-17-19-80203	108.0	..6			93.0	0.4						
OPHICHTHUS OCELLATUS														
	8741130402	2106-30-19-80203	450.0	74.1		1								
SYNODUS POEYI														
	8762020103	2106-17-19-80203	65.0	1.7		2	91.0	5.4		2	61.0	1.4		2
	8762020103	2106-17-19-80203	68.0	2.2		2	80.0	4.0		2	70.0	2.4		1
	8762020103	2106-17-19-80203	80.0	3.6		2	82.0	3.6		2	86.0	5.2		2
	8762020103	2106-17-19-80203	71.0	2.1		1								
	8762020103	2106-30-19-80203	84.0	4.5		2	83.0	4.0		2	79.0	3.5		1
	8762020103	2106-30-19-80203	89.0	5.5		1	79.0	4.0		2	85.0	4.4		2
	8762020103	2106-30-19-80203	79.0	3.5		2	75.0	2.6		2	71.0	2.7		2
	8762020103	2106-30-19-80203	74.0	2.6		1	61.0	2.3			68.0	2.4		
	8762020103	2106-30-19-80203	57.0	1.2			65.0	2.1			69.0	2.6		
	8762020103	2106-30-19-80203	66.0	2.0			60.0	1.5						
SAURIDA BRASILIENSIS														
	8762020201	2106-17-19-80203	54.0	1.0		2	56.0	1.2		2	60.0	1.6		2

TABLE 89 (CONTINUED)

NAME	NOAA TAXONOMIC CODE	SAMPLE NUMBER	FIRST SPECIMEN				SECOND SPECIMEN				THIRD SPECIMEN			
			LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE
TRACHURUS LATHAMI														
	8835280102	2106-30-19-80203	161.0	68.2		2								
PRISTIPOMOIDES AQUILONARIS														
	8835360201	2106-17-19-80203	175.0	128.0		2	197.0	137.3		2				
	8835360201	2106-30-19-80203	168.0	110.9		1								
MULLUS AURATUS														
	8835450101	2106-17-19-80203	164.0	85.5		2								
	8835450101	2106-30-19-80203	156.0	79.8		2	151.0	67.6		2				
DECODON PUELLARIS														
	8839010301	2106-17-19-80203	110.0	22.8		2	74.0	6.7		2				
	8839010301	2106-30-19-80203	110.0	27.2		1	97.0	20.1		1	100.0	19.9		2
LONCHOPISTHUS														
	88400201	2106-17-19-80203	70.0	5.5		1	64.0	4.5		1	71.0	5.0		1
	88400201	2106-17-19-80203	70.0	5.1		1	68.0	5.2		1	50.0	2.0		1
	88400201	2106-17-19-80203	63.0	4.5		1	60.0	4.3		1	60.0	3.6		1
	88400201	2106-17-19-80203	50.0	2.2		2	41.0	1.5		2				
	88400201	2106-30-19-80203	62.0	3.4		2	50.0	2.7		1				
CALLIONYMUS AGASSIZI														
	8846010101	2106-17-19-80203	87.0	6.5		2	93.0	8.5		2	99.0	10.5		2
	8846010101	2106-17-19-80203	105.0	11.1		1	78.0	4.9		1	82.0	5.4		1
	8846010101	2106-30-19-80203	129.0	20.4		2								
<u>CITHARICHTHYS CORNUTUS</u>														
	8857030103	2106-17-19-80203	58.0	2.9			54.0	2.3			61.0	3.1		
	8857030103	2106-17-19-80203	50.0	1.5			48.0	1.4			52.0	1.8		
	8857030103	2106-17-19-80203	51.0	1.8			63.0	3.7			66.0	4.1		
	8857030103	2106-17-19-80203	57.0	2.5			60.0	3.2			54.0	2.3		
	8857030103	2106-17-19-80203	49.0	1.4			60.0	3.3			50.0	2.0		
	8857030103	2106-17-19-80203	47.0	1.6			46.0	1.2			52.0	2.1		
	8857030103	2106-17-19-80203	63.0	3.7			61.0	3.5			59.0	2.7		
	8857030103	2106-17-19-80203	53.0	2.9			51.0	1.7			62.0	3.5		
	8857030103	2106-17-19-80203	59.0	2.9			55.0	2.6			56.0	2.4		
	8857030103	2106-17-19-80203	47.0	1.2			48.0	1.3			46.0	1.2		
	8857030103	2106-17-19-80203	58.0	2.6			58.0	2.5			42.0	1.0		
	8857030103	2106-17-19-80203	51.0	1.7			56.0	2.4			47.0	1.3		
	8857030103	2106-17-19-80203	52.0	1.7			51.0	1.5			47.0	1.4		
	8857030103	2106-17-19-80203	53.0	2.1			52.0	2.0			48.0	1.4		
	8857030103	2106-17-19-80203	49.0	1.6			48.0	1.6			57.0	1.7		
	8857030103	2106-17-19-80203	58.0	2.5			49.0	1.5			46.0	1.2		
	8857030103	2106-17-19-80203	50.0	2.1			42.0	1.0			41.0	0.8		
	8857030103	2106-17-19-80203	50.0	2.3										
	8857030103	2106-17-19-80203	64.0	3.9		1	61.0	3.4		1	58.0	2.7		1

TABLE 89 (CONTINUED)

NAME NOAA TAXONOMIC CODE	SAMPLE NUMBER	FIRST SPECIMEN				SECOND SPECIMEN				THIRD SPECIMEN			
		LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE
8857030103	2106-17-19-80203	65.0	4.1		1	52.0	2.0		1	53.0	1.9		2
8857030103	2106-17-19-80203	48.0	1.4		2	54.0	2.0		2	48.0	1.3		2
8857030103	2106-17-19-80203	45.0	1.2		2	64.0	3.7			65.0	3.7		
8857030103	2106-17-19-80203	54.0	2.5			55.0	2.0			57.0	2.5		
8857030103	2106-17-19-80203	61.0	3.0			58.0	2.8			55.0	2.1		
8857030103	2106-17-19-80203	53.0	2.2			47.0	1.3			46.0	1.3		
8857030103	2106-17-19-80203	64.0	3.8			52.0	2.0			64.0	4.0		
8857030103	2106-17-19-80203	55.0	2.4			65.0	4.2			56.0	2.2		
8857030103	2106-17-19-80203	59.0	3.2			57.0	2.7			54.0	2.2		
8857030103	2106-17-19-80203	60.0	2.9			52.0	2.0			61.0	3.2		
8857030103	2106-17-19-80203	50.0	1.8			62.0	3.4			53.0	1.9		
8857030103	2106-17-19-80203	58.0	2.8			59.0	2.8			64.0	3.7		
8857030103	2106-17-19-80203	62.0	3.9			60.0	3.2			52.0	2.1		
8857030103	2106-17-19-80203	51.0	2.0			54.0	2.4			53.0	2.5		
8857030103	2106-17-19-80203	68.0	5.0			67.0	4.7			65.0	3.9		
8857030103	2106-30-19-80203	68.0	4.1		1	56.0	2.6		1	59.0	2.9		2
8857030103	2106-30-19-80203	52.0	2.0			54.0	2.1			53.0	2.1		
8857030103	2106-30-19-80203	62.0	3.8			51.0	1.6			57.0	2.5		
8857030103	2106-30-19-80203	63.0	3.4			66.0	3.8			57.0	2.4		
8857030103	2106-30-19-80203	58.0	2.6			50.0	1.7			46.0	1.2		
8857030103	2106-30-19-80203	60.0	3.0			49.0	1.8			55.0	2.1		
8857030103	2106-30-19-80203	48.0	1.4			48.0	1.4			61.0	2.9		
8857030103	2106-30-19-80203	58.0	2.4			47.0	1.2			56.0	2.8		
8857030103	2106-30-19-80203	52.0	1.9			51.0	1.8			65.0	3.6		
8857030103	2106-30-19-80203	61.0	2.9			57.0	2.5			59.0	2.7		
8857030103	2106-30-19-80203	60.0	2.8			52.0	1.9			56.0	2.4		
8857030103	2106-30-19-80203	52.0	2.0			49.0	1.3			50.0	1.7		
8857030103	2106-30-19-80203	47.0	1.3			55.0	2.0			66.0	4.0		
8857030103	2106-30-19-80203	56.0	2.1			55.0	2.1			59.0	3.1		
8857030103	2106-30-19-80203	54.0	2.1			51.0	1.7			49.0	1.5		
8857030103	2106-30-19-80203	60.0	2.8			64.0	3.7			63.0	2.8		
8857030103	2106-30-19-80203	62.0	3.8			61.0	3.0			54.0	2.1		
8857030103	2106-30-19-80203	56.0	2.4			61.0	2.9			51.0	1.8		
8857030103	2106-30-19-80203	59.0	3.1			68.0	4.5			56.0	2.4		
8857030103	2106-30-19-80203	67.0	4.5			68.0	4.3			51.0	1.6		
8857030103	2106-30-19-80203	60.0	3.1			63.0	3.9			48.0	1.2		
8857030103	2106-30-19-80203	51.0	1.9			59.0	2.7			58.0	2.5		
8857030103	2106-30-19-80203	69.0	4.2			63.0	3.6			52.0	1.5		
8857030103	2106-30-19-80203	38.0	0.7										
8857030103	2106-30-19-80203	60.0	2.9		1	55.0	2.1		2	56.0	2.4		2
8857030103	2106-30-19-80203	53.0	2.2		2	51.0	1.8		2	59.0	2.8		1

TABLE 89 (CONTINUED)

NAME	NOAA TAXONOMIC CODE	SAMPLE NUMBER	FIRST SPECIMEN				SECOND SPECIMEN				THIRD SPECIMEN			
			LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE	LENGTH MM	WEIGHT G	PATH CODE	SEX CODE
	8857030103	2106-30-19-80203	64.0	3.6		1	59.0	3.0			69.0	4.7		
	8857030103	2106-30-19-80203	48.0	1.6			59.0	3.2			62.0	3.3		
	8857030103	2106-30-19-80203	58.0	2.6			64.0	3.8			52.0	2.0		
	8857030103	2106-30-19-80203	49.0	1.5			55.0	2.6			58.0	2.7		
	8857030103	2106-30-19-80203	57.0	2.6			52.0	1.9			63.0	3.9		
	8857030103	2106-30-19-80203	55.0	2.5			61.0	3.7			63.0	3.7		
	8857030103	2106-30-19-80203	64.0	3.7			55.0	2.5			63.0	3.8		
	8857030103	2106-30-19-80203	62.0	3.7			56.0	2.5			61.0	3.3		
CITHARICHTHYS DINOCEROS														
	8857030104	2106-17-19-80203	71.0	3.3		2	85.0	5.8		1				
ANCYLOPSETTA DILECTA														
	8857030501	2106-17-19-80203	191.0	99.4		2	90.0	11.2		2	94.0	11.7		1
	8857030501	2106-30-19-80203	217.0	139.2		2	137.0	32.2		2	97.0	12.7		1
	8857030501	2106-30-19-80203	99.0	12.6		1	97.0	11.7		2	100.0	10.1		1
	8857030501	2106-30-19-80203	92.0	11.5		1								
SYACIUM PAPILLOSUM														
	8857031102	2106-18-19-80203	159.0	46.4		1	111.0	20.0		1	91.0	9.8		2
PARAHOLLARDIA LINEATA														
	8860040101	2106-17-19-80203	24.0	1.0			25.0	1.0						
	8860040101	2106-30-19-80203	29.0	1.4			23.0	1.0			25.0	1.0		
	8860040101	2106-30-19-80203	23.0	0.8										
	8860040101	2106-30-19-80203	35.0	2.2			24.0	0.9			27.0	1.3		
RAJA EGLANTERIA														
	8713040114	2209-17-19-80205	597.0	1416.8		2								
SARDINELLA ANCHOVIA														
	8747010801	2209-17-19-80205	120.0	18.3		2								
SYNODUS POEYI														
	8762020103	2209-17-19-80205	96.0	6.9		2	92.0	6.8		2	96.0	8.1		1
	8762020103	2209-17-19-80205	92.0	6.6		1	97.0	8.3		1	83.0	4.7		1
	8762020103	2209-17-19-80205	80.0	4.3		1	86.0	5.7		1	94.0	7.8		1
	8762020103	2209-17-19-80205	85.0	5.5		1	82.0	4.6			81.0	4.3		
	8762020103	2209-17-19-80205	60.0	2.2										
SAURIDA NORMANI														
	8762020203	2209-17-19-80205	190.0	54.8		1	173.0	42.7		1	208.0	75.2		1
	8762020203	2209-17-19-80205	239.0	120.0		1	248.0	148.6		2	234.0	122.9		2
	8762020203	2209-17-19-80205	253.0	141.1		2	256.0	150.9		2	324.0	278.7		2
	8762020203	2209-17-19-80205	266.0	212.5		2	238.0	134.3			240.0	129.8		
	8762020203	2209-17-19-80205	251.0	138.8			185.0	50.4			245.0	126.7		
	8762020203	2209-17-19-80205	248.0	157.4			238.0	137.9			153.0	28.6		
	8762020203	2209-17-19-80205	165.0	33.5			226.0	111.7			202.0	62.8		
	8762020203	2209-17-19-80205	210.0	60.7			183.0	47.5			278.0	152.7		

was abundant at all shallow and middle depth stations over the entire MAFLA area. It is not a pelagic form, and thus is a strong indicator of various elements of a specific area as they are accumulated in upper carnivores. Its life history is well known (see Topp and Hoff, 1972) and thus it is amenable to extensive interpretation as to environmental influences, such as fecundity alteration due to TM changes. An example of population structure based on length frequency distribution is given in Figure 235.

In addition to the reservoir of information on demersal fishes available on the Data Tape, as well as the hand-transcribed data in the possession of the Principal Investigators, the actual specimens themselves have been carefully preserved and archived at the University of South Alabama and the University of West Florida. Color slide photographs of many specimens, including representatives from the series of Syacium papillosum used in TM and HC analysis are held by the Principal Investigators. Investigators of any facet of future environmental studies in the MAFLA area relating to demersal fishes should be cognizant of the existence of these data sources. Possible studies could be so diverse in their intent and purpose that only with raw data for comparison can an adequate interpretation be realized.

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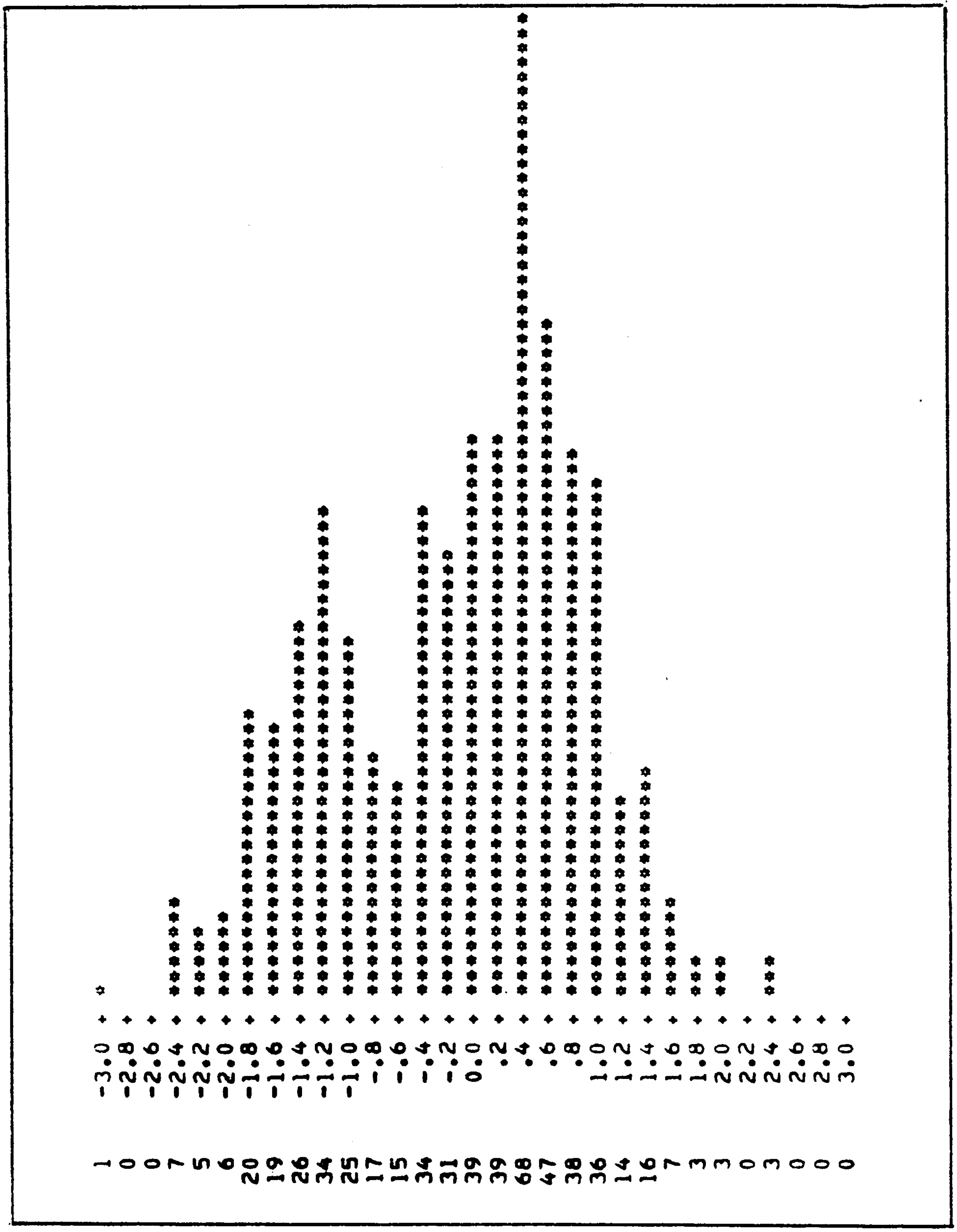

Figure 235 Sample of length/frequency data, using Syacium papillosum, the species from which TM/HC samples were taken. Length units are standard deviations from the mean Standard length of 117.5 mm.

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APPENDIX A

SPECIES LIST

Appendix A. Coded species list. Demersal fishes begin with 85001.

NOAA CODE	NAME
81060104	ASTROPECTEN
8108010101	STARFISH USNM
8125030101	ASTROPORPA ANNULATA
81530101	CLYPEASTER
850001	BRANCHIOSTOMIDAE
85000101	BRANCHIOSTOMA
8500010101	BRANCHIOSTOMA CARIBAEUM
8500010102	BRANCHIOSTOMA FLORIDAE
870802	CARCHARHINIDAE
87080203	RHIZOPRIONODON
8708020301	RHIZOPRIONODON TERRAENOVAE
87080204	MUSTELUS
8708020401	MUSTELUS CANIS
8708020402	MUSTELUS NORRISI
871101	SQUATINIDAE
87110101	SQUATINA
8711010102	SQUATINA DUMERILI
871304	RAJIDAE
87130401	RAJA
8713040114	RAJA EGLANTERIA
8713040117	RAJA GARMANI
8713040118	RAJA TEXANA
8713040119	RAJA OLSENI
8713050106	DASYSTUS SAYI
8741000001	LEPTOCEPHALUS LARVA
874105	MURAENIDAE
87410501	GYMNOTHORAX
8741050101	GYMNOTHORAX MORINGA
8741050102	GYMNOTHORAX NIGROMARGINATUS
8741050103	GYMNOTHORAX SAXICOLA
8741050201	MURAENA RETIFERA
8741050301	ANARCHIAS YOSHIAE
874108	MURAENESOCIDAE
87410801	HOPLUNNIS
874110	NETTASTOMATIDAE
8741100101	HOPLUNNIS DIOMEDIANA
8741100102	HOPLUNNIS MACRURA
8741100103	HOPLUNNIS TENUIS
87411002	METOPOMYCTER
87411003	SAURENCHELYS
87411004	FACCIOLELLA
87411005	VENEFICA
87411006	NETTASTOMA
8741100601	NETTASTOMA MELANURUM
87411007	NETTASTOMATID GENUS A
874112	CONGRIDAE
87411201	CONGER
8741120101	CONGER OCEANICUS
87411202	ARIOSOMA
8741120201	ARIOSOMA BALEARICUM

NOAA CODE	NAME
87411203	HILDEBRANDIA
8741120301	HILDEBRANDIA GRACILIOR
8741120302	HILDEBRANDIA FLAVA
87411204	METOPOMYCTER
87411205	PARACONGER
8741120501	PARACONGER CAUDILIMBATUS
87411206	PSEUDOXENOMYSTAX
8741120601	PSEUDOXENOMYSTAX DUBIUS
87411207	RECHIAS (FORMERLY CONGRINA:D:SMITH)
87411208	SAURENCHELYS
87411209	UROCONGER
8741120901	UROCONGER SYRINGINUS
874113	OPHICHTHIDAE
87411301	MYROPHIS
8741130101	MYROPHIS PUNCTATUS
87411302	MYSTRIOPHIS
8741130201	MYSTRIOPHIS INTERTINCTUS
8741130202	MYSTRIOPHIS PUNCTIFER
87411303	NYSTACTICHTHYS
87411304	OPHICHTHUS
8741130401	OPHICHTHUS GOMESI
8741130402	OPHICHTHUS OCELLATUS
87411305	GORDIICHTHYS
8741130501	GORDIICHTHYS IRRETITUS
8741130601	VERMA KENDALLI
874701	CLUPEIDAE
87470106	ETRUMEUS
8747010601	ETRUMEUS TERES
87470108	SARDINELLA
8747010801	SARDINELLA ANCHOVIA
87470109	JENKENSIA
8747010901	JENKENSIA LAMPROTAENIA
875601	ARGENTINIDAE
87560102	ARGENTINA
8756010201	ARGENTINA STRIATA
8756010202	ARGENTINA SILUS
8756010301	GLOSSANODON PYGMAEUS
876202	SYNODONTIDAE
87620201	SYNODUS
8762020101	SYNODUS FOETENS
8762020102	SYNODUS INTERMEDIUS
8762020103	SYNODUS POEYI
87620202	SAURIDA
8762020201	SAURIDA BRASILIENSIS
8762020202	SAURIDA CARIBBAEA
8762020203	SAURIDA NORMANI
87620203	TRACHINOCEPHALUS
8762020301	TRACHINOCEPHALUS MYOPS
876214	MYCTOPHIDAE
87621402	DIAPHUS

NOAA CODE	NAME
8762140202	DIAPHUS DUMERILI
878301	BATRACHOIDIDAE
87830101	PORICHTHYS
8783010102	PORICHTHYS POROSISSIMUS
87830102	OPSANUS
8783010202	OPSANUS PARDUS
878401	GOBIESOCIDAE
87840101	GOBIESOX
8784010102	GOBIESOX STRUMOSUS
8784010103	GOBIESOX PUNCTULATUS
878601	LOPHIIDAE
87860102	LOPHIOMUS
878702	ANTENNARIIDAE
87870201	HISTRIO
8787020101	HISTRIO HISTRIO
87870202	ANTENNARIUS
8787020201	ANTENNARIUS OCELLATUS
8787020202	ANTENNARIUS RADIOSUS
8787020203	ANTENNARIUS SCABER
878704	OGCOCEPHALIDAE
87870401	OGCOCEPHALUS
8787040102	OGCOCEPHALUS D
8787040103	OGCEPHALUS CUBIFRONS
8787040104	OGCOCEPHALUS P
8787040105	OGCOCEPHALUS PARVUS
8787040106	OGCOCEPHALUS C
8787040108	OGCOCEPHALUS VESPERTILIO
87870402	DIBRANCHUS
8787040201	DIBRANCHUS ATLANTICUS
87870403	HALIEUTICHTHYS
8787040301	HALIEUTICHTHYS ACULEATUS
87870404	ZALIEUTES
8787040401	ZALIEUTES MCGINTYI
879102	BREGMACEROTIDAE
87910201	BREGMACEROS
8791020101	BREGMACEROS ATLANTICUS
879103	GADIDAE
87910310	UROPHYCIS
8791031002	UROPHYCIS REGIUS
8791031004	UROPHYCIS CIRRATUS
8791031005	UROPHYCIS FLORIDANUS
87910311	PHYSICULUS
8791031101	PHYSICULUS FULVUS
879104	MERLUCIDAE
8791040101	MERLUCCIUS BILINEARIS
879105	STEINDACHNERIIDAE
8791050101	STEINDACHNERA ARGENTEA
879201	OPHIDIIDAE
87920103	LEPOPHIDIUM
8792010301	LEPOPHIDIUM GRAELLSI

NOAA CODE	NAME
88190201	FISTULARIA
8819020101	FISTULARIA TABACARIA
881904	CENTRISCIDAE
88190401	MACRORHAMPHOSUS
8819040101	MACRORHAMPHOSUS SCOLOPAX
882002	SYNGNATHIDAE
88200201	SYNGNATHUS
8820020105	SYNGNATHUS HILDEBRANDI
8820020106	SYNGNATHUS PELAGICUS
8820020107	SYNGNATHUS SPRINGERI
8820020108	SYNGNATHUS SP. (C. ALBIROSTRIS PREVIOUSLY C.E. DAW
8820020109	SYNGNATHUS ELUCENS
88200202	HIPPOCAMPUS
8820020201	HIPPOCAMPUS ERECTUS
882601	SCORPAENIDAE
88260103	NEOMERINTHE
8826010301	NEOMERINTHE HEMINGWAYI
88260104	PONTINUS
8826010401	PONTINUS LONGISPINIS
8826010402	PONTINUS RATHBUNI
88260105	SCORPAENA
8826010501	SCORPAENA AGASSIZI
8826010502	SCORPAENA BRASILIENSIS
8826010503	SCORPAENA CALCARATA
8826010504	SCORPAENA DISPAR
882602	TRIGLIDAE
88260201	PRIONOTUS
8826020103	PRIONOTUS SCITULUS
8826020104	PRIONOTUS TRIBULUS
8826020105	PRIONOTUS ALATUS
8826020106	PRIONOTUS MARTIS
8826020107	PRIONOTUS OPHRYAS
8826020108	PRIONOTUS PARALATUS
8826020109	PRIONOTUS ROSEUS
8826020110	PRIONOTUS RUBIO
8826020111	PRIONOTUS SALMONICOLOR
8826020112	PRIONOTUS STEARNSI
88260202	BELLATOR
8826020201	BELLATOR EGRETTA
8826020202	BELLATOR MILITARIS
8826020203	BELLATOR BRACHYCHIR
88260203	PERISTEDION
8826020301	PERISTEDION GRACILE
8826020302	PERISTEDION MINIATUM
883201	DACTYLOPTERIDAE
8832010101	DACTYLOPTERUS VOLITANS
883502	SERRANIDAE
88350203	CENTROPRISTIS
8835020302	CENTROPRISTIS OCYURUS
8835020303	CENTROPRISTIS PHILADELPHICA

NOAA CODE	NAME
8792010302	LEPOPHIDIUM JEANNAE
8792010303	LEPOPHIDIUM SP A. (L. STAURIPHORA OF C.R. ROBINS)
87920104	NEOBYTHYTES
8792010401	NEOBYTHYTES GILLI
87920105	OPHIDION
8792010501	OPHIDION BEANI
8792010502	OPHIDION GRAYI
8792010503	OPHIDION HOLBROOKI
8792010601	OTOPHIDIUM OMOSTIGMUM
8792010701	BROTULA BARBATA
879202	CARAPIDAE
87920201	CARAPUS
8792020101	CARAPUS BERMUDENSIS
87920202	ECHIODON
879401	MACROURIDAE
880301	EXOCOETIDAE
88030101	CYPSELURUS
8803010101	CYPSELURUS HETERURUS
8803010102	CYPSELURUS EXSILIENS
88030102	EXOCOETUS
88030103	HEMIRAMPHUS
8803010301	HEMIRAMPHUS BRASILIENSIS
88030104	HIRUNDICHTHYS
8803010401	HIRUNDICHTHYS RONDELETI
88030105	PAREXOCOETUS
8803010501	PAREXOCOETUS BRACHYPTERUS
88030106	PROGNICHTHYS
8803010601	PROGNICHTHYS GIBBIFRONS
880302	BELONIDAE
88030201	ABLENNES
8803020101	ABLENNES HIANS
880901	POLYMIXIIDAE
88090101	POLYMIXIA
8809010101	POLYMIXIA LOWEI
881008	HOLOCENTRIDAE
88100801	HOLOCENTRUS
8810080101	HOLOCENTRUS ASCENSIONIS
8810080102	HOLOCENTRUS BULLISI
88100802	OSTICHTHYS
8810080201	OSTICHTHYS TRACHYPOMUS
88100803	CORNIGER
8810080301	CORNIGER SPINOSUS
881103	ZEIDAE
88110301	ZENOPSIS
8811030101	ZENOPSIS OCELLATA
881106	CAPROIDAE
88110601	ANTIGONIA
8811060101	ANTIGONIA CAPROS
8811060102	ANTIGONIA COMBATIA
881902	FISTULARIIDAE

NOAA CODE	NAME
88350204	EPINEPHELUS
8835020402	EPINEPHELUS FLAVOLIMBATUS
8835020403	EPINEPHELUS MORIO
8835020404	EPINEPHELUS NIGRITUS
88350205	MYCTEROPERCA
8835020502	MYCTEROPERCA INTERSTITIALIS
8835020503	MYCTEROPERCA PHENAX
88350206	DIPLECTRUM
8835020601	DIPLECTRUM BIVITTATUM
8835020602	DIPLECTRUM FORMOSUM
88350207	HEMANTHIAS
8835020701	HEMANTHIAS VIVANUS
8835020702	HEMANTHIAS LEPTUS
88350208	HYPOPLECTRUS
8835020801	HYPOPLECTRUS PUELLA
88350209	PARANTHIAS
8835020901	PARANTHIAS FURCIFER
88350210	PIKEA
8835021001	PIKEA MEXICANA
88350211	SERRANICULUS
8835021101	SERRANICULUS PUMILIO
88350212	SERRANUS
8835021201	SERRANUS ATROBRANCHUS
8835021202	SERRANUS MAYTAGI
8835021203	SERRANUS NOTOSPILUS
8835021204	SERRANUS PHOEBE
883503	GRAMMISTIDAE
88350301	RYPTICUS
8835030101	RYPTICUS BISTRISPINUS
8835030102	RYPTICUS MACULATUS
883517	PRIACANTHIDAE
88351701	PRIACANTHUS
8835170101	PRIACANTHUS ARENATUS
8835170102	PRIACANTHUS CRUENTATUS
88351702	PRISTIGENYS
8835170201	PRISTIGENYS ALTA
883518	APOGONIDAE
88351801	APOGON
8835180101	APOGON AUROLINEATUS
8835180102	APOGON PSEUDOMACULATUS
8835180103	APOGON QUADRISQUAMATUS
8835180104	APOGON XENUS
88351802	ASTRAPOGON
8835180201	ASTRAPOGON ALUTUS
8835180202	ASTRAPOGON STELLATUS
88351803	PHAEOPTYX
8835180301	PHAEOPTYX PIGMENTARIA
88351804	SYNAGROPS
8835180401	SYNAGROPS BELLA
8835180402	SYNAGROPS SPINOSA

NOAA CODE	NAME
883522	BRANCHIOSTEGIDAE
88352201	CAULOLATILUS
8835220102	CAULOLATILUS CYANOPS
8835220103	CAULOLATILUS INTERMEDIUS
88352202	LOPHOLATILUS
8835220201	LOPHOLATILUS CHAMAELEONTICEPS
883526	RACHYCENTRIDAE
88352601	RACHYCENTRON
8835260101	RACHYCENTRON CANADUM
883527	ECHENEIDAE
88352701	REMORA
8835270102	REMORA OSTEOCHIR
88352702	ECHENEIS
8835270201	ECHENEIS NAUCRATES
8835270202	ECHENEIS NEUCRATOIDES
883528	CARANGIDAE
88352801	TRACHURUS
8835280102	TRACHURUS LATHAMI
88352803	CARANX
8835280301	CARANX BARTHOLOMAEI
8835280303	CARANX HIPPOS
8835280305	CARANX CHRYSOS
8835280306	CARANX RUBER
88352804	CHLOROSCOMBRUS
8835280401	CHLOROSCOMBRUS CHRYSURUS
88352806	SELAR
8835280601	SELAR CRUMENOPTHALMUS
88352808	SERIOLA
8835280801	SERIOLA DUMERILI
8835280802	SERIOLA FASCIATA
8835280803	SERIOLA RIVOLIANA
88352810	VOMER
8835281001	VOMER SETIPINNIS
88352812	DECAPTERUS
8835281201	DECAPTERUS PUNCTATUS
883529	CORYPHAENIDAE
88352901	CORYPHAENA
8835290101	CORYPHAENA HIPPURUS
8835290102	CORYPHAENA EQUISETIS
883536	LUTJANIDAE
88353601	LUTJANUS
8835360103	LUTJANUS CAMPECHANUS
8835360104	LUTJANUS SYNAGRIS
88353602	PRISTIPOMOIDES
8835360201	PRISTIPOMOIDES AQUILONARIS
88353603	RHOMBOPLITES
8835360301	RHOMBOPLITES AURORUBENS
883539	GERREIDAE
88353901	EUCINOSTOMUS
8835390101	EUCINOSTOMUS ARGENTEUS

NOAA CODE	NAME
8835390102	EUCINOSTOMUS GULA
883540	POMADASYIDAE
88354001	HAEMULON
8835400101	HAEMULON AUROLINEATUM
8835400201	ORTHOPRISTIS CHRYSOPTERA
883543	SPARIDAE
88354301	STENOTOMUS
8835430102	STENOTOMUS CAPRINUS
88354302	LAGODON
8835430201	LAGODON RHOMBOIDES
88354305	CALAMUS
8835430501	CALAMUS BAJONADO
8835430502	CALAMUS CALAMUS
8835430503	CALAMUS LEUCOSTEUS
8835430504	CALAMUS NODOSUS
8835430505	CALAMUS PENNA
8835430506	CALAMUS PRORIDENS
88354306	PAGRUS
8835430601	PAGRUS PAGRUS
883544	SCIAENIDAE
88354403	BAIRDIELLA
8835440301	BAIRDIELLA CHRYSURA
8835440401	LEIOSTOMUS XANTHURUS
8835440701	MICROPOGON UNDULATUS
88354412	EQUETUS
8835441201	EQUETUS ACUMINATUS
8835441202	EQUETUS LANCEOLATUS
8835441203	EQUETUS UMBROSUS
8835441204	EQUETUS SP
883545	MULLIDAE
88354501	MULLUS
8835450101	MULLUS AURATUS
88354502	PSEUDUPENEUS
8835450201	PSEUDUPENEUS MACULATUS
8835520101	CHAETODIPTERUS FABER
883555	CHAETODONTIDAE
88355501	CHAETODON
8835550101	CHAETODON OCELLATUS
8835550102	CHAETODON AYA
8835550103	CHAETODON SEDENTARIUS
88355502	HOLACANTHUS
8835550201	HOLACANTHUS BERMUDENSIS
8835550202	HOLACANTHUS CILIARIS
8835550301	POMACANTHUS ARCUATUS
883562	POMACENTRIDAE
88356201	CHROMIS
8835620101	CHROMIS ENCHRYSURUS
8835620102	CHROMIS INSOLATUS
8835620103	CHROMIS SCOTTI
88356202	POMACENTRUS

NOAA CODE	NAME
8835620201	POMACENTRUS VARIABILIS
883701	SPHYRAENIDAE
88370101	SPHYRAENA
8837010103	SPHYRAENA GUACHANCHO
8837010104	SPHYRAENA BARRACUDA
883801	POLYNEMIDAE
88380101	POLYDACTYLUS
8838010101	POLYDACTYLUS OCTONEMUS
883901	LABRIDAE
88390103	DECODON
8839010301	DECODON PUELLARIS
88390104	HALICHOERES
8839010401	HALICHOERES BIVITTATUS
8839010402	HALICHOERES CAUDALIS
8839010403	HALICHOERES MACULIPINNA
8839010404	HALICHOERES BATHYPHILUS
88390105	HEMIPTERONOTUS
8839010501	HEMIPTERONOTUS NOVACULA
88390106	THALASSOMA
8839010601	THALASSOMA BIFASCIATUM
883903	SCARIDAE
88390301	SCARUS
8839030102	SCARUS TAENIOPTERUS
88390302	NICHOLSINA
8839030201	NICHOLSINA USTA
88390303	SPARISOMA
8839030301	SPARISOMA ATOMARIUM
8839030302	SPARISOMA AUROFRENATUM
884002	OPISTOGNATHIDAE
88400201	LONCHOPISTHUS
8840020101	LONCHOPISTHUS LINDNERI
88400202	OPISTOGNATHUS
8840020201	OPISTOGNATHUS WHITEHURSTI
8840020202	OPISTOGNATHUS MELACHASME
884007	PERCOPHIDIDAE
88400701	BEMBROPS
8840070101	BEMBROPS ANATIROSTRIS
8840070102	BEMBROPS GOBIOIDES
884013	DACTYLOSCOPIDAE
88401301	GILLELLUS
884014	URANOSCOPIDAE
88401402	KATHETOSTOMA
8840140201	KATHETOSTOMA ALBIGUTTA
884201	BLENNIIDAE
88420101	BLENNIUS
8842010101	BLENNIUS MARMOREUS
8842010401	HYPLEUROCHILUS BERMUDENSIS
884209	CLINIDAE
88420902	LABRISOMUS
8842090201	LABRISOMUS NUCHIPINNIS

NOAA CODE	NAME
8842090202	LABRISOMUS GUPPYI
8842090203	LABRISOMUS HAITIENSIS
88420903	STARKSIA
8842090301	STARKSIA OCELLATA
884210	CHAENOPSIDAE
88421001	CHAENOPSIS
88421002	EMBLEMARIA
8842100201	EMBLEMARIA ATLANTICA
8842100202	EMBLEMARIA PANDIONIS
8842100203	EMBLEMARIA PIRATULA
884601	CALLIONYMIDAE
88460101	CALLIONYMUS
8846010101	CALLIONYMUS AGASSIZI
8846010102	CALLIONYMUS BAIRDI
8846010103	CALLIONYMUS PAUCIRADIATUS
884701	GOBIIDAE
88470102	CORYPHOPTERUS
8847010202	CORYPHOPTERUS GLAUCOFRAENUM
8847010203	CORYPHOPTERUS PUNCTIPECTOPHORUS
88470105	GOBIONELLUS
88470106	GOBIOSOMA
8847010604	GOBIOSOMA OCEANOPS
8847010605	GOBIOSOMA XANTHIPRORA
88470107	MICROGOBIUS
8847010703	MICROGOBIUS CARRI
88470108	BOLLMANNIA
8847010801	BOLLMANNIA COMMUNIS
88470109	EVERMANNICHTHYS
8847010901	EVERMANNICHTHYS SPONGICOLA
88470110	GOBULUS
8847011001	GOBULUS MYERSI
88470111	IOGLOSSUS
8847011101	IOGLOSSUS CALLIURUS
88470112	LYTHRYPNUS
8847011201	LYTHRYPNUS ELASSON
8847011202	LYTHRYPNUS NESIOTES
8847011203	LYTHRYPNUS SPILUS
88470113	PALATOGOBIUS
8847011301	PALATOGOBIUS PARADOXUS
88470114	RISOR
8847011401	RISOR RUBER
88470115	CHRIOLEPIS
884901	ACANTHURIDAE
88490101	ACANTHURUS
8849010101	ACANTHURUS CHIRURGUS
885002	TRICHIURIDAE
88500202	TRICHIURUS
8850020201	TRICHIURUS LEPTURUS
885003	SCOMBRIDAE
8850030301	SCOMBER JAPONICUS

NOAA CODE	NAME
88500306	EPINNULA
8850030601	EPINNULA ORIENTALIS
885103	STROMATEIDAE
88510301	PEPRILUS
8851030104	PEPRILUS ALEPIDOTUS
8851030105	PEPRILUS BURTI
88510302	ARIOMMA
8851030201	ARIOMMA BONDI
8851030202	ARIOMMA REGULUS
88510303	CUBICEPS
8851030301	CUBICEPS ATHENAE
88510304	NOMEUS
8851030401	NOMEUS GRONOVII
88510305	PSENES
8851030501	PSENES PELLUCIDUS
885703	BOTHIDAE
88570301	CITHARICHTHYS
8857030103	CITHARICHTHYS CORNUTUS
8857030104	CITHARICHTHYS DINOCEROS
8857030105	CITHARICHTHYS GYMNORHINUS
8857030106	CITHARICHTHYS MACROPS
8857030107	CITHARICHTHYS SPILOPTERUS
88570302	ETROPUS
8857030201	ETROPUS CROSSOTUS
8857030203	ETROPUS RIMOSUS
88570303	PARALICHTHYS
8857030302	PARALICHTHYS ALBIGUTTA
8857030303	PARALICHTHYS LETHOSTIGMA
8857030304	PARALICHTHYS SQUAMILENTUS
88570305	ANCYLOPSETTA
8857030501	ANCYLOPSETTA DILECTA
8857030502	ANCYLOPSETTA QUADROCELLATA
88570306	BOTHUS
8857030601	BOTHUS OCELLATUS
8857030602	BOTHUS ROBINSI
88570307	CYCLOPSETTA
8857030701	CYCLOPSETTA CHITTENDENI
8857030702	CYCLOPSETTA FIMBRIATA
88570308	ENGYOPHRYS
8857030801	ENGYOPHRYS SENTA
88570309	GASTROPSETTA
8857030901	GASTROPSETTA FRONTALIS
88570310	MONOLENE
8857031001	MONOLENE SESSILICAUDA
8857031002	MONOLENE ANTILLARUM
88570311	SYACIUM
8857031101	SYACIUM GUNTERI
8857031102	SYACIUM PAPILLOSUM
8857031103	SYACIUM MICRURUM
88570312	TRICHOPSETTA

NOAA CODE	NAME
8857031201	TRICHOPSETTA VENTRALIS
885704	PLEURONECTIDAE
88570409	LIMANDA
8857040904	LIMANDA BEANI
885801	SOLEIDAE
88580102	ACHIRUS
8858010201	ACHIRUS LINEATUS
88580103	GYMNACHIRUS
8858010301	GYMNACHIRUS MELAS
8858010302	GYMNACHIRUS TEXAE
885802	CYNOGLOSSIDAE
88580201	SYMPHURUS
8858020101	SYMPHURUS PLAGIUSA
8858020102	SYMPHURUS CIVITATUS
8858020103	SYMPHURUS DIOMEDIANUS
8858020104	SYMPHURUS MINOR
8858020105	SYMPHURUS PARVUS
8858020106	SYMPHURUS PIGER
8858020107	SYMPHURUS PUSILLUS
8858020108	SYMPHURUS UROSPILUS
886002	BALISTIDAE
88600201	ALUTERUS
8860020101	ALUTERUS SCHOEPFI
8860020102	ALUTERUS HUEDELOTI
8860020103	ALUTERUS SCRIPTUS
88600202	BALISTES
8860020201	BALISTES CAPRISCUS
88600204	CANTHIDERMIS
8860020401	CANTHIDERMIS MACULATUS
8860020402	CANTHIDERMIS SUFFLAMEN
88600205	MELICHTHYS
8860020501	MELICHTHYS NIGER
88600206	MONACANTHUS
8860020601	MONACANTHUS CILIATUS
8860020602	MONACANTHUS HISPIDUS
88600207	XANTHICHTHYS
8860020701	XANTHICHTHYS RINGENS
886003	OSTRACIIDAE (= OSTRACIONTIDAE)
88600301	LACTOPHRYS
8860030102	LACTOPHRYS QUADRICORNIS
886004	TRIACANTHODIDAE
88600401	PARAHOLLARDIA
8860040101	PARAHOLLARDIA LINEATA
886101	TETRAODONTIDAE
88610101	LAGOCEPHALUS
8861010101	LAGOCEPHALUS LAEVIGATUS
88610102	SPHOEROIDES
8861010203	SPHOEROIDES DORSALIS
8861010204	SPHOEROIDES NEPHELUS
8861010205	SPHOEROIDES PACHYGASTER

NOAA CODE	NAME
8861010206	SPHOEROIDES PARVUS
8861010207	SPHOEROIDES SPENGLERI
88610103	CANTHIGASTER
8861010301	CANTHIGASTER ROSTRATA
886103	DIODONTIDAE
88610301	CHILOMYCTERUS
8861030101	CHILOMYCTERUS SCHOEPFI
88610302	DIODON
8861030201	DIODON HYSTRIX

TOTAL NUMBER OF TAXA 609

VOLUME II

CHAPTER 20

PHYSICAL OCEANOGRAPHY

MR. LEE FAUSAK
DAMES & MOORE
CONTRACT NO. AA550-CT7-34

SALINITY, TEMPERATURE, AND LIGHT PENETRATION OBSERVATIONS ON THE MAFLA OUTER CONTINENTAL SHELF

L.E. Fausak
DAMES & MOORE
Los Angeles, California

Final Report

1977-1978 MAFLA Benchmark Survey
Contract A550-CT7-34

to

U.S. Department of Interior
Bureau of Land Management

Dames & Moore Reference No. 8699-008-88

Draft Submitted 13 October 1978

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ABSTRACT

Depth-dependent measurements of salinity, temperature, and light penetration have been taken at 57 stations throughout the MAFLA OCS during four cruises in the 1977/78 study. Salinity and temperature data obtained during the 1975/76 study period have also been analyzed. The data were collected and analyzed in support of biological and chemical baseline studies for the U.S. Department of Interior, Bureau of Land Management under Contract AA550-CT7-34.

The results of the study augment and support earlier investigations which have shown seasonal and geographic variations in distribution patterns. It was found that variations in temperature, salinity, and light penetration, on both time and spatial scales, are greater on the Mississippi-Alabama shelf than on the west Florida shelf. Offshore variability (i.e., near the shelf edge) can be related to broad circulation patterns in the eastern Gulf of Mexico; variation on the central and inshore portions of the shelf appear to be functions of seasonal climatic influences and poorly-defined shelf circulation patterns.

INTRODUCTION

PURPOSE AND SCOPE

This study was undertaken at the request of the U.S. Department of Interior, Bureau of Land Management (BLM), to satisfy a requirement for environmental data in potential petroleum lease areas of the eastern Gulf of Mexico outer continental shelf (OCS). The objective of the BLM study program was to develop quantitative, statistically-supportable data in order to establish ranges of spatial and temporal variation for key parameters prior to oil and gas development, so that changes induced by that development could be detected.

The environmental benchmark studies offshore of Mississippi, Alabama, and Florida (collectively termed the MAFLA OCS area) were carried out by Dames & Moore under authority of BLM contract Number AA550-CT7-34. Data collection and analysis activities occurred between July 1977 and October 1978, and were a continuation of three prior years of study that were directed by the Florida State University System Institute of Oceanography (SUSIO).

The objective of the study element that forms the subject of this chapter, namely salinity and temperature data collection and analyses and light penetration studies, was to provide information required by, and in support of, the biological and chemical study elements. As such, the thrust of the study was the collection, correction, and display of temperature, salinity, and light peneration data, and the dissemination of the reduced data to other principal investigators.

DESCRIPTION OF THE STUDY

The study area lies over the outer continental shelf of the eastern Gulf of Mexico between the 200 m isobath and the shorelines of Mississippi, Alabama, and western Florida (Figure 236). A total of 57 stations were occupied at various times throughout the study period; with the exception of six supplemental stations, the sampling locations were arrayed along eight transects.

Four cruises were undertaken during the 1977/78 MAFLA program. The first (DM I) was at sea during August-September 1977 and collected data on benthic biology, geology, and chemistry. DM II was a combined benthic and water column cruise during October-November 1977. DM III was a water column cruise run concurrently with DM IV, a benthic effort, during February 1978.

OCEANOGRAPHIC SETTING

The Gulf of Mexico is a restricted basin with connections to the Caribbean Sea through the Yucatan Strait and to the Atlantic Ocean through the Straits of Florida (Figure 237). Maximum depths within the Gulf exceed 3,600 m, but the exchange of deep waters with adjacent seas is restricted by sill depths of about 2,000 m for the Yucatan Strait, and less than 900 for the Straits of Florida. Broad continental shelves are found on the northern

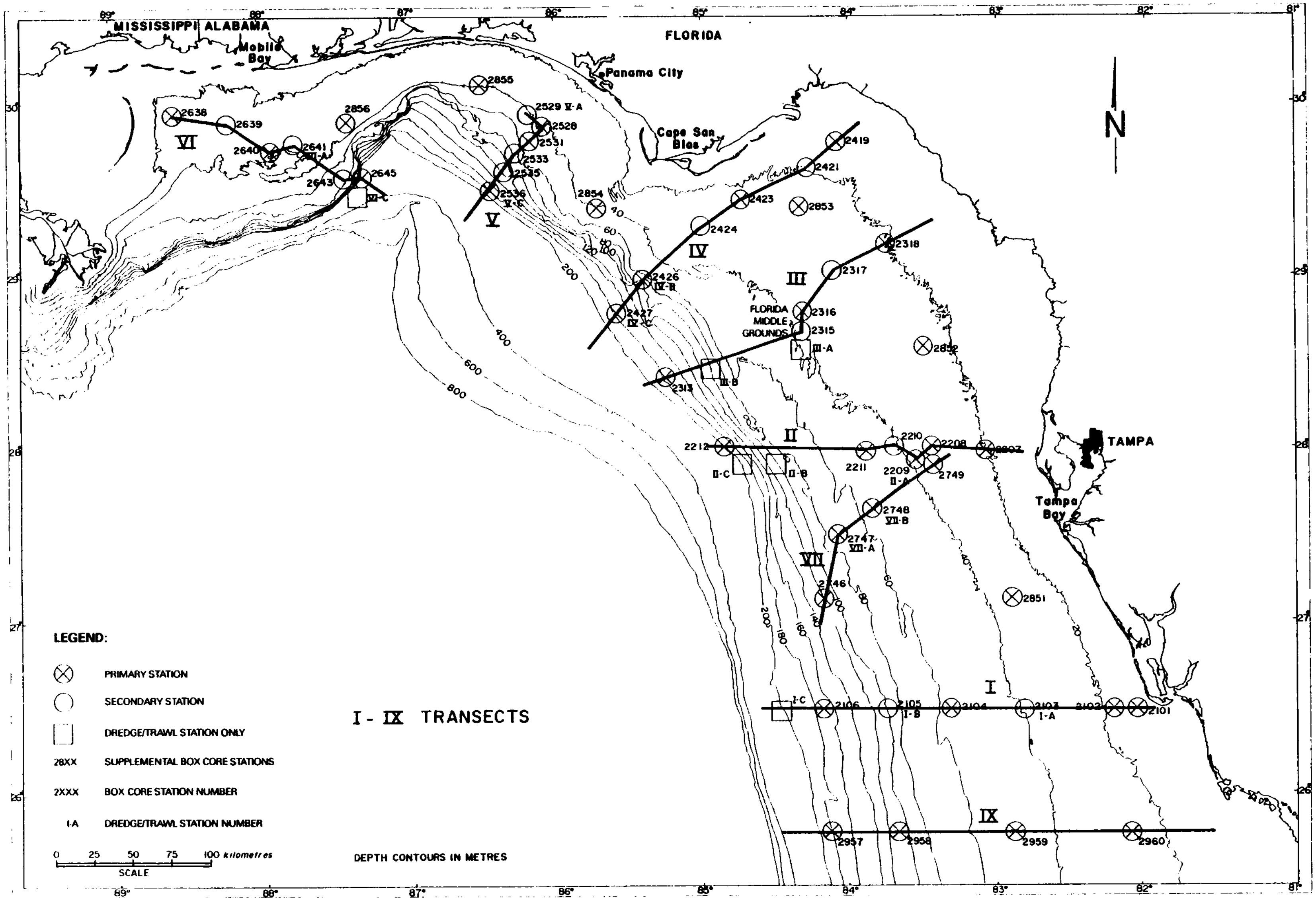


FIGURE 236

BLM 1977/1978 MAFLA SURVEY STATION AND TRANSECT LOCATIONS

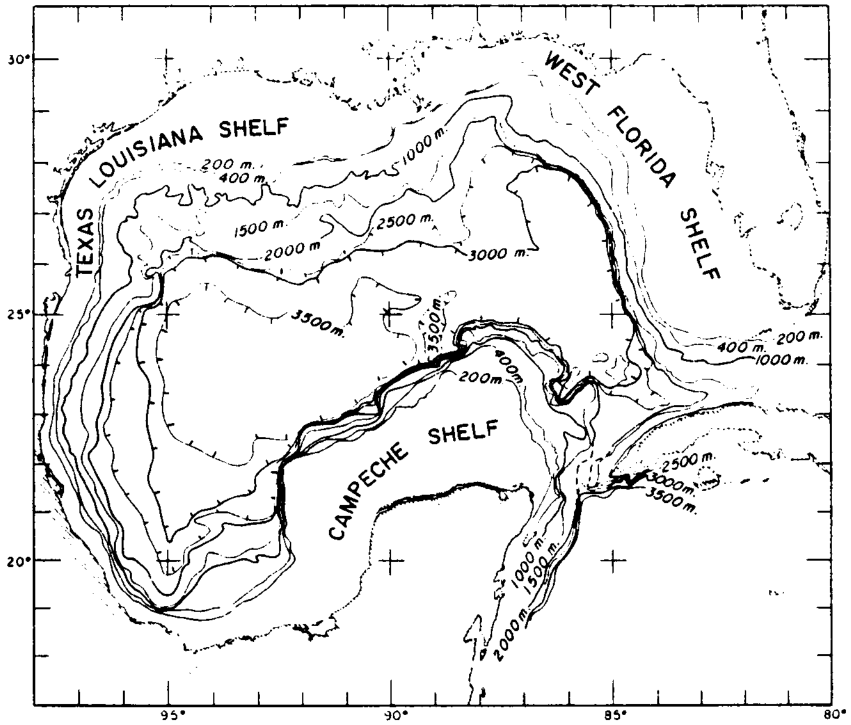


FIGURE 237

BATHYMETRY OF THE GULF OF MEXICO

(AFTER NOWLIN, 1971)

and western sides of the Yucatan Peninsula, and along the west Florida coastline. The restricted channels and broad shelf areas profoundly affect water mass characteristics and circulation patterns through channelization and friction with the seafloor.

Descriptions of water mass characteristics have been made by Nowlin (1971, 1972), Jones et al. (1973), Caruthers (1972), and Ichiye (1962). Nowlin (1971) presented vertical profiles of temperature, salinity, and oxygen concentrations (Figure 238) which are representative of the Gulf waters. The water strata are identified by characteristic extreme values or strong gradients of one or more of the parameters. For example, the Subtropical Underwater (SUW) is typified by a relative salinity maximum, while Antarctic Intermediate Water is identified by a salinity minimum. The Surface Mixed Layer shows relatively constant temperature and salinity values lying immediately above very sharp gradients of those parameters. Because the MAFLA study area, which is the subject of this report, lies inshore of the 180 m isobath, the only water masses we expected to encounter were the Surface Mixed Layer and the SUW.

The dominant circulation feature of the Gulf of Mexico is the anticyclonic Loop Current, which enters the basin from the Caribbean Sea through the Yucatan Strait, and exits to the Atlantic Ocean through the Florida Strait where it joins and forms a major volumetric input to the Gulf Stream. The existence of a clockwise current in the eastern Gulf had been known for decades based on dynamic computations and by the drift of vessels sailing through the Gulf (Chew, 1955; Austin, 1955, Leipper, 1954), and had been shown on U.S. Navy Hydrographic Office pilot charts. The current was named and studied more intensively beginning in the late 1960's (Leipper, 1867, Nowlin, 1971, 1972; Leipper, Cochrane, and Hewitt, 1972; Nowlin and Hubertz, 1972; Hubertz, Garcia, and Reid, 1972). Leipper (1967 and 1970) used a temperature data set collected on eight cruises over a 16-month period to define seasonal variation of thermal stratification, and by so doing, was also able to define seasonal changes in Loop Current patterns. He found a progressive northward intrusion of the Loop Current in spring and early summer that extended up to the continental shelf off the Mississippi River, and the subsequent formation, detachment, and westward immigration of a separate eddy. Those general findings have been supported by more recent investigations (Morrison and Nowlin, 1977), as well as modified by the observation that northward intrusion and eddy formation often occurred earlier in the year and with much greater temporal variability than had previously been reported (Maul, 1977; Molinari, Baig, Behringer, Maul, and Legeckis, 1977; Behringer, Molinari, and Festa, 1977). The most recent studies have included satellite and other remote sensing data of sea surface temperatures as indicators of Loop Current position.

The Loop Current has been defined by Molinari et al. (1975) as waters in the eastern Gulf of Mexico having salinities greater than 36.5 $^{o}/oo$. The existence and position of the Loop Current has also been seen through studies of plankton and suspended partial concentrations in surface waters (Jones et al., 1973; Carder and Schlemmer, 1973).

The Loop Current can attain speeds in excess of 250 cm · sec^{-1} in the Yucatan Strait (Eleuterius, 1974) although speeds of 10 to 12 cm · sec^{-1}

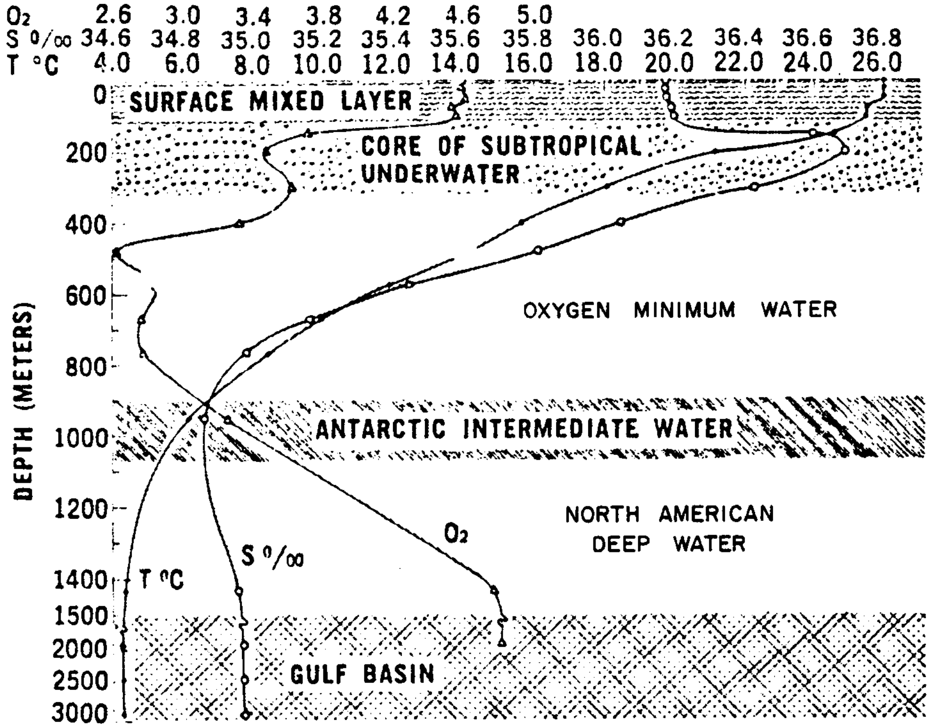


FIGURE 238

WATER MASS IDENTIFICATION IN THE GULF OF MEXICO THROUGH TEMPERATURE, SALINITY, AND OXYGEN PROFILES

(AFTER NOWLIN, 1971)

are more representative along the southern and western edges of the MAFLA OCS (Mooers and Price, 1975). The influence of the current has been reported (Ichiye et al., 1973) to extend to a depth of over 500 m.

Sea surface temperatures show well-established patterns of seasonal variability (Leipper, 1954; U.S. Naval Oceanographic Office, 1967). The temperature distribution pattern is primarily meridional throughout the winter months, changing to nearly isothermal conditions by late spring which persist through the fall. A northward deflection of the isotherms is generally apparent north of the Yucatan Strait where the Yucatan Current enters the Gulf and becomes the Loop Current. Surface temperature patterns are highly variable, particularly in nearshore waters where wind wave mixing and local weather effects become relatively more important. Surface temperatures ranging from about 14°C to 33°C have been reported in the MAFLA region (U.S. Naval Oceanographic Office, 1967), with the highest temperatures occurring in the southern part of the region and during late summer months.

Surface salinities show less variation than do temperature values; isohalines on the outer continental shelf generally follow the isobaths (U.S. Naval Oceanographic Office, 1967, Nowlin, 1971), with lower salinities in the north and along the coastline. Salinity values vary from 25 $^{o}/oo$ or less near the mouth of the Mississippi River to about 37 $^{o}/oo$ off southern Florida (Ichiye et al., 1973). The isohalines, like the isotherms, show a northward deflection in the path of the northerly Yucatan/Loop Current.

METHODS AND MATERIALS

STD PROFILING

STD profiling was done on the fall combined benthic/water column cruise (cruise DM II) and on the winter water column cruise (cruise DM III). During DM II, STD profiles were taken at all box-core and dredge/trawl stations, as well as at four abbreviated time-series stations. STD profiles were taken at 2-hour intervals for five days each at four time-series stations during DM III.

Instrumentation and Field Deployment

Cruise DM II

A model Mark III CTD system (serial number 1295) manufactured by Neil Brown Instrument Systems, Inc., was used during cruise DM II. Specifications for the CTD are given in Table 90. The instrument is termed a CTD because it displays uncorrected and unconverted seawater conductivity rather than salinity. The CTD profiler was made available to Dames & Moore through the courtesy of the Bureau of Land Management and the Virginia Institute of Marine Science. The instrument was calibrated by the manufacturer immediately prior to cruise DM II.

The NBIS CTD system consists of an underwater unit containing the four-electrode conductivity cell, thermistor, platinum resistance thermometer, pressure transducer, amplifier, and digitizer, and a deck unit with

TABLE 90

Specifications

Mark III Digital CTD System
Neil Brown Instrument Systems, Inc.

Sensor response:	30 milliseconds
Scan rate:	32 milliseconds
Spatial resolution:	1 centimetre

Measurement Range and Accuracy:

Range	Accuracy	Resolution
Pressure		
0-320 decibar		
0-650 decibar		
0-1,600 decibar	0.1% of full scale	0.0015% of full scale
0-3,200 decibar		
0-6,500 decibar		
Temperature		
-32 to +32C°	0.005C°	0.0005C°
Conductivity		
1-65 mmhos	0.005 mmhos	0.001 mmhos

Power Requirements: 105-125 VAC, 50-400 Hz, 200 watts

Underwater Unit:

Weight in air:	43.1 kg
Weight in water:	32.7 kg
Material:	17-4 PH stainless steel
Maximum safe working pressure:	7,500 decibars

Shipboard Unit:

Weight:	11.3 kg
Material:	Anodized aluminum alloy

digital displays and a digital-to-analog converter. The underwater and deck units are connected by an electromechanical cable spooled onto an electrically-driven winch.

The CTD deck display unit was interfaced with an Esterline Angus X-YY' plotter, which provided visual profiles of temperatures and conductivity. In addition to the depth-dependent plots, manual recordings of temperature, conductivity, and pressure were taken at the surface, bottom, and at a variable number of intermediate depths. These manually-recorded values were used in conjunction with plotter scale factors to define starting and ending points of the traces.

Cruise DM III

A Plessey Environmental Systems model 9060 STD (serial number 5939) was used to obtain depth-dependent profiles of salinity and temperature on cruise DM III. This instrument is a battery-operated, self-contained system that records on a cylindrical X_1X_2Y graphic plotter. Specifications for this instrument are given in Table 91. It is attached to a nonelectrical cable lowered and retrieved with standard hydrographic winches. The unit was factory calibrated prior to cruise DM III.

The Plessey STD was prepared in a portable laboratory on deck, then carried to the fantail and attached to a hydrographic wire. A Niskin water sampling bottle with reversing thermometer frame (used for calibration purposes and described below) was attached to the hydrographic cable immediately above the STD unit and one metre above the STD sensors. The STD was then lowered into the water and allowed to equilibrate for five minutes, after which it was lowered to within approximately three metres of the bottom. A second Niskin bottle was attached to the wire, and the array was lowered at a rate of 20 to 25 m $\min^{-1}$ to nominally within one metre of the bottom, and allowed to equilibrate for a minimum of five minutes. No additional cable was payed out during the equilibration period to allow for ship drift and resultant lifting of the STD off the bottom. After a messenger was sent down the cable to trip the water sampling bottles and reversing thermometers, the array was retrieved at a rate of 20 to 25 m $\cdot$ $\min^{-1}$. The bottles were removed, the STD unit was detached and washed with fresh water, and returned to the onboard laboratory for removal of the chart.

Reduction of Profiles

Cruise DM II

The profiles obtained through use of the NBIS CTD on Cruise DM II were digitized using a Tektronix semiautomatic digitizing system consisting of a digitizing table, an interactive graphics terminal, and a magnetic tape storage unit. The profiles were prepared by marking inflection points on the profiles between which the trace is assumed to be linear, and then entering the surface and bottom temperature and conductivity values, as well as the calibration temperatures from the reversing thermometers and calibration salinities resulting from laboratory analysis of water samples. After the inflection points were digitized with reference to the raw temperature

TABLE 91

Specifications

Model 9060 STD Profiling System (S/N 5939)
Plessey Environmental System

SALINITY

Range	Accuracy	Resolution
30-40 ppt	± 0.05 ppt	0.02 ppt

Temperature Compensation Time Constant: 350 milliseconds or less
Recorder Slew Rate: 3 ppt/sec

TEMPERATURE

Range	Accuracy	Resolution
-2° to +35° in 2 overlapping and automatically switched ranges	± 1° C	0.05°C

Temperature Sensor Time Constant: 350 milliseconds or less
Recorder Slew Rate: 6°C/sec

DEPTH

Range	Accuracy	Resolution
0-300m	± 0.25% of full scale	± 0.1% of full scale

RECORDER

Type: Cylindrical drum plotter with two overlapping styli
Recording Format: Analog X_1X_1Y Plot
Chart Size: 6-1/2 inches x 9-1/2 inches (one frame) x 100 feet long (100 charts/roll)
Chart Capacity: 100 frames
Sampling Rate: Continuous
Recording Rate: Continuous. Recorder responds to a step change input in less than 3 seconds for full-scale travel of styli; 5 seconds for full rotation of drum

GENERAL FEATURES

Pressure Case Material: Aluminum alloy for operation to 2,000 metres
Size: 32 inches long overall; 6-inch-diameter barrel with 20-inch guard frame
Weight: Aluminum alloy case: 53 lbs in air; 21 lbs in water
Access to Chart: Through double o-ring sealed-end cap
Power: Self-contained batteries; size AA rechargeable nickle-cadmium; 10 batteries supplied with unit unless other type specified

intervals was generated. Those values were then used to calculate salinity as a function of temperature, conductivity, and pressure; the program used to compute salinity was based on Fofonoff et al. (1974). Once the salinity was computed at three-metre depth intervals, the temperature and derived salinity curves were corrected to correspond to the surface temperature and salinity calibration values.

The final array of temperature, salinity, and sigma-t values at three-metre intervals was displayed as a computer printout and as depth-dependent profiles. The original profiles derived from the XYY' plotter had little value as visual displays because of (1) varying temperature, conductivity, and depth scales; (2) scale jumps between parts of the same trace; and (3) uncompensated conductivity traces rather than salinity traces.

Cruise DM III

The STD traces from cruise DM III were considerably easier to reduce than those from cruise DM II because the former were of smaller size, all at the same scales, had less detail, and read in salinity rather than uncompensated conductivity. The accuracy and resolution, on the other hand, was less than that provided by the NBIS CTD system. The profiles were digitized at inflection points using the system described earlier, were corrected for surface temperature and salinity calibration values, and were interpolated onto an array with either two- or three-metre depth intervals. The 2 m interval was used at Station 2639 in order to more adequately define the extremely steep gradients at that location. The temperature and salinity were used to derive sigma-t values, and were displayed as were the data from Cruise DM II.

TEMPERATURE MEASUREMENTS

Temperature measurements were taken at the surface and bottom of the water column at all stations during each of the four cruises. The general arrangement of thermometers consisted of a pair of protected reversing thermometers (manufactured by Watanabe Keiki Mfg. Co., Ltd.) contained in reversing thermometer frames attached to water sampling bottles. The thermometers were lowered, allowed to equilibrate for at least five minutes, then tripped and retrieved. The water sampling bottles were placed in a rack in a sheltered location, where the thermometers were allowed to equilibrate to ambient temperature before being read; a second reading followed the first by a 10 to 15 min. interval.

Reversing thermometer correction factors were determined using the following formula, as given in U.S. Naval Oceanographic Office (1968):

$$C_p = \frac{(T'-t)(T'+V_o)}{k-1/2(T'-t)-(T'V_o)}$$

where: C_p = correction factor
T' = main thermometer reading
t = auxiliary thermometer reading
V_o = volume of mercury at zero degrees Celcius (constant for any given thermometer)

k = glass-mercury coefficient of expansion constant
(= 6300 for the Watanabe Keiki thermometers used here)

The main and auxiliary thermometer readings were corrected according to the individual calibration curves supplied by the manufacturer for each thermometer prior to being used in the formula given above. The four corrected readings for surface and bottom temperatures were averaged to obtain the final temperature values entered into the data file and used for STD calibration on cruises DM II and DM III. Clearly aberrant values were discarded.

SALINITY DETERMINATIONS

As with water temperatures, surface and bottom salinities were determined at all stations during the four cruises. Water samples were collected using standard hydrocast methods and Niskin 1.7 ℓ Niskin water sampling bottles. The samples were withdrawn from the sampling bottles and placed in clean salinity sample bottles that were rinsed three times with the sample waters. The sample bottles were completely filled, tightly capped, labeled, and returned to the chemistry laboratory of the Department of Marine Science, University of South Florida, St. Petersburg, Florida for analysis.

The salinity values were determined with an AUTOSAL model 8400 laboratory salinometer. The instrument measures the conductivity ratio between a sample of seawater and 35 $^{o}/oo$ water by continuously comparing the seawater sample conductance with an integral reference conductance, with an accuracy of ±0.003 $^{o}/oo$ equivalent salinity. The measurement of the ratio of conductivity of the sample to that of standard Copenhagen water is indicated by a digital display of six figures.

The formula for the calculation of salinity from the conductivity ratio is:

$$\begin{aligned} S\ ^{o}/oo = & -0.08996 + 28.8567R + 12.1888R^2 \\ & -10.61869R^3 + 5.98624\ R^4 \\ & -1.32311\ R^5 + R(R-1)(0.442\times10^{-1}T \\ & -0.046 \times 10^{-3}T^2 - 4\times10^{-3}RT) \end{aligned}$$

where: $R = \text{conductivity ratio} = \dfrac{\text{conductivity of sample water}}{\text{conductivity of 35 ppt water}}$

T = measuring temperature (selected)

DENSITY DERIVATIONS

Given corrected pairs of temperature and salinity values, the density of the sea waters, expressed as sigma-t, were computed using the following algorithm based on Knudsen (1901) and Cox, McCartney, and Culkin (1970):

$$
\begin{aligned}
\sigma_t = {} & 8.00969062 \times 10^{-2} + 5.88194023 \times 10^{-2}T \\
& +7.97018644 \times 10^{-1}S - 8.11465413 \times 10^{-3}T^2 \\
& -3.25310441 \times 10^{-3}ST + 1.31710842 \times 10^{-4}S^2 \\
& +4.76600414 \times 10^{-5}T^3 + 3.89187483 \times 10^{-5}ST^2 \\
& +2.8797.530 \times 10^{-6}S^2T - 6.11831499 \times 10^{-8}S^3
\end{aligned}
$$

where: S = salinity in parts per thousand (g/kg)

T = temperature in degrees Celcius

LIGHT PENETRATION MEASUREMENTS

A Kahlisico model 268WA310 Radiometric Underwater Irradiameter was used to obtain light penetration measurements, as a function of depth, on cruises DM II and DM III. The instrument system consists of a deck control unit with internal batteries, electronic controls, and indicating meter (reading out in $\mu W \cdot cm^{-2}$), an underwater photocell on a metal frame for measuring sunlight penetration through the water, a gimballed ambient photocell for measuring ambient sunlight on deck, and connecting cables.

The underwater unit was lowered by hand over the sunlit side of the vessel; comparative readings of ambient and underwater illuminance were manually recorded at five-metre intervals.

RESULTS AND DISCUSSIONS

The data collection effort was composed of two parts; first, four cruises, each of three to four weeks duration, undertaken as part of the 1977/78 MAFLA studies program, and secondly, assimilation of the data collected during the summer 1976 field effort under the previous Contract 08550-CTS-30 between BLM and SUSIO. Dates and functional objectives of the four Dames & Moore cruises were given earlier.

All surface and bottom temperature and salinity data, and STD and photometer profiles collected during the four Dames & Moore cruises are inventoried in the following table:

	Cruise DM I	Cruise DM II	Cruise DM III	Cruise DM IV	Σ
Surface T	53	79	236	62	430
Bottom T	53	79	236	62	430
Surface S	53	79	236	62	430
Bottom S	53	79	236	62	430
STD profiles	0	78	237	0	315
Photometer profiles	0	16	36	0	52

The STD and supporting data collected during the summer 1976 SUSIO cruise were received by Dames & Moore in only partially reduced form, and at a late enough time that did not allow its incorporation in this report. Data from earlier cruises, however, that had been reduced and entered into the computer data file, namely from the June-July 1975, September-October 1975, and January-February 1976 cruises, have been reviewed as part of our current effort, and will be discussed herein. That data set consists of 23 STD profiles from June-July 1975, 44 profiles from September-October 1975, and 45 profiles from January-February 1976.

The 1977/78 data were reduced, as described earlier in the Methods and Materials section, and were subsequently displayed on several basic types of visuals for comparative purposes. The surface and bottom temperature and salinity data (i.e., that collected by standard hydrographic costs) were mapped in plan view, and contoured for each of the seasonal cruises DM I, II, and IV; they are shown as Figures A-1, A-2, and A-3 in the Appendix. The STD profiles from cruise DM II were replotted at a common scale by computer (Figure 239; in addition, the five-day time-series stations from DM III were computer plotted, and contoured as time-history diagrams, as illustrated in Figures A-4 through A-7 in the Appendix). The STD profiles from DM II that were not part of the abbreviated time-series stations were used to construct temperature and salinity cross sections along transect lines (Figure 240 is representative). STD profiles from the 1975/76 cruises performed under the prior MAFLA contract were computer plotted in the same format as the STD profiles from the current program.

Some cautionary notes are in order regarding the visuals and their interpretive use. The temperature and salinity plan view diagrams and cross-section diagrams imply synopticity of the data set when, in fact, the individual data points may have been collected as much as three to four weeks apart in the case of the plans from cruise DM I, and two to three days in the case of the cross sections from DM II. Accordingly, the data certainly show regional and seasonal trends, but specific interstation comparisons should allow for potentially large time differences in data collection schedules.

Several general trends are evident on the seasonal contoured plan views of temperature and salinity; the lower panels in Figure A-1 show bottom temperature and bottom salinity for the later summer 1977 cruise DM I, and are indicative of the general patterns. Isopleths of temperature and salinity are oriented subparallel to the shoreline, with the greatest lateral gradients along the northern coastline. That observation pertains to both surface and bottom data contours, although the patterns are stronger and the gradients are better developed on the bottom, away from surface mixing effects, and at the intersection of the pycnocline and the seafloor. Northeastward deflections of the temperature and salinity isopleths occur with fair regularity over the Florida Middle Ground station for both surface and bottom waters, suggesting a persistent incursion of warmer and more saline Loop Current water onto the shelf at that location. That observation is certainly supported by the presence of hermatypic corals on the Florida Middle Ground. The plots for summer 77 and winter 78 show only small pods of water having salinities greater than 36.5% (thereby, defined as Loop Current water). The fall 77 data (Figure A-2), on the other hand, show a very distinct intrusion of Loop Current onto and over the shelf edge.

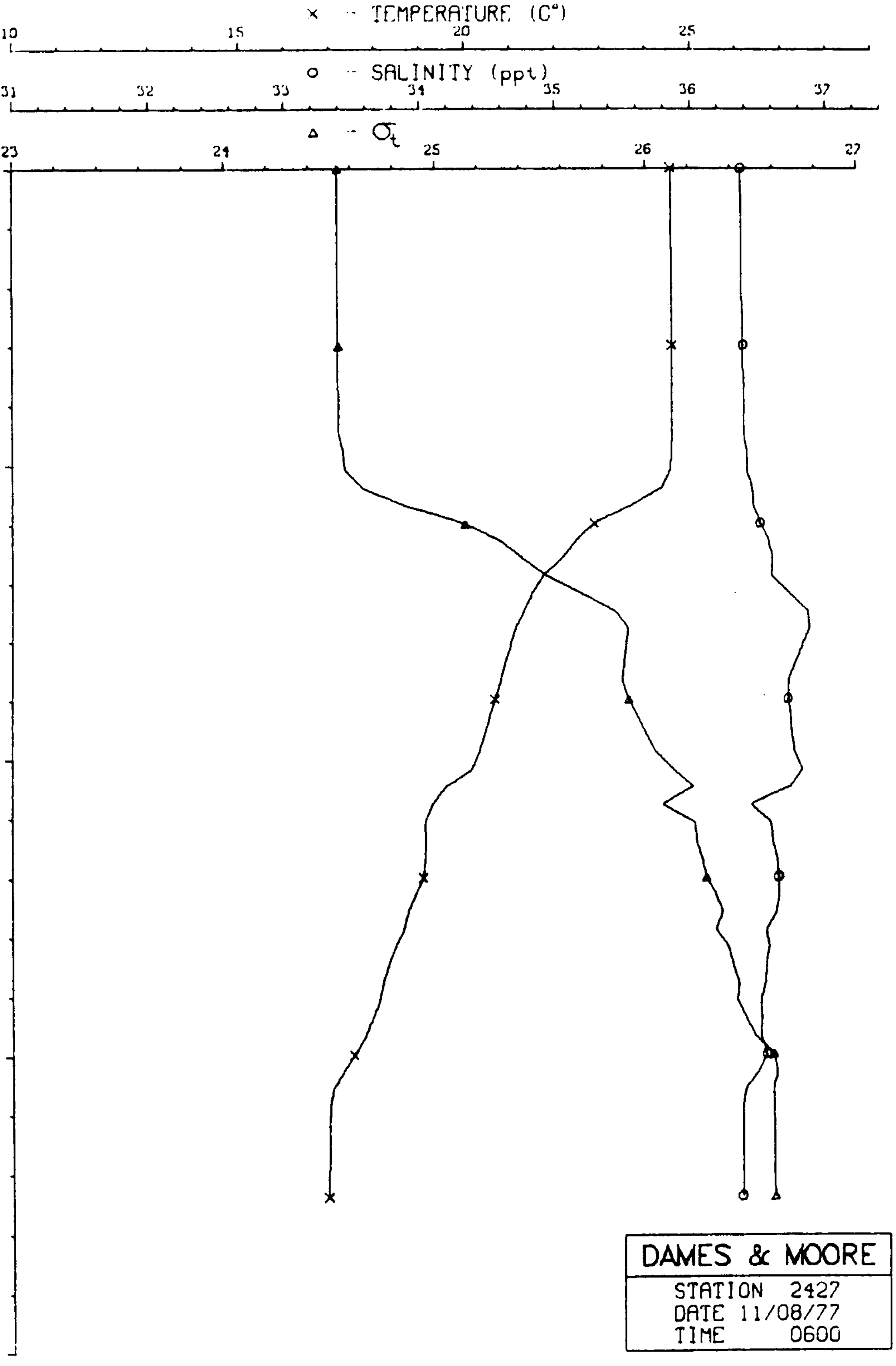


FIGURE 239

COMPUTER - PLOTTED CHARACTERISTIC PROFILES OF TEMPERATURE, SALINITY, AND DENSITY (AS SIGMA-t), MAFLA OCS

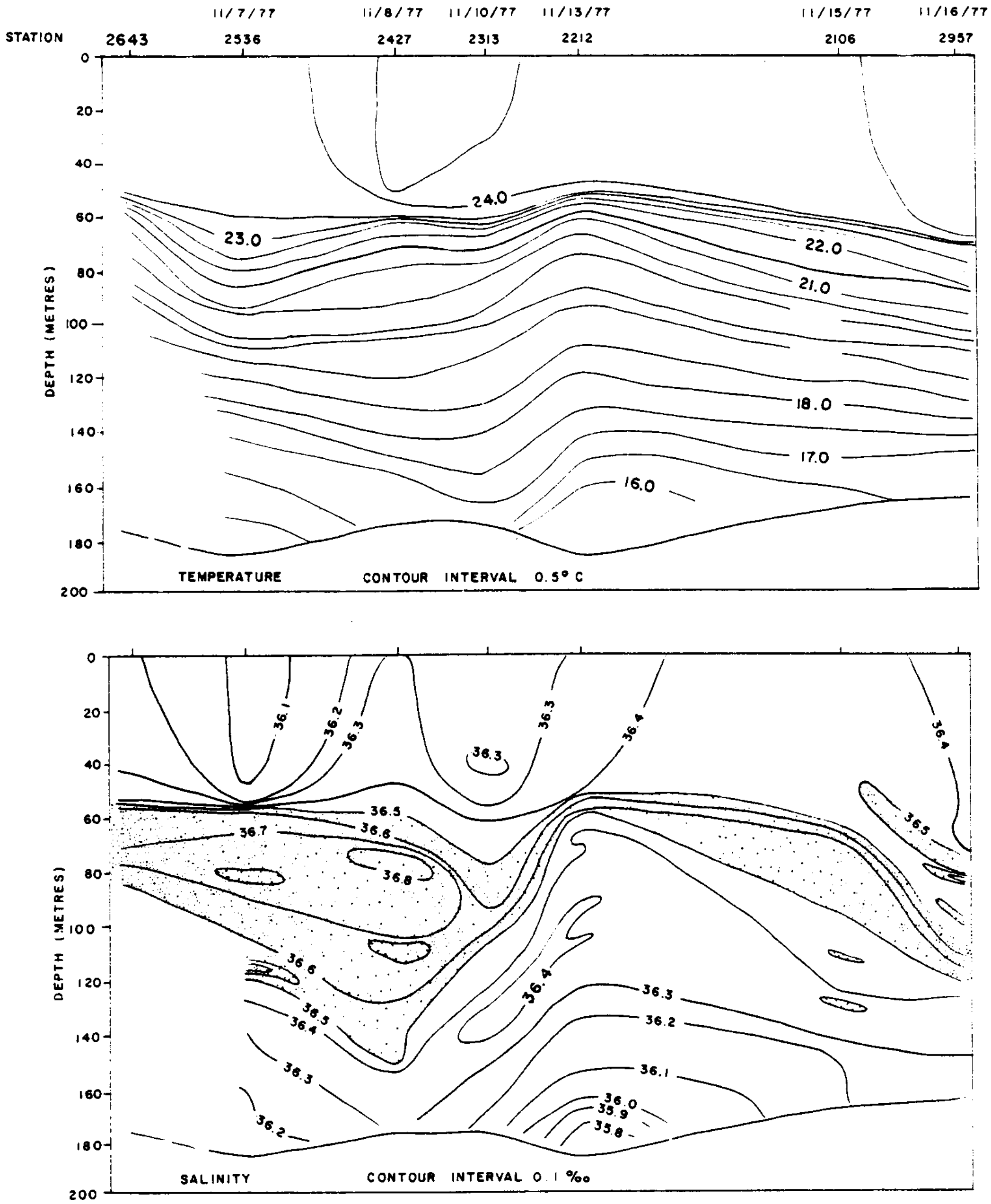


FIGURE 240

TEMPERATURE AND SALINITY CROSS SECTIONS BETWEEN OFFSHORE ENDS OF TRANSECTS, CRUISE DM II, LEG II, FALL 1977

Both surface and bottom waters show the discharge of freshwater from Mobile Bay, the largest point source of freshwater input within the study area. Salinity tends to increase with distance from shore; that correlation is very strong for surface waters for all seasons, and is only slightly less so for bottom waters. Temperature values, being nonconservative, show a great deal more variability based not only on season and depth, but also (for surface waters) on time of day of the measurement; the anomalous patterns shown on the upper left panel of Figure A-1 are undoubtedly the result of day versus night sampling. Summer bottom temperatures tend to be highest at inshore, shallow water stations. Fall surface temperatures are generally highest at the offshore ends of the transects, while fall bottom temperatures are, in all cases, highest near the middle of the transects. Wintertime surface temperatures are, without exception, highest at the seaward ends of the transects, and bottom temperatures are generally higher at the outer ends of the transects during the winter.

Figure 239 shows representative temperature, salinity, and sigma-t profiles for the deeper stations during the fall cruise DM II. The thermocline at a depth of 50 to 60 m separates the well-mixed and homogeneous surface layer from the SUW. The thermocline (and related pycnocline) occur in all profiles at all deeper stations, and appear at depths generally ranging from 40 to 60 m below the surface, although it may be as shallow as 25 m or as deep as 75 m. The thermocline lies deeper in the southern part of the MAFLA area. The salinity trace shown on Figure 239 illustrates another characteristic feature, namely a salinity maximum, occurring within the SUW (the salinity maximum, in fact, defines the core of the SUW).

Figure 240 shows temperature and salinity cross sections between the offshore end stations of Transects IX, I, II, III, IV, V, and VI obtained during the fall 77 cruise DM II. The homogeneous surface mixed layer is seen to overlie the thermocline; the halocline is less well defined, but generally coincides with the position of the thermocline. The salinity section reveals a layer of variable thickness of waters with salinities in excess of 36.5%.

A scatter plot of all surface and bottom reversing thermometer temperatures from the benthic cruises DM I, II, and IV are shown on Figure 241, and illustrates the relatively greater seasonal stability of bottom temperatures below a depth of 50 to 60 m. By contrast, the bottom (and surface) temperatures at stations shallower than 50 to 60 m show a marked seasonal cooling. Note also that while mean surface temperatures drop from summer to winter, the range of surface temperatures increases from summer to winter. Summer and fall temperatures are greater above the 50 to 60 m level than below it, while winter temperatures are lower than those below that depth.

Areawide STD profiles are available only for the fall cruise (DM II) of the 1977/78 MAFLA program, so no seasonal comparisons can be made on the basis of that data set alone. However, the profiles from the 1975/76 program, encompassing the June-July 78, September-October 75, and January-February 76 cruises, have been replotted and compared, and some seasonal trends are evident. With one exception, the summer 75 thermocline lay at depths of about 5 to 15 m; one profile located at the offshore end of

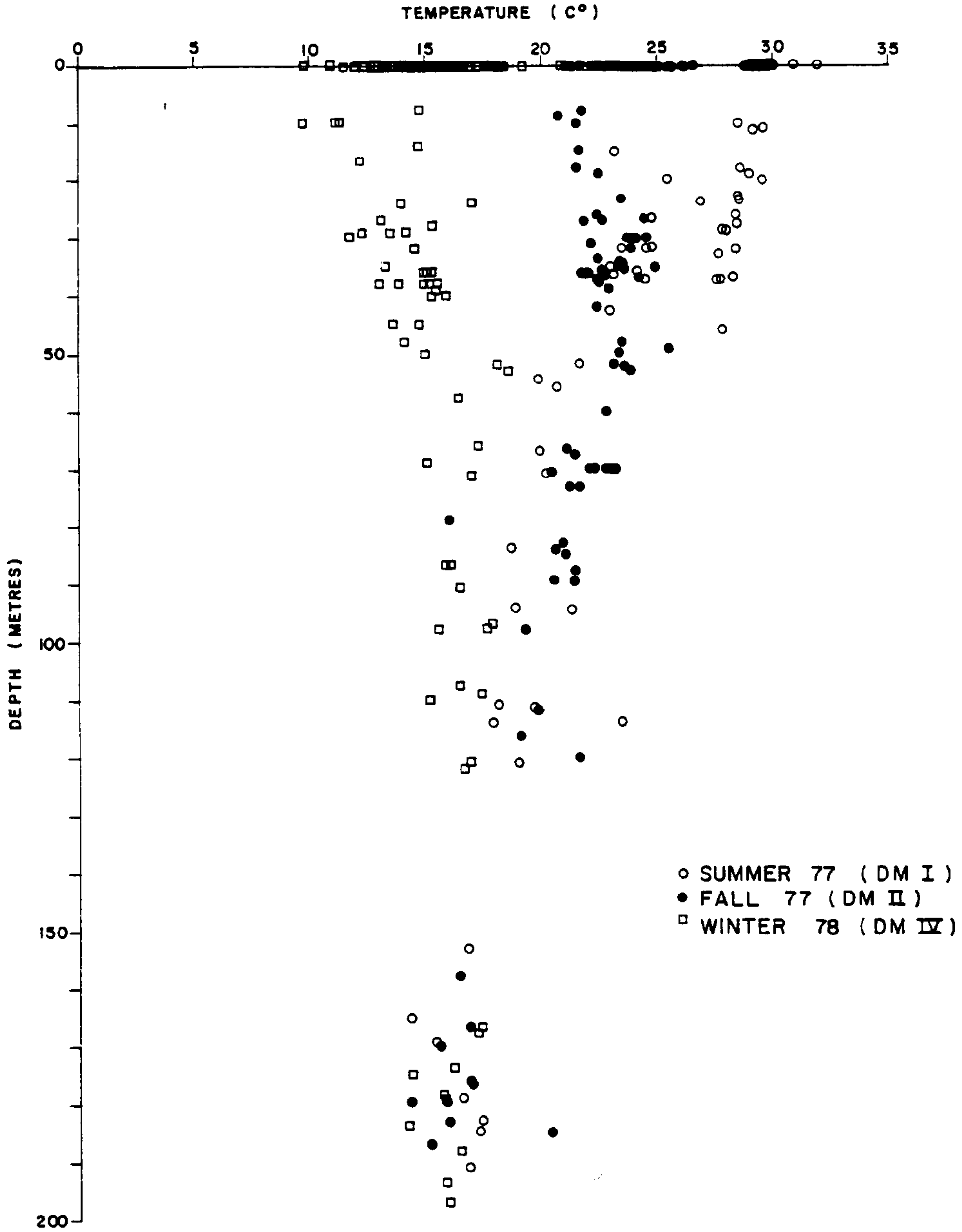


FIGURE 241

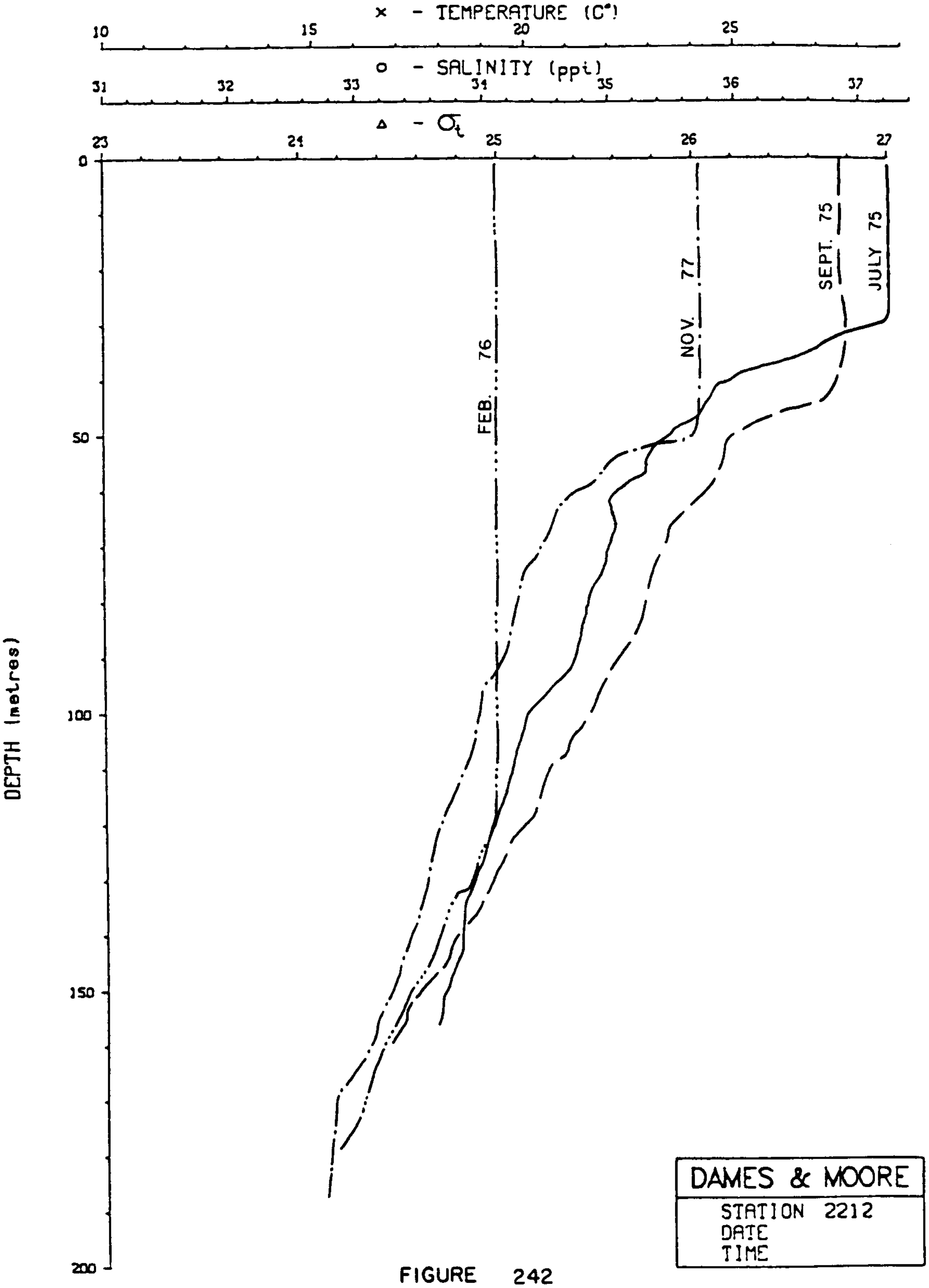
SCATTER PLOT OF ALL SURFACE AND BOTTOM TEMPERATURE MEASUREMENTS, CRUISES DM I, II, IV, 1977/1978

Transect II (near Station 2212), had a thermocline at a depth of 30 m. By the time of the fall 1975 cruise, the thermocline had been lowered to depths of 40 to 50 m. The winter 76 cruise data show the thermocline ranging from 90 to 130 m. Figure 242 shows four temperature profiles obtained at or very near Station 2212, and illustrate the seasonal cooling and thickening of the Surface Mixed Layer.

Figures 243 and 244 show seasonal variations in surface and bottom temperatures and salinities by transect, in terms of the range of salinity and temperature values within a transect. Surface temperatures (Figure 243) show greater ranges within a transect in winter than in summer, whereas bottom temperatures show the opposite relationship, i.e., more uniform bottom temperatures along a transect line in wintertime. The temperature ranges tend to be higher along the northern transects, but the increase is not great. A similar, but much stronger, northward increase in range is seen with surface and bottom salinities (Figure 244), reflecting the influence of freshwater runoff on the northern water masses.

The short-term temporal variability of standard physical oceanographic parameters is well illustrated by the five-day time-series of measurements taken at Stations 2747, 2315, 2528, and 2639 during the winter 78 cruise (DM III). The results of the STD profiling are shown on Figures A-4, A-5, A-6, and A-7 (in Appendix) for Stations 2747, 2315, 2528, and 2639, respectively; time histories are shown for temperature, salinity, and sigma-t. Station 2747, offshore of Tampa Bay, and Station 2315, on the Florida Middle Ground, exhibit essentially homogenous water columns with no (or very weak and transitory) stratification. Changes in temperature, salinity, and density that occur in the water columns are small at those stations, and are most likely to occur throughout the entire water column. The salinity drops somewhat to the north (Station 2528), and weak haloclines are seen during the first two to three days of the time-series, but the water remains relatively isothermal and density is basically homogenous. At Station 2639, however, offshore of Mobile Bay, extremely strong gradients are seen that migrate up or down in the water column with time, and that form and are destroyed rapidly. Vertical changes in temperature are as great as 2.5°C within a two- to three-metre distance. Salinities may change by 2.0 ppt in a vertical distance of less than five metres; changes of similar magnitude also occur within time periods of less than two hours at the same depth. While these very rapid and significant changes may stress the surface and midwater biota at Station 2639, it can also be seen that bottom conditions are far less variable, and tend to change more slowly.

Light penetration data taken on cruises DM II (fall 77) and DM III (winter 78) show generally greater penetration during the fall cruise (Figure 245). DM III data, on the other hand, show much greater accumulative light attenuance, with less than 10% relative illuminance occurring at depths shallower than 20 m, and at times as shallow as 6 m. Table 92 lists approximate depths of given percent relative illuminance levels, and shows not only the difference between cruises DM II and DM III, but also progressively lower relative illuminance as one proceeds northward. More light penetrates to any given depth at Station 2747 (offshore Tampa Bay) than the other stations; Station 2639 (offshore Mobile Bay) shows the least penetration. It is difficult to establish any casual mechanisms for the



DAMES & MOORE

STATION 2212
DATE
TIME

FIGURE 242

SEASONAL CHANGES IN THERMOCLINE DEPTH AND THICKNESS OF SURFACE MIXED LAYER, STATION 2212

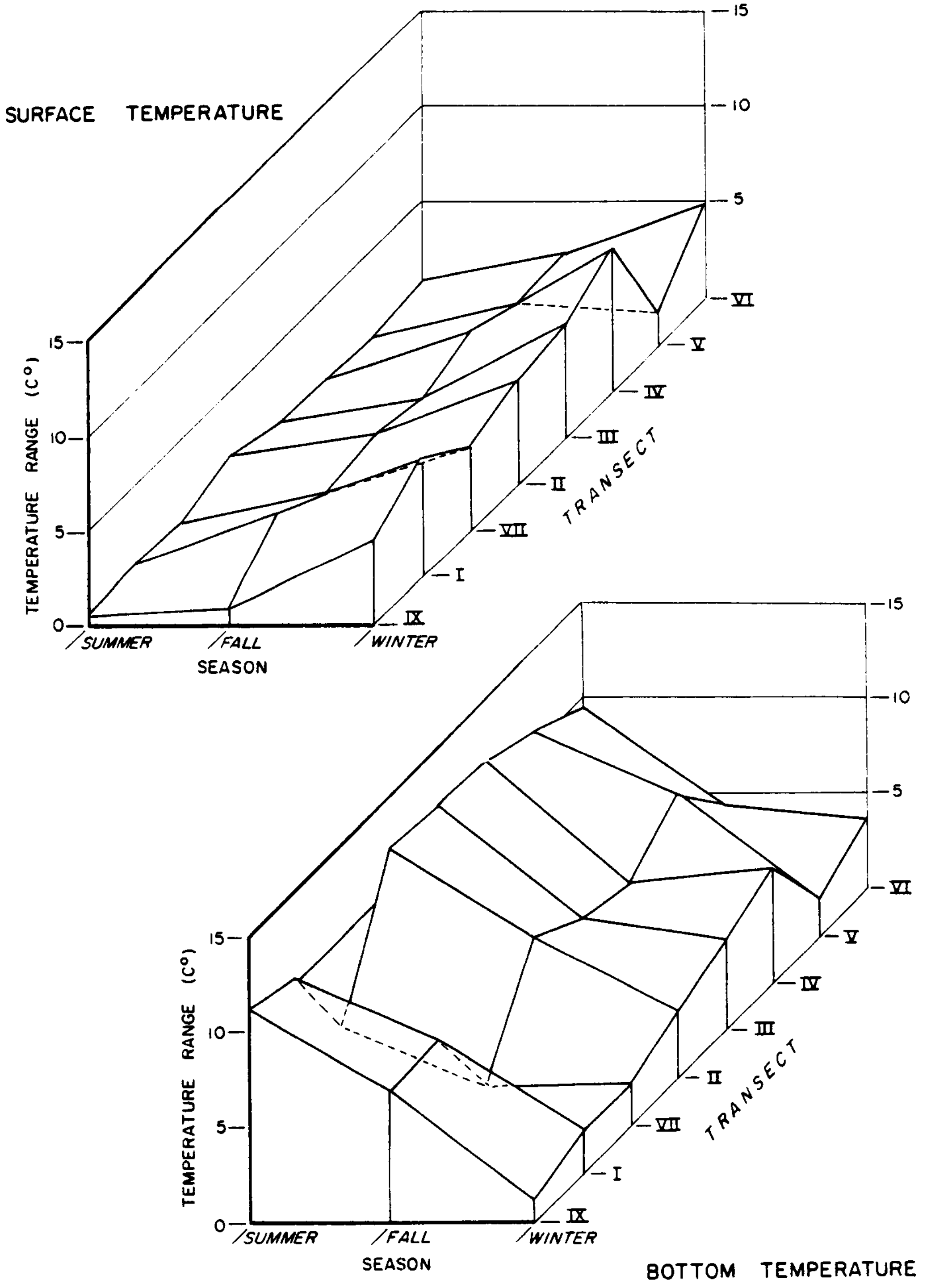


FIGURE 243

RANGE OF SURFACE AND BOTTOM TEMPERATURES FOR ALL 1977/1978 STATIONS BY SEASON AND TRANSECT

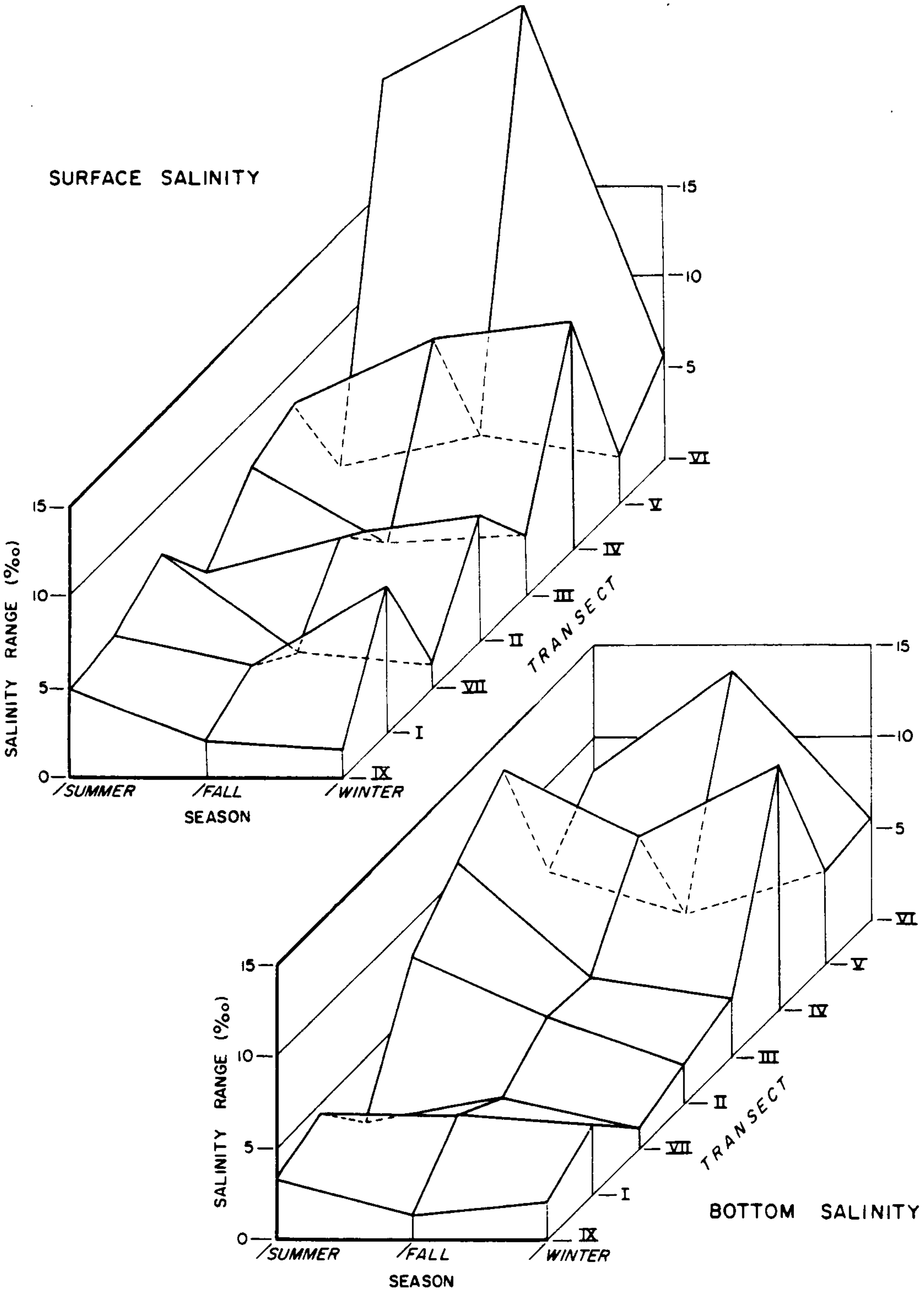


FIGURE 244

RANGE OF SURFACE AND BOTTOM SALINITY FOR ALL 1977/1978 STATIONS BY SEASON AND TRANSECT

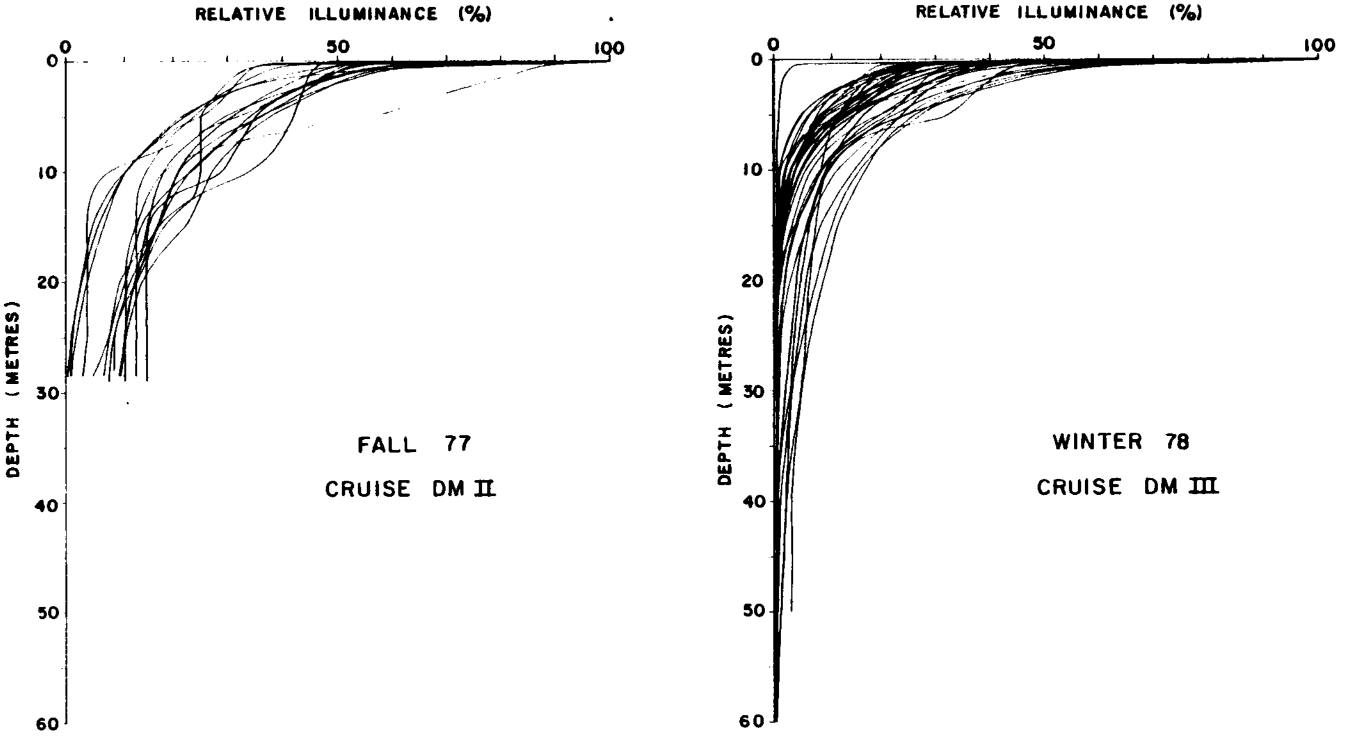


FIGURE 245

PERCENT RELATIVE ILLUMINANCE VERSUS DEPTH
CRUISE DM II AND DM III

TABLE 92

Relative Illuminance	DM II	DM III			
	ALL*	2747	2315	2528	2639
50%	<6 m	<2 m	<2 m	<1 m	<1 m
25%	4-15 m	<7 m	<5 m	<3 m	<3 m
10%	<9 m	9-18 m	4-10 m	3-7 m	3-6 m
1%	>25 m	30-50 m	5-30 m	11-20 m	10-15 m

Approximate depths of 50%, 25%, 10%, and 1% relative illuminance values.

* DM II Stations: 2747 (3), 0005 (3), 2639, 2640, 2535, 2531, 2426, 2318, 2212, 2746, 2960.

light penetration patterns observed here. While some part of the increased attenuance with season and location may be due to absorption or scattering by particulates, other factors, such as surface roughness or lower sun angles, may have overriding significance.

CONCLUSIONS

1. Surface temperatures vary from less than 9°C to over 30°C, and show marked seasonal and geographic variation. Higher surface temperatures are generally found offshore, particularly in the fall and winter, and in the southern parts of the MAFLA OCS.

2. Bottom temperatures show a range almost as great as for surface waters. Maximum bottom temperatures occur at the inshore ends of each transect during summer, at midtransect locations during fall, and at the offshore ends during winter; that sequence reflects seasonal cooling and mixing of inshore waters.

3. Observed salinities range from approximately 21 ppt off Mobile Bay, to greater than 37 ppt on Transect IX. Salinity increases in a seaward direction from shore, and increases with depth down to a salinity maximum, below which it may decrease slightly. The salinity maxima occur at depths of from 60 to greater than 100 m, and are generally deeper in the southern MAFLA area.

4. Short-term varability in water column stratification is greatest in the northern and western MAFLA area, where freshwater inflow is greatest, and where temperature changes of more than 2.5°C may occur with a depth change of two to three metres and within a time period of less than two hours. Similarly, salinity may change by 2.00 ppt with a change of depth of less than five metres, and in a similar time period. Water column structure becomes more stable and homogeneous with increasing distance away from the northern and western limits of the MAFLA area.

5. Light penetration measurements suggest greater penetration with depth during the fall than winter seasons. The depth at which only 10 percent of the ambient surface light reaches ranges from approximately 3 to 10 m, with the smaller (i.e., shallower) values occurring at northern stations.

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APPENDIX

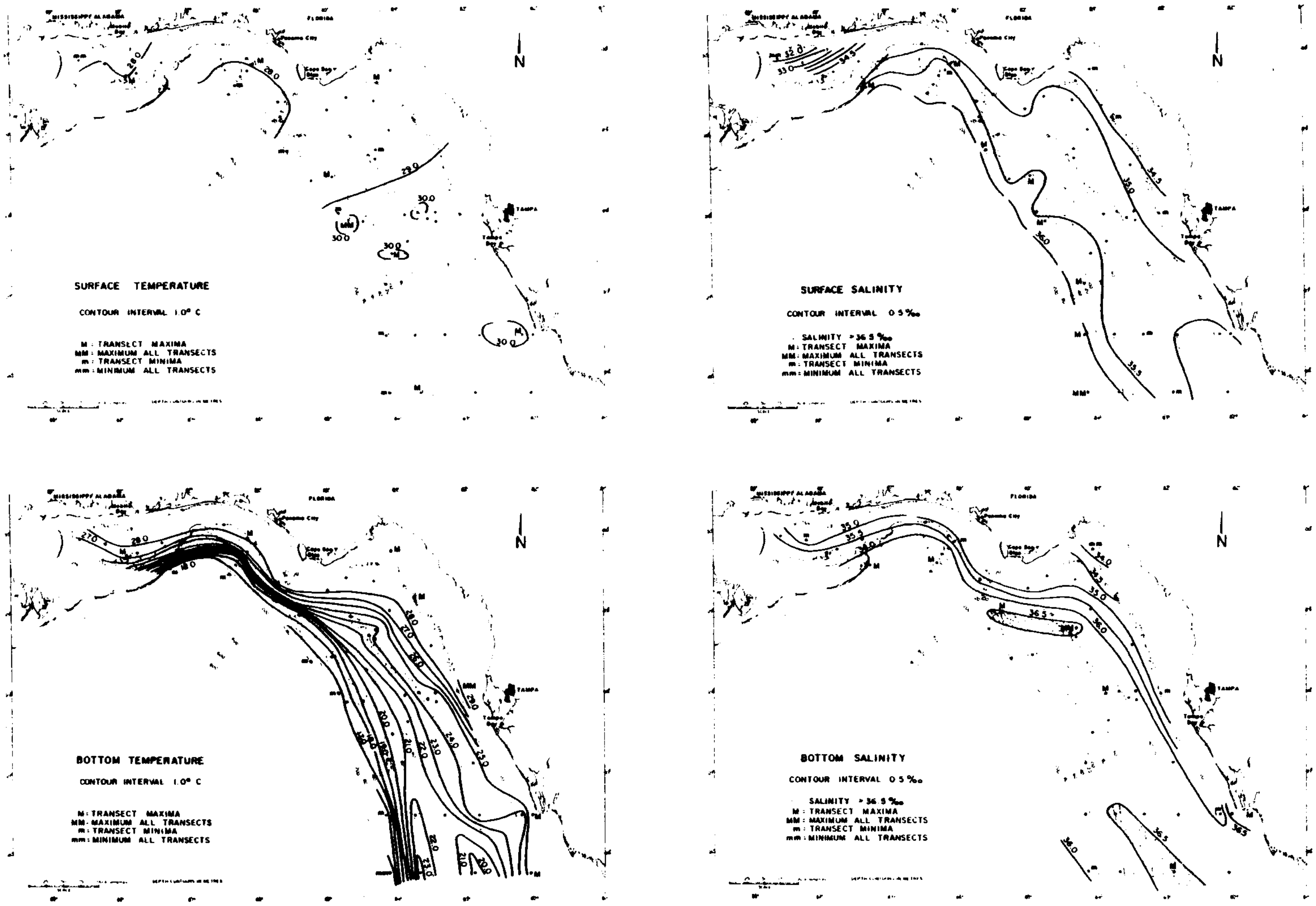

FIGURE A-1

CONTOUR CHARTS OF SURFACE AND BOTTOM TEMPERATURE AND SALINITY, CRUISE DM I, AUGUST - SEPTEMBER 1977

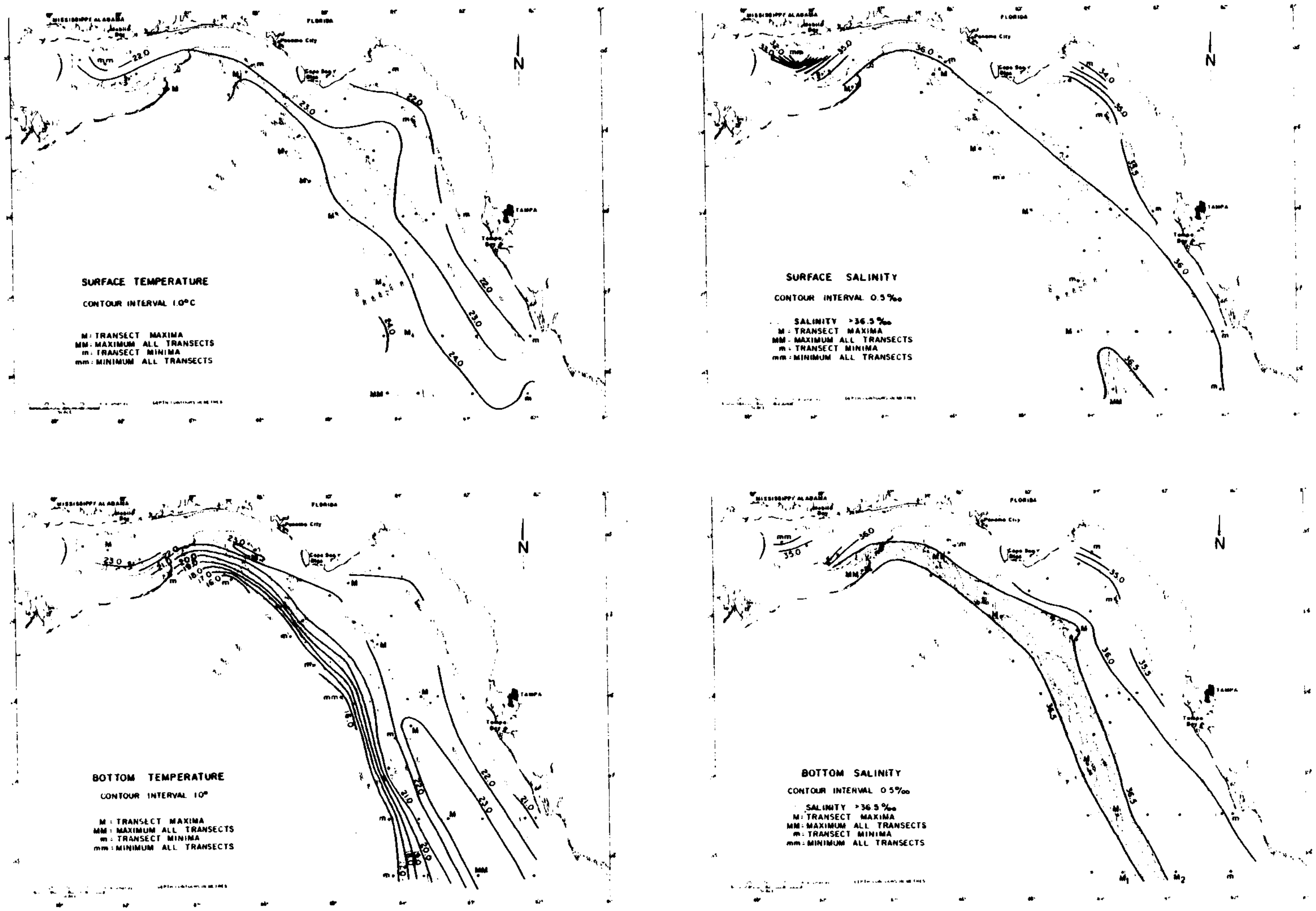

FIGURE A-2

CONTOUR CHARTS OF SURFACE AND BOTTOM TEMPERATURE AND SALINITY, CRUISE DM II, LEG II, NOVEMBER 1977

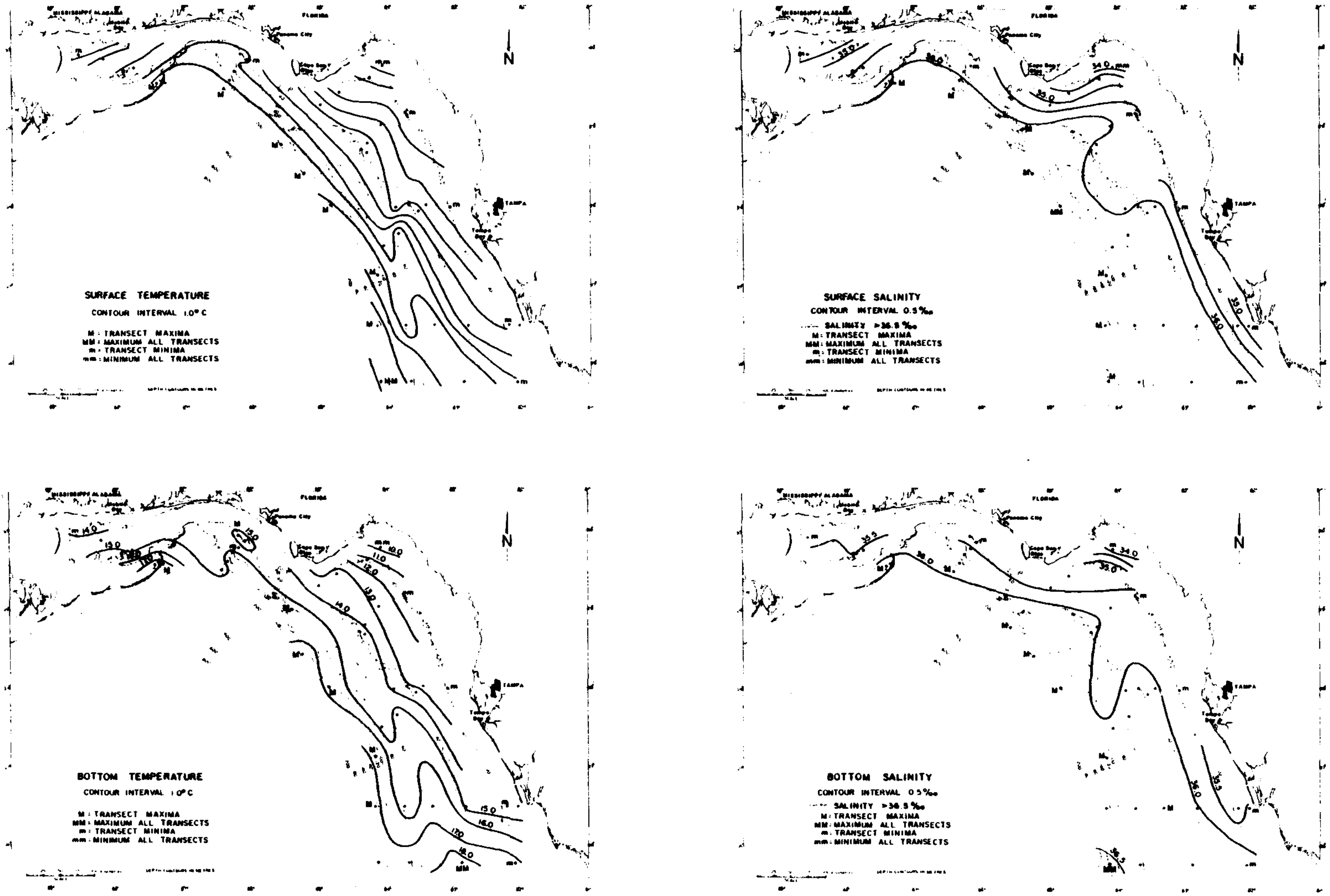

FIGURE A-3

CONTOUR CHARTS OF SUFACE AND BOTTOM TEMPERATURE AND SALINITY
CRUISE DM IV, LEG II, FEBRUARY 1977

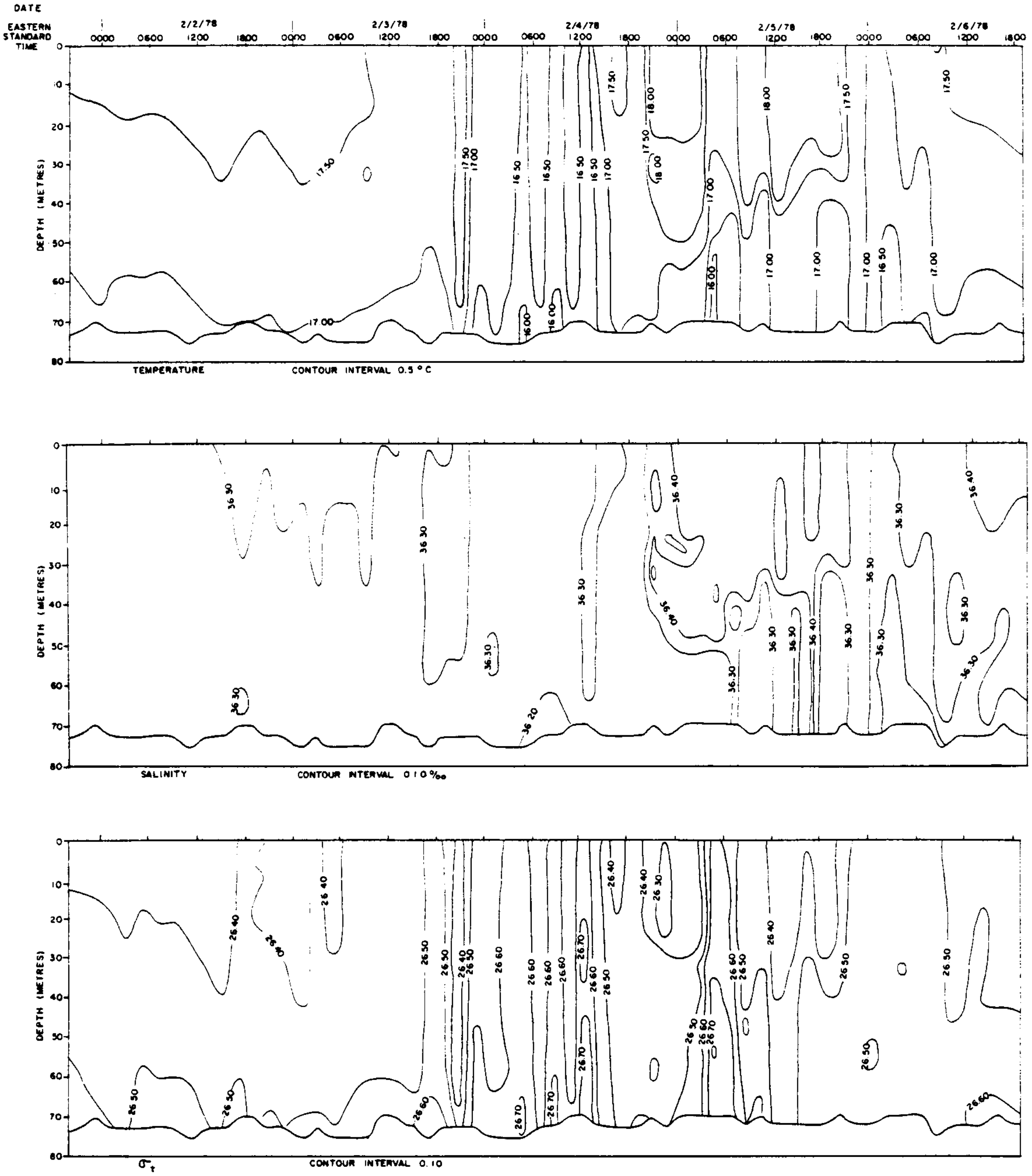

FIGURE A-4

TIME SERIES PLOTS OF TEMPERATURE, SALINITY, AND SIGMA-t, STATION 2747, FEBRUARY 1978

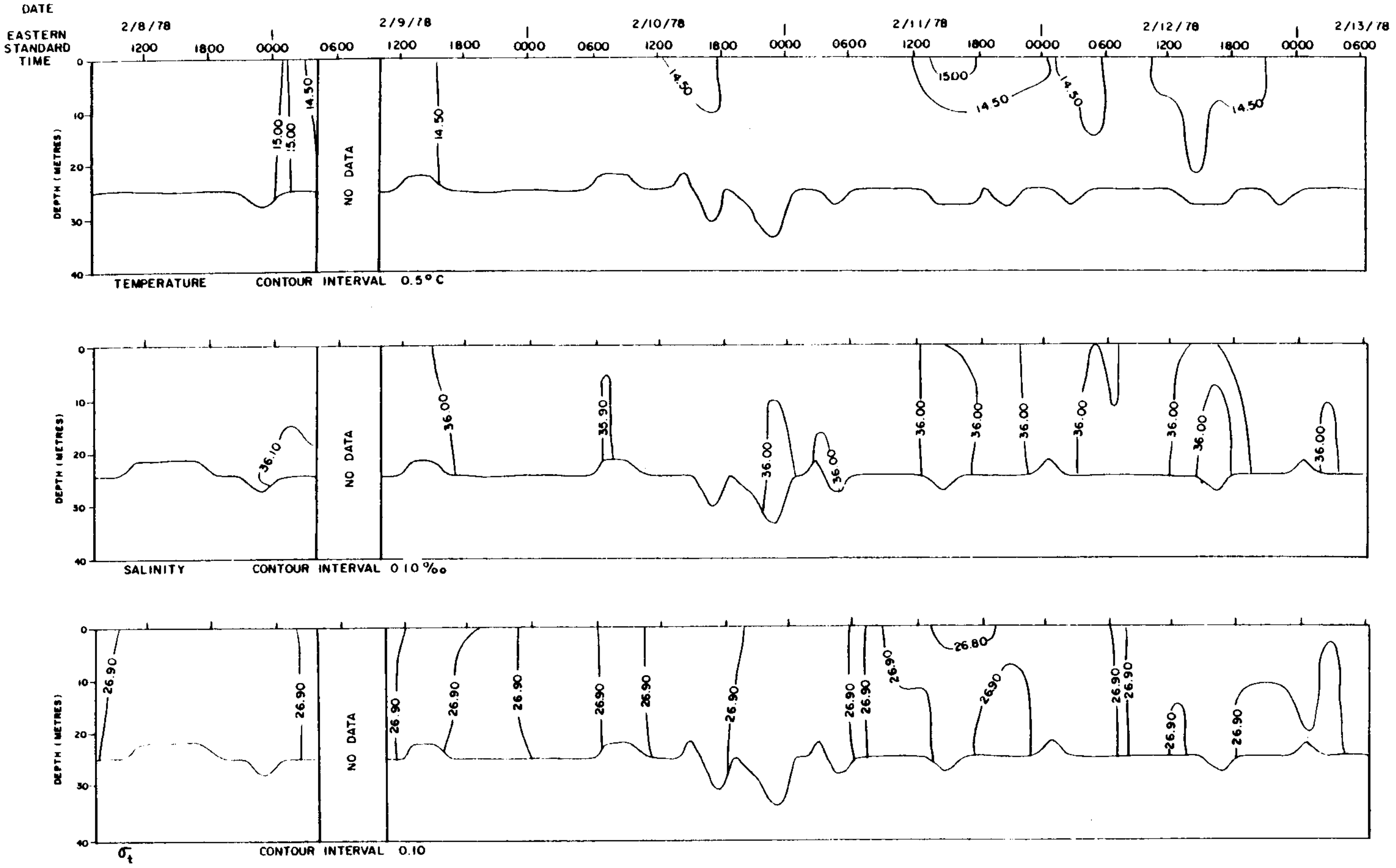

FIGURE A-5

TIME SERIES PLOTS OF TEMPERATURE, SALINITY, AND SIGMA-t, STATION 2315, FEBRUARY 1978

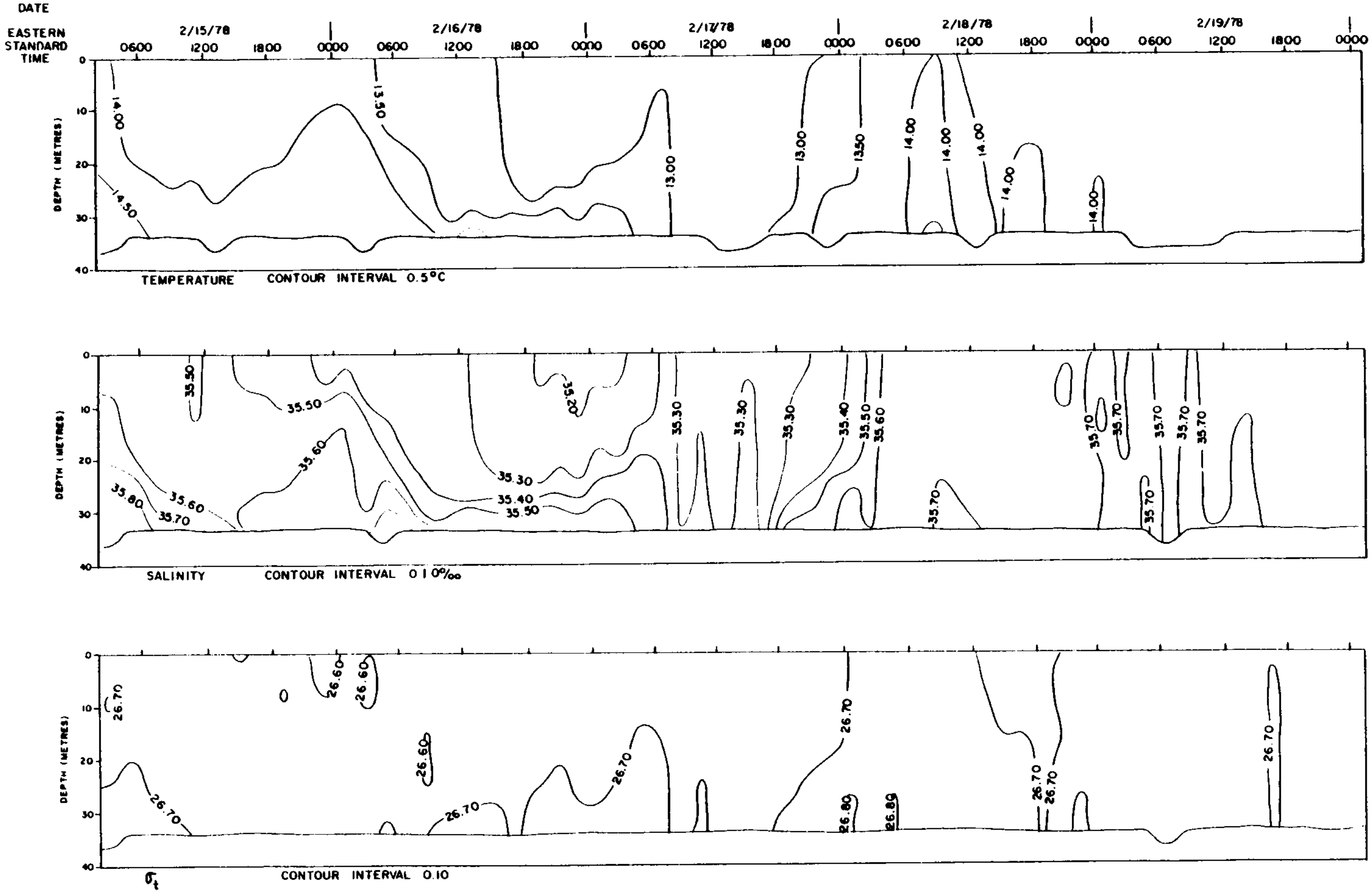

FIGURE A-6

TIME SERIES PLOTS OF TEMPERATURE, SALINITY, AND SIGMA-t, STATION 2528, FEBRUARY 1978

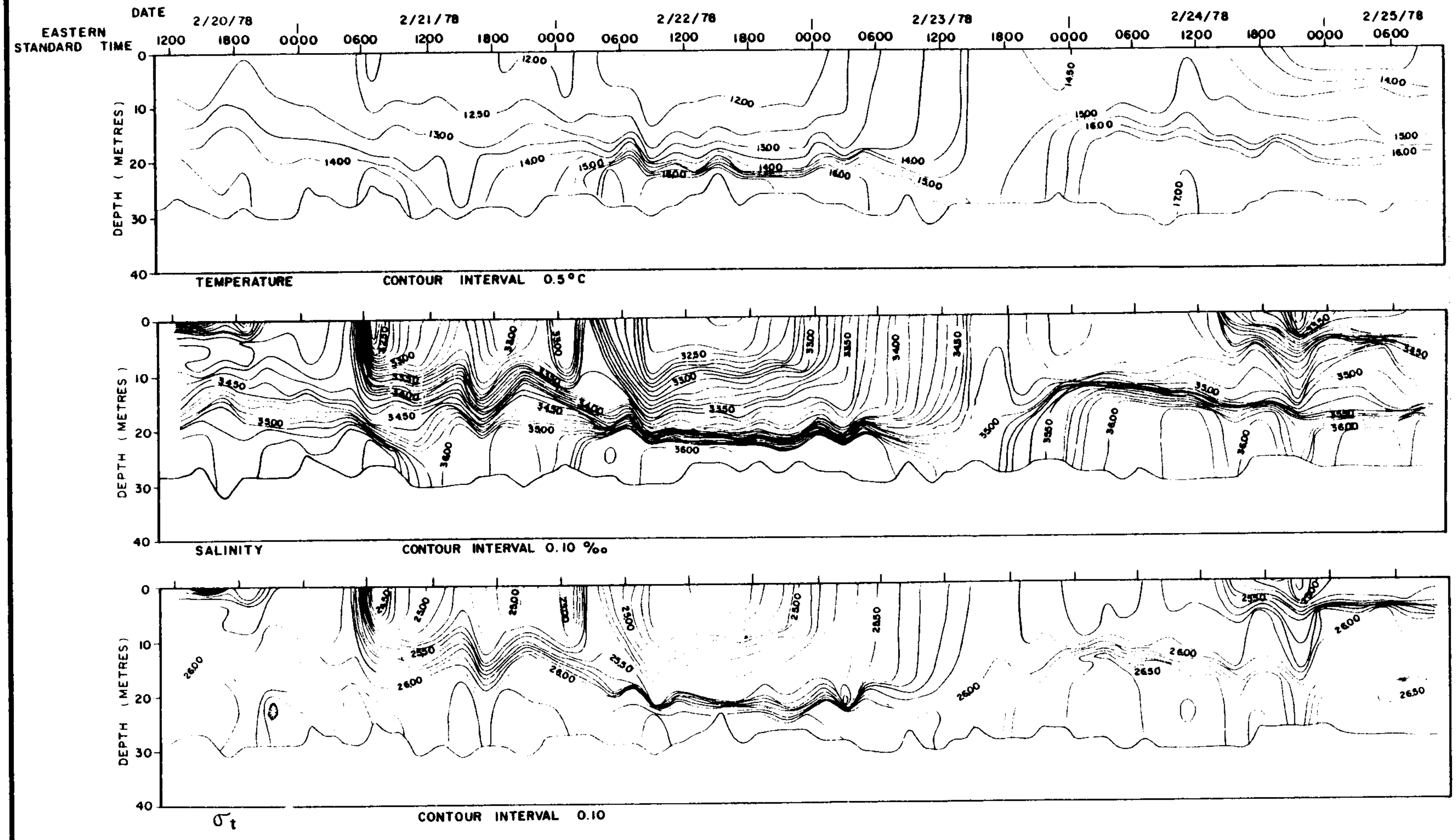

FIGURE A-7

TIME SERIES PLOTS OF TEMPERATURE, SALINITY, AND SIGMA-t, STATION 2315, FEBRUARY 1978

VOLUME II

CHAPTER 21

TRANSMISSOMETRY

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CONTRACT NO. AA550-CT7-34

TRANSMISSOMETRY ON THE EASTERN GULF OF MEXICO SHELVES,
MAFLA SURVEY
1976-1978

by

K.L. Carder* and K.D. Haddad

FINAL REPORT

TO

BUREAU OF LAND MANAGEMENT

under

Dames & Moore Contract AA550-CT7-34

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ABSTRACT

Water clarity in the eastern Gulf of Mexico increases away from vertical or horizontal interfaces, as one would expect. In the benthic boundary layer it increases with a decrease in turbulent energy (currents, seiches, internal waves, hurricanes) available to act on the bottom. In the surface layer, turbidity was largely relatable to runoff or biological productivity.

Water of a clarity comparable to Sargasso Sea water was measured in the Loop Current, which was found at times at the seaward ends of all transects. This water was 50 to 100 times as clear as water found at the northern winter stations in the nepheloid layer.

Near-bottom water clarity was affected by non-periodic (Loop Current) and periodic (internal waves, seiches, inertial currents) bottom currents, with nepheloid layers found at times in all regions of the study area. However, the rapidly shoaling, fine sediment-laden shelf off Mobile resulted in nepheloid layers during all sampling seasons. The Loop Current was energetic enough to produce massive nepheloid layers over even the coarsely sedimented southwest Florida Shelf.

The Loop Current is the primary transport mechanism for particles in the study area. The periodic current phenomena do not result in a net transport unless they are superimposed upon a current with a net directionality. However, they do provide significant erosional energy to the bottom which, coupled even with a slow (non-eroding) current, could result in a net sediment transport. In the summer and fall when the Loop Current intrudes furthest into the Gulf of Mexico, a net southward transport of outer shelf sediments should result. The Loop Current also drives, at times, an eddy centered over the Middle Grounds.

During the winter, when northerly or northeasterly winds blows in conjunction with seiche activity, a general westward to northwestward transport of sediments should result. That may explain the presence of sediments suspended in the water column off Mobile, Alabama that were similar to those found on the bottom off Panama City, Florida during DM III.

There is no doubt that bottom sediments are moved considerable distances by currents in the MAFLA region. Any trace metals or petroleum hydrocarbons absorbed onto such sediments will be transported with them. Transmissometers and current meters moored near the bottom at or near drill and production rigs could continuously monitor the local suspended sediment transport and help define the periodic bottom current mechanisms of the area. If an accidental oil spill occurred, this readily accessible information would help in the design of sampling strategies for assessment of the impact of the spill.

INTRODUCTION

PURPOSE

The development of a producing offshore oil field involves a number of steps which could affect the natural environment. These include the transport and deposition of drill muds and tailings, oil seeps or leaks at the drill site, bottom disruption and siltation from burying pipelines, and oil spills or seeps in the transport of oil. All of these processes involve either the transport and deposition and particles directly or the adsorption of petroleum-derived hydrocarbons and trace metals onto natural particles and their subsequent transport and deposition on the benthic interface. Thus a measure of the spatial and temporal variability of background particle concentrations in a region of potential oil production is a worthwhile endeavor. Furthermore, the distribution and temporal variability of suspended particle concentrations allows the trained observer to elucidate important circulaton patterns and erosional mechanisms, and to estimate the energy acting on the benthic boundary.

To perform this mission, a continuously recording *in situ* instrument is ideal since it can be used to quickly determine spatial and temporal variations in particle concentrations. Optical devices are the only reliable instruments available on the market to perform such functions, and of these the transmissometer is the most widely employed. It provides a measure of the gross particle concentrations without consideration for subdivision into biological, geological, or chemical components. However, if measures of other particle variables are taken at a few selected points in time and space, transmissometry can provide valuable interpolative information between data points.

BACKGROUND

Suspended matter studies of analytical or optical character are especially limited in the eastern Gulf of Mexico (Manheim et al., 1972; Carder and Schlemmer, 1973, and references cited). Prior to the BLM MAFLA study, transmissometry data points were almost non-existent for the eastern Gulf of Mexico. A few near-shore studies (e.g., McCarthy et al., 1974) have been performed, and the general character of clear open Gulf water can be deduced from the Caribbean study of Jerlov (1953).

The major particle sources for the MAFLA study area are rivers (primarily the Mississippi), bottom sediment, and the biosphere. Water clarity generally increases away from the horizontal and vertical boundaries, with oceanic water of Caribbean origin being the cleanest. The shelf portions of the study area north of Cape San Blas can be characterized as turbid, while the southern portion can be considered to be generally clear.

The Loop Current is the major source of clear Caribbean water to the MAFLA area. Part of the Loop Current (Subtropical Underwater, SUW) originates in the Sargasso Sea and is especially particle-free for a near-surface water mass. Jerlov (1953) reported values of $c-c_w$ or c_p of 0.06 to 0.09 m^{-1} for the Caribbean Sea and 0.05 m^{-1} for the Sargasso Sea. SUW is defined in the Gulf and Caribbean as water with salinities in excess of 36.6

$^o/oo$ (Wüst, 1964), and it is usually found below the thermocline. It has temperatures in the 10° to 23°C range. Eastern Gulf Water has salinities of about 36.4 $^o/oo$ (Rinkel, 1976) and is either associated with the Loop Current or results from a detached Loop Current eddy. Any water with salinities in excess of 36.5 $^o/oo$ is considered Loop Current Water (Molinari et al., 1975).

Manheim, Steward and Carder (1976) have reported spatial and seasonal transmissometry patterns for the 1975-76 MAFLA cruises, but short-term temporal variations in suspended particle concentrations were not addressed. Also, the fall sampling schedule was broken by Hurricane Eloise, preventing a typical fall distribution of water column variables from being ascertained. Thus the summer 1976 (SUSIO) and winter 1978 (DM II) time series programs (120 hours duration, 2-hour interval) were undertaken to investigate the short-term temporal variations in suspended particle concentrations. A modified time series (12 hours, 2-hour intervals) program was conducted in late October (DM II, Leg I). A spatially varying suite of samples was taken in early November (DM II, Leg II) to provide fall seasonal data uninterrupted by a hurricane.

METHODS AND MATERIALS

Identification of particulate regimes during cruises DM II and DM III, 1977-1978 (Contract Number AA550-CT7-34), was by a commercially marketed transmissometer. The instrument, a Hydro Products Model 612/912S with a Hydro Products Model 902S depth package, was modified at the factory to accept the depth package prior to the first cruise. This instrument measured the attenuation of a 20 mm diameter, collimated beam over a 1 metre path. The peak photo cell response was at 550 mm (10^{-10} m). The probe consisted of a light source and a detector housed in a three-piece aluminum housing. The assembly, which had on-deck readout, was lowered through the water column on a Hydro Produce seven-conductor, 300 m sheathed cable. To protect the cable and connections from stress, the submersible unit was strapped to a rigid carriage which was then attached to the cable. On the lower end of the carriage, a 100 kg weight was added to minimize wire angles. Both the detector and sensor were accessible without removal of the unit from its carriage. The Hydro Products winch (220 volt electrical motor-driven) was used to raise the system after it had been gravity-lowered. The conducting cable was terminated at the winch to seven Hydro Products slip-rings, which in turn were connected to the readout and power modules. An Omniscribe (Series B-5000, Y_1 - Y_2 vs time) recorder was adapted to the external outputs of the transmittance and depth modules to provide a continuous chart readout of depth and percent transmittance.

The power supplied for both transmittance and depth operations required a stable AC input. An Elgar (Model 251) AC-DC-AC power source was used to stabilize the ship's power. It should be noted that power stability from the ship's generators was occasionally poor and the utilization of the Elgar power source proved a tremendous advantage.

Prior to each cast the external windows of the light source and the photodetector were rinsed with distilled water and carefully wiped dry with Kimwipes. The transmissometer was then lifted on a A-frame to a vertical position above the ship's deck for calibration. The detector window faced downward.

Field calibration consisted of adjusting the current adjustment to the 50% meter reading and then switching to the operate mode and adjusting the detector gain to the 90% transmittance meter reading in air. The in-air reading supposedly simulated a laboratory reading of 100% transmittance in filtered, distilled water. However, laboratory calibration indicated that adjustments were necessary. During the field calibration procedure, the open ends of the transmissometer housing were covered with black plastic bags to eliminate external light interference and to protect the probe windows from optical contamination. At the conclusion of the calibration procedure, the plastic bags were removed and the transmissometer was lowered in a vertical position through the water column.

A record of each cast of the transmissometer was kept in a logbook, including station number, time, date, and bottom depth, along with any difficulties, weather conditions, and observations. On each strip chart record (profile) the time (beginning of cast), date, station number, and cast number were logged. Each profile was stored in an acetate separator contained in a binder.

The strip charts were reduced to computer format by digitizing major inflection points for each transmission profile and then determining the corresponding depths. A straight line may be assumed between digitized transmittance data points. The down trace was interpreted for computer format.

Data are stored with the contracting agency in percent transmittance values although data presented in the text are described as attenuation coefficients. The attenuation coefficient can be related to percent transmittance as follows (see Jerlov, 1968):

$$T\% = (F_t/F_o) \times 100\%$$

and

$$F_t/F_o = c^{-cr}.$$

thus $$c = \ln F_t/F_o,$$

where F_t is the transmitted radiant flux in a collimated beam at distance r (in this case 1 m) and F_o is the incident radiant flux entering the 1 m water column. The beam attenuation coefficient, c, is due to the particles and dissolved materials (e.g., yellow substance) in the water. Yellow substance is usually found in terrestrial runoff, so in studies of nearshore areas it is often present. "c" can be expressed as:

$$c = a_w + b_w + a_p + b_p + a_d + b_d = c_w + c_p + c_d$$

where "a" and "b" are the light absorption and scattering coefficients, respectively, and the subscripts "w" and "p", and "d" signify that the term is for water, suspended particles, or dissolved materials, respectively. Since particle-free distilled water has values of $c_w > 0$, T% should never be as large as 100% for the oceans.

Most transmissometers are of a fixed path length design. To overcome the problem of not being able to directly measure F_o, several manufacturers of transmissometers calibrate their instruments so that they read 100% transmission in particle-free water. They then take a reading immediately thereafter in air. Thus, a 92% reading in air (smaller than 100% since a slightly divergent beam diverges more in air than in water, and glass interfaces reflect more in air than in water) was designated by Hydro Products to correspond to 100% in particle-free water. A major problem is one of filtering large volumes of water sufficiently that no particles remain to attenuate light. The authors have found several instances where clean, open ocea water provided readings in excess of 100% relative to readings in filtered waters. Thus, since seawater can be cleaner than many manufacturers get their "particle-free" water, it is clear that the standard water was not truly particle-free and a different approach is needed.

The Hydro Products instrument can be used to measure beam attenuation through either a 0.1 m or 1.0 m path. Taking a measurement in a given parcel of water at each position provides data to calculate the attenuation due to a 0.9 m water path length:

$$\frac{F_t(.1)}{F_t(1)} = \frac{F_o e^{-c(.1)}}{F_o e^{-c(1)}} = e^{c(.9)}$$

or

$$\frac{\ln F_t(.1)/F(1)}{0.9} = c.$$

Thus, the attenuation coefficient can be determined in the laboratory for a given parcel of water. Also, by noting the light flux $F_A(1)$ reaching the detector of the transmissometer after traveling 1 m in air, a calibration factor, G, can be determined so that

$$F_o = G\ F_A(1).$$

So

$$T = \frac{F_t(1)}{F_o} = \frac{F_t(1)}{G\ F_A(1)} = e^{-cr},$$

and

$$G = \frac{F_t(1)}{F_A(1)e^{-cr}}.$$

However, for most transmissometry studies the part of the attenuation coefficient of interest is c_p. If the study is well away from the influence of yellow substance, the transmittance due to the particles, T_p, can be written

$$T_p = e^{-(c-c_w)r} = e^{-c_p r}.$$

This can also be written

$$T_p = \frac{e^{-cr}}{e^{-c_w r}} = \frac{F_t(1)}{G\ F_A(1)e^{-c_w r}} = \frac{F_t(1)}{F_A(1)H}\ ,$$

where $H = Ge^{-c_w r}$.

The peak detector sensitivity of the Hydro Products instrument was at 550 nm, so $e^{-c}w$ is 0.933 (Clarke and James, 1939). Thus, H = 0.933G. Experimental values of G and H were determined to be 1.27 and 1.19, respectively for the Hydro Products instrument during the fall 1977 and winter 1978 surveys.

In a particulate survey such as this, the absorption by both the dissolved and particulate regimes are understood as having only a minimal effect on the evaluation of c (except in Mississippi or other river effluents) and are therefore considered to be a constant. Thus, in this case, the light scattering coefficient, b, is linearly related to c. This relationship allows an independent check on the transmissometry data by a light scattering photometer (see below) and provides a common unit of measurement for either data collected on a transmissometer or a light scattering photometer (Tyler, 1961 Beardsley et al., 1970).

Two back-up instruments were available aboard ship in case of failure of the primary instrument. A Montedoro Whitney transmissometer with a self-contained Instro X-Y axis recording package was calibrated to the Hydro Products transmissometer and was available for immediate service. Also, a Brice-Phoenix light scattering photometer (Model 2000) was available in case of subsequent failure of the Montedoro Whitney transmissometer. The Brice-Phoenix was also used through each cruise to provide the investigators with a calibration check on the transmissometer and to aid in the assessment of the suspended particulate regimes. A Brice-Phoenix sample was drawn from surface, bottom, and occasionally mid-depth Niskin bottles. The volume scattering coefficients at 45°, 90°, and 135° in a collimated beam of green light (546 nm) were determined, but these data will only be reported for the summer 1976 cruise when the transmissometer malfunctioned.

During the 1976 summer time series water column sampling period of Contract 080550-CT5-30 in the Mississippi, Alabama, Florida lease area, two devices were used to optically characterize the water column particulates. The primary instrument was a Hydro Products Model 612/912S transmissometer. When problems arose with that device, a Brice-Phoenix light scattering photometer was agreed upon to fulfill the contractual obligations of the principal investigators.

The Hydro Produces instrument measured the amount of light attenuated across a 1 m path in water. This device was ostensibly calibrated by the manufacturer to maximum (100%) transmittance in moteless, distilled water. Supposedly, this gave an "in air" value of 92% transmittance for each pre-cast field calibration. Our laboratory calibration (as discussed above) indicated that an H value of 1.19 provided the correct values for T_p, and that number has been used in data reductions reported in this contract.

The light source and detector were housed in an aluminum tube fitted with submersible electrical connections. Prior to each cast, this underwater unit was vertically clamped onto the end of the conducting hydrowire with the photodetector window facing downward. After the "in air" field calibration had stabilized, the unit was lowered through the water column by an electric winch. The on-deck power supply for the light and readout was mated to the winch by slip-rings. Transmittance measurements were collected at two or five m increments, depending upon the depth of the station and the amount of time allotted for the cast. The depth was determined from metre-block readings. For each measurement, the lowering was stopped to allow equilibrium to become established. The depth and percent transmittance were hand-digitized in the transmissometry log book. The casts were performed every two hours and coded in the log with station letter and consecutive number. The cast was lowered until the hydroweight just touched the bottom and retrieved to the surface without interruption. The "in air" calibration was then rechecked and logged if any drift had occurred.

Early in the cruise, a short circuit developed in the underwater connection on the conducting hydrowire due to an improvised clamp for attaching a hydroweight to the bitter end of the cable. The proper clamp had failed to arrive in time for departure on the cruise. This failure forced the use of the Brice-Phoenix light scattering photometer.

Since the Brice-Phoenix is a bench instrument, a hydrocast was necessary to collect the water column samples for onboard measurement. Instead of making a separate cast, two to three extra $1.5\,\ell$ Niskin bottles were added to the STD cast. Combined with the two Niskin bottles already on this cast for calibration of the STD trace, this procedure allowed four to five points in the wate column to be photometrically measured for particulates. The sampling depths were determined by the characteristics of the preceding STD trace.

The water from each of the Niskin bottles on the hydrocast was carefully transferred to the photometer cuvette to avoid the entrapment of gas bubbles. The amount of green light ($\simeq 546$ nm) transmitted directly through the cuvette (0°) and scattered by the particulates at 45° and 135° to the straight beam was measured. This information was recorded on a Hewlett-Packard strip chart recorder which was annotated with the number of the STD cast. When time permitted, subsamples of the water collected for suspended mineralogy and particulate organic carbon were also analyzed. After each measurement, the sample was dumped and the cuvette was rinsed and stored with distilled water.

The techniques and computer program used to reduce the Brice-Phoenix data are identical to those reported by Pak (170) and Carder (1970). The resultant numbers reported to be contracting agency are values of the volume scattering coefficient $\beta(45)$ at a scattering angle 45° from the forward direction of the incident beam. Deirmendjan (1963) has shown the ratio of $\beta(40)/b = 0.1$ while Jerlov (1953) and Tyler (1961) have shown $\beta(45)/b$ to be constant for particle suspensions. Thus, for most open ocean samples (where c_d and a_p are small)

$$\beta(45) \doteq kc,$$

where k is a constant of proportionality.

RESULTS AND DISCUSSION

SPATIAL PATTERNS OF c_p

The spatial patterns of salinity and c_p are presented first to provide the reader with a sense of the positions that water masses, currents, and turbidity sources may have when the Loop Current is present along the outer edge of the study area. Advection of some of these features and bottom erosion by currents are examples of mechanisms that can provide temporal changes in the optical characteristics at a given point in space. Thus, spatially varying data will precede temporally varying data in our presentation.

The penetration of Loop Current components onto the MAFLA shelf areas during DM II is indicated by positions of the contours of the maximum salinity values at each station[1] (see Figure 246). For depths shallower than 100 m, this was always in a layer near the bottom. As a comparison, the surface salinity values (Figure 247) were always lower, indicative that Loop Current components were wedging in under the shelf waters, especially just south of Cape San Blas and off Fort Myers. A pattern indicative of a gyre is present over the Middle Grounds area in the surface salinity patterns, which is not unusual according to Nowlin (1972).

In August, September, and October, Loop Current waters also penetrated onto the west Florida shelf, reaching within two nautical miles of Sarasota. This intrusion is believed to have helped initiate the red tide in October 1977 (Haddad and Carder, in press). Such a penetration of upwelled water has the potential of increasing turbidity by eroding bottom sediment and nutritionally supporting phytoplankton blooms.

A measure of the erosional potential of the Loop Current is apparent in the data shown in Figure 248. Here, bottom patterns of c_p are shown which range from $<0.10\ m^{-1}$ to $>1.50\ m^{-1}$ for Loop Current water ($S>36.5$ $^o/oo$). The clear water values are typical of Caribbean water, while the turbid waters are effects of bottom erosion. This will be more apparent in cross-sections to be presented later. While the surface waters (Figure 249) are often less turbid than near-bottom waters, the mid-depth waters away from any boundaries are typically clearest. No significant river influences are apparent in either the surface salinity or the surface c_p data for the November 1977 cruise.

The erosional effect of the Loop Current scouring shelf areas of the MAFLA area is best exemplified by Figures 250 and 251. Those are cross-sections of salinity and c_p along the southernmost transect. Salinities in excess of 36.5 $^o/oo$ had penetrated shoreward nearly to Station 2959, but erosional effects were evident near the bottom to beyond that point. Thus, water of as little as 36.3 $^o/oo$ salinity was still part of the velocity field of the Loop Current on the shelf, and erosion of slope sediments occurred at depths in excess of 180 m. The % transmission values found in this near-bottom nepheloid layer were less than 19%, and except for

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[1] Data taken on November 1, 1977 at four stations off Sarasota was provided by L. Freeburg, Mote Marine Laboratory, Sarasota, Florida.

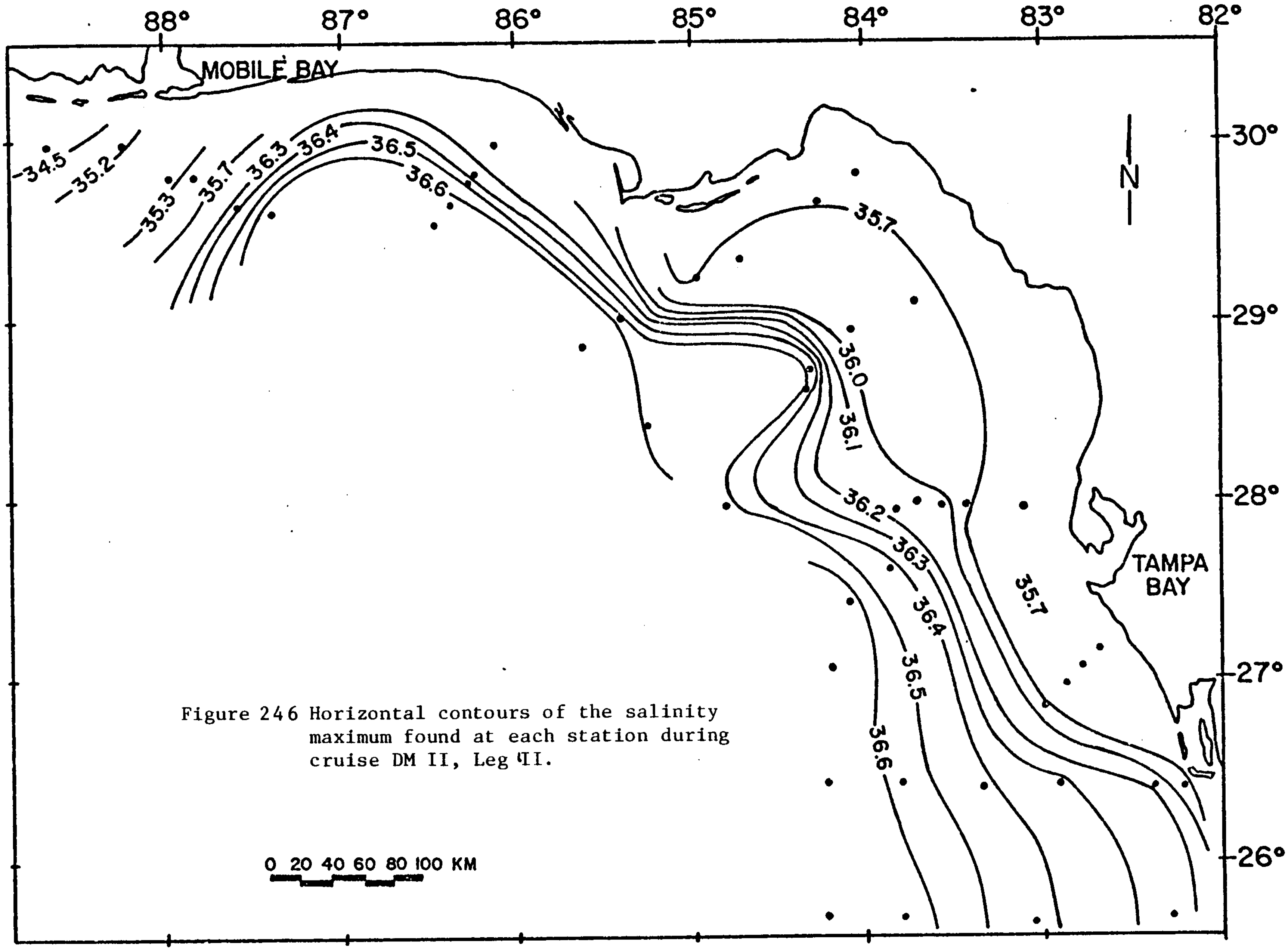

Figure 246 Horizontal contours of the salinity maximum found at each station during cruise DM II, Leg III.

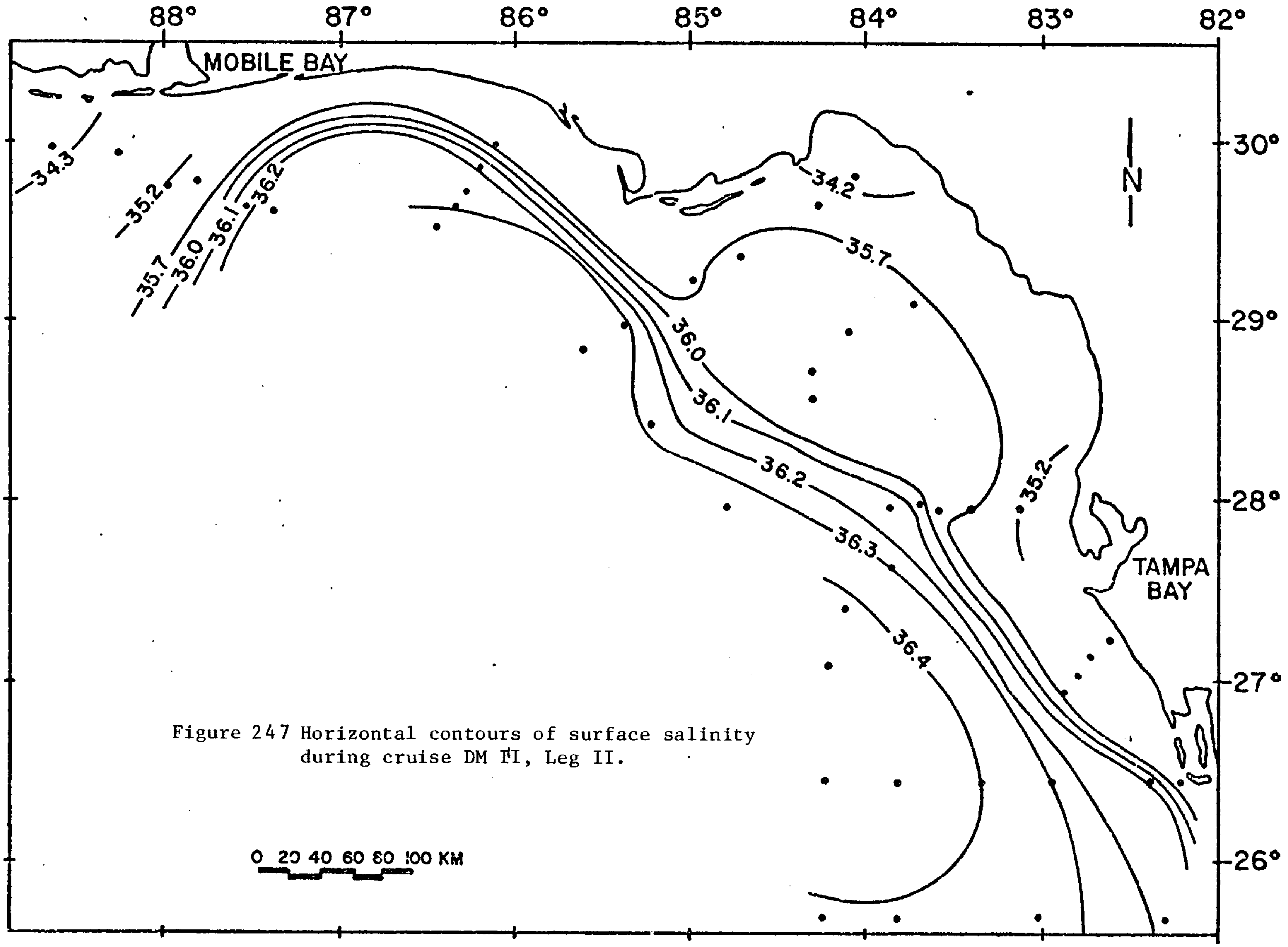

Figure 247 Horizontal contours of surface salinity during cruise DM II, Leg II.

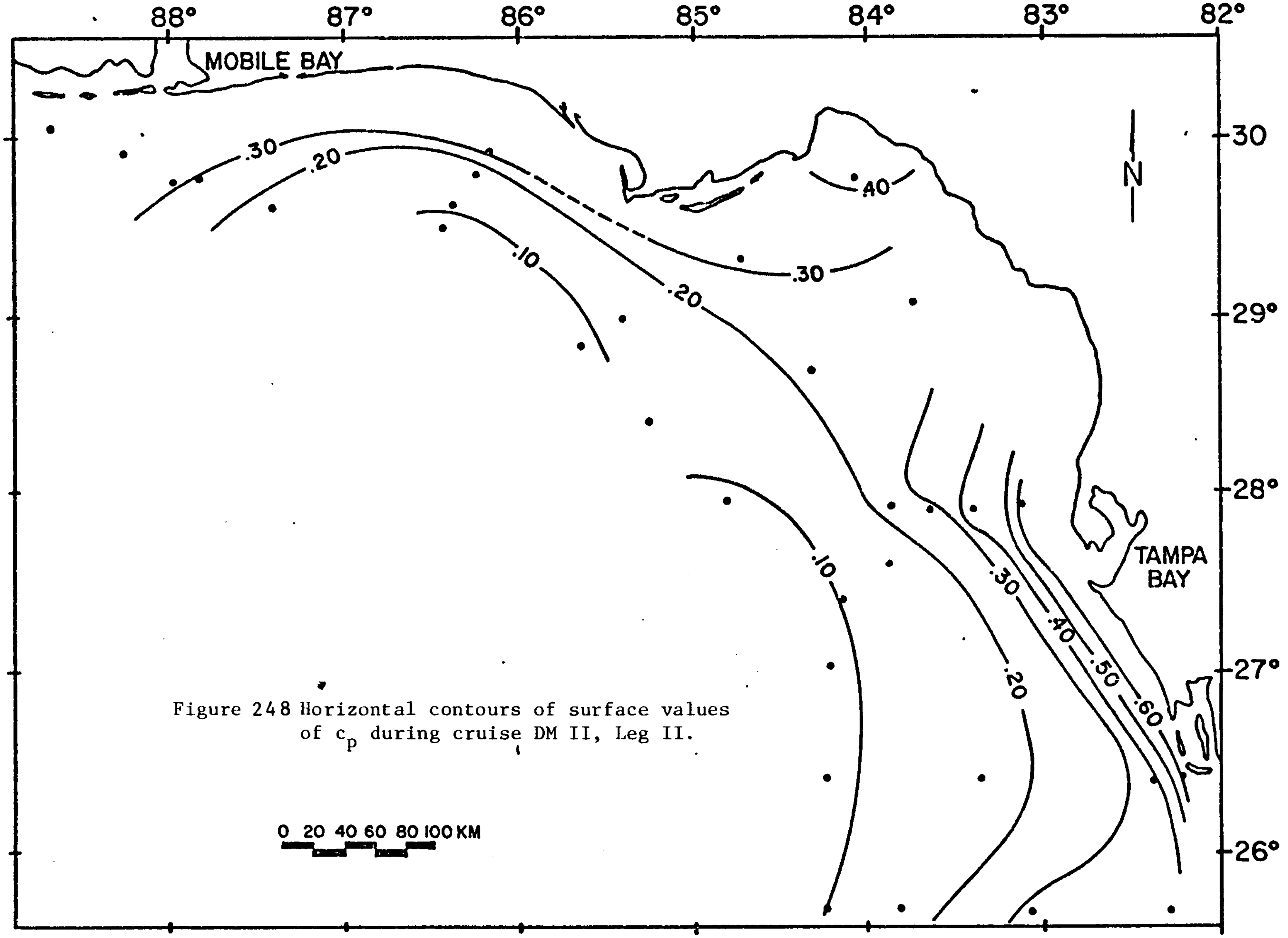

Figure 248 Horizontal contours of surface values of c_p during cruise DM II, Leg II.

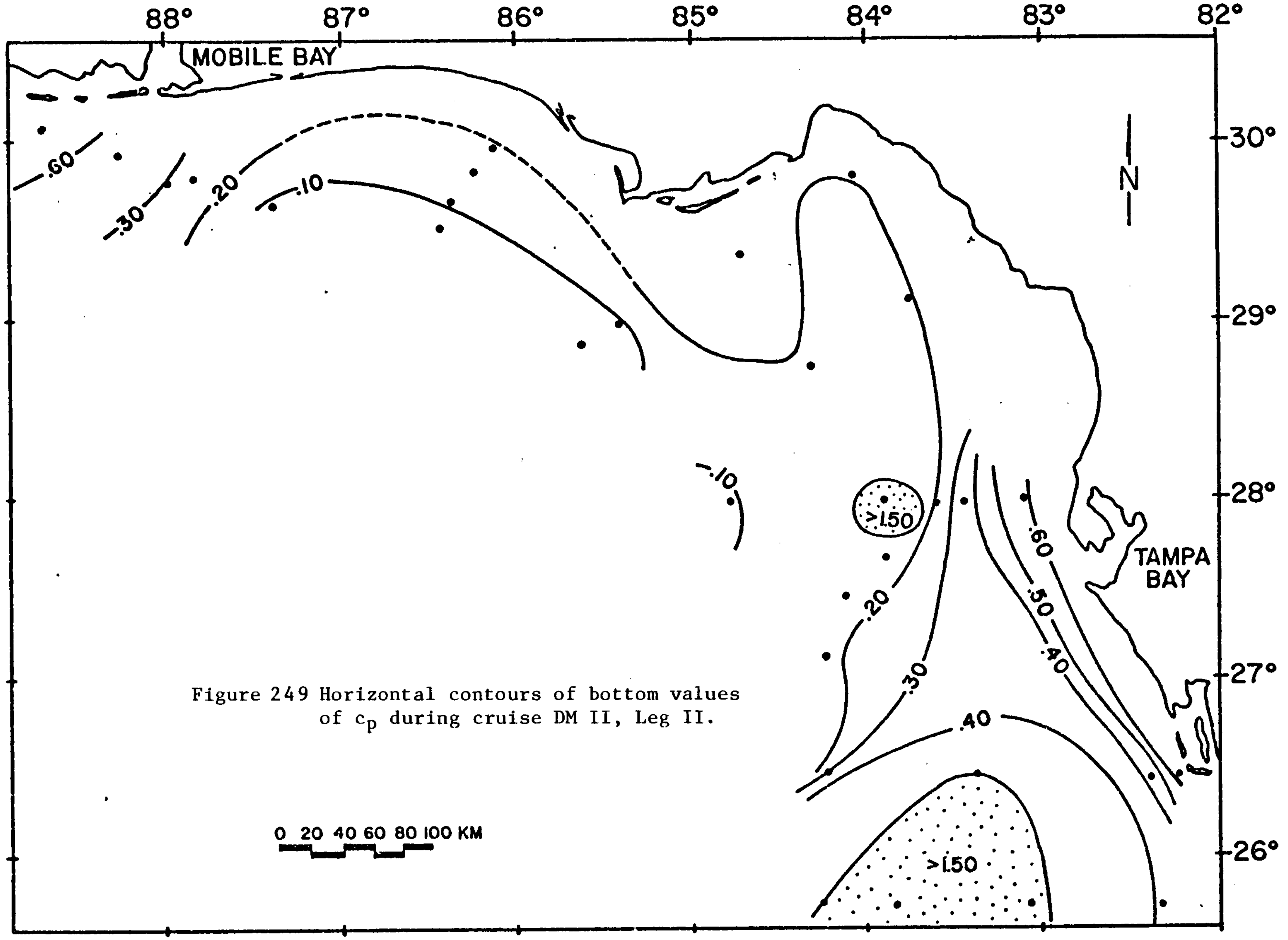

Figure 249 Horizontal contours of bottom values of c_p during cruise DM II, Leg II.

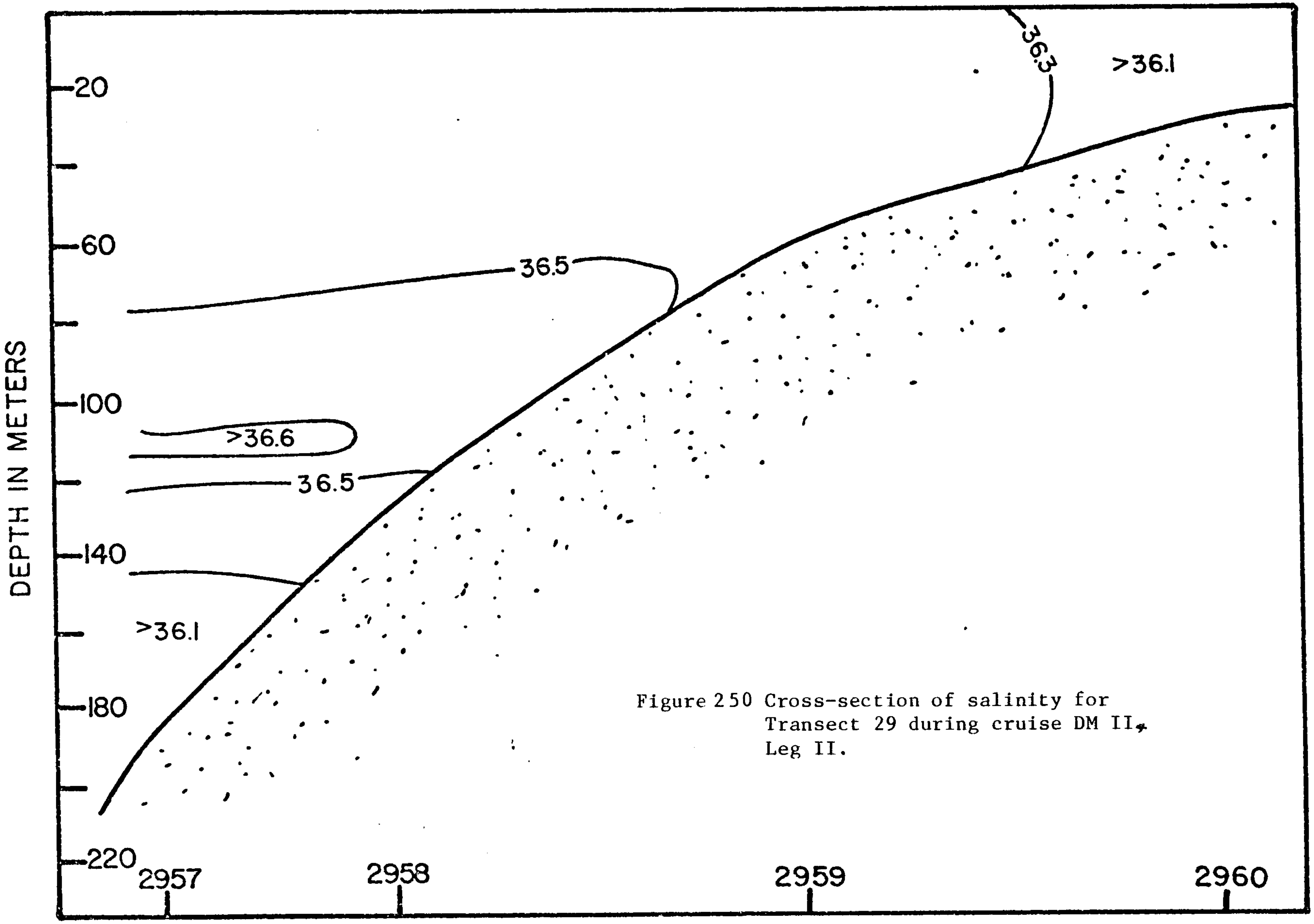

Figure 250 Cross-section of salinity for Transect 29 during cruise DM II, Leg II.

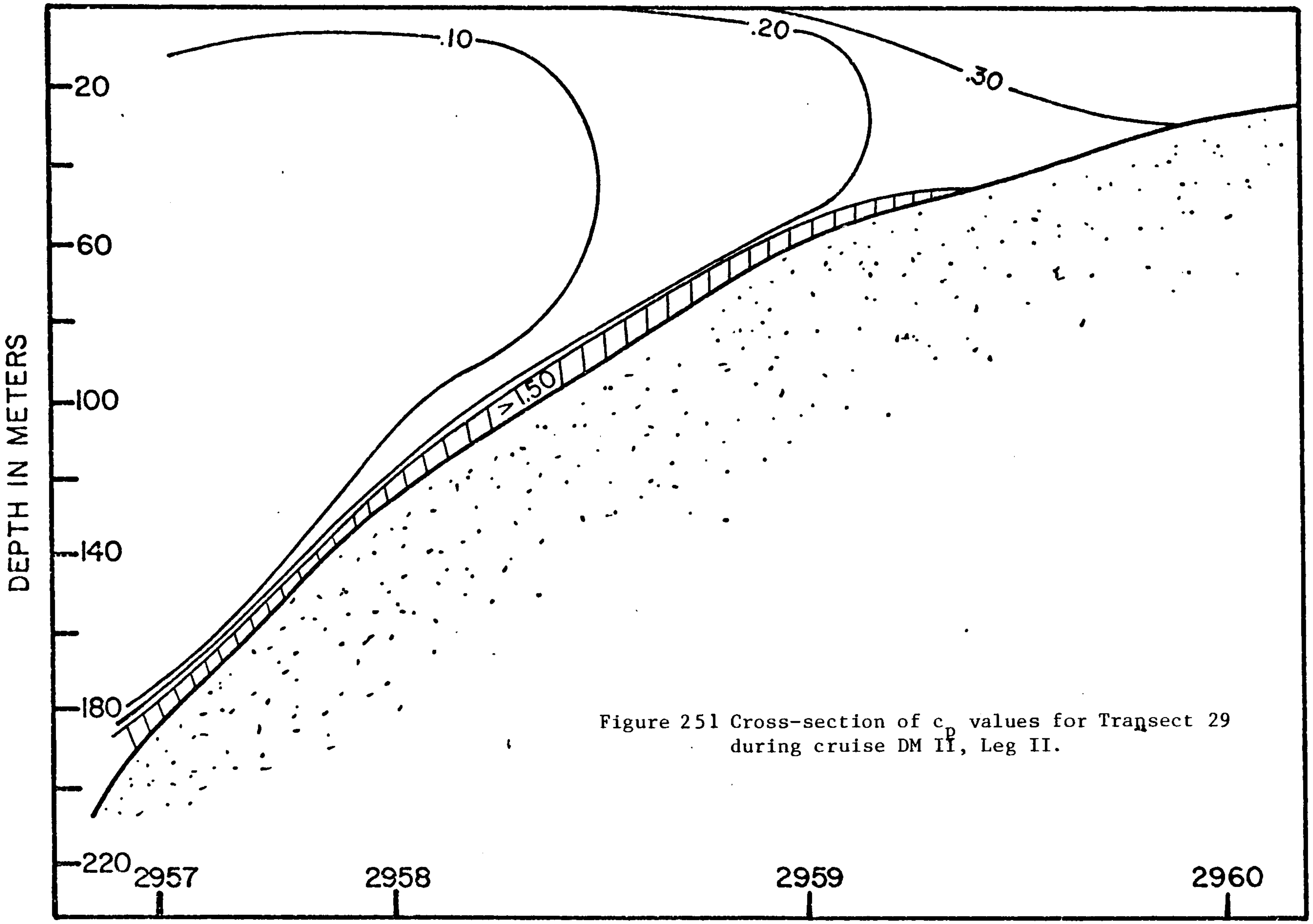

Figure 251 Cross-section of c_p values for Transect 29 during cruise DM II, Leg II.

the sampling in shallow water off Mobile and Panama City, these were the most turbid waters measured during the entire MAFLA project (1975-1978). That is even more significant in view of the general coarseness of the carbonate sediments of this southern region. Less extreme examples of oceanic waters penetrating onto and eroding the MAFLA shelf regions were found on Transects 21, 22, and 23 (see Figures A-1 through A-11 in the Appendix).

TEMPORAL VARIATIONS

Summer 1976

Results from three 120-hour time series stations conducted during the summer of 1976 are shown in appendix Figures A-12 through A-14. The station locations for that study are shown in Figure 252. Details of the summer sampling program have been reported in Steward and Carder (1977) and Steward et al. (1978), and only results will be summarized here.

A highly turbid lens of brackish water (Mississippi Water) was located to the southeast of Station B, extending to a depth of about 15 m. A similar lens was found inshore near Mobile Bay. A nepheloid layer extended across the entire shelf near the bottom. Clear water was found between the surface and bottom turbidity regimes at the two offshore stations, providing a horizontally stratified turbidity regime. Advection of any of those features onshore or offshore would cause a time-varying c_p signal at Station B. Attenuation coefficients as high as 2.3 m^{-1} were found in the nepheloid layer inshore of Station B, and values in excess of 0.9 m^{-1} were in the Mississippi plume. During the time series at Station B, values exceeding 1.5 m^{-1} occurred in the surface plume, but nepheloid layer values never exceeded 1.0 m^{-1}. Between those boundaries, values less than 0.2 m^{-1} were found due to penetration of ocean water.

In Steward et al. (1978), were reported that analysis of variations in the up and down temperature traces indicated than 15 to 20 minute period internal waves were present. When wave amplitudes were maximum (0500 - 1300 hours, 6/14), the turbidity in the nepheloid layer was greatest. Thus, erosion of the shallow bottom (33 m) by internal waves in the thermocline is an important nepheloid generation mechanism in the regions adjacent to the DeSoto Canyon due in part to the narrow shelves. Roberts (1975), Boston (1964), and Dowling (1966) all have found this region subject to internal gravity waves during the summer when strong thermocline develops. This is also a major unwelling area of Loop Current waters during the summer, suggesting that Loop Current water may be the source of the clear ocean water, separating at times the river plume effects at the surface from the bottom nepheloid layer. Vertical stratification in the turbidity patterns was the general rule at Station B.

At Station C, the waters were generally quite clear and vertically homogeneous. Horizontal advection of water masses of differing clarity could cause this type of temporal pattern. The reduced variability of the clarity of waters at this station supports the temporal validity of the seasonal measurements.

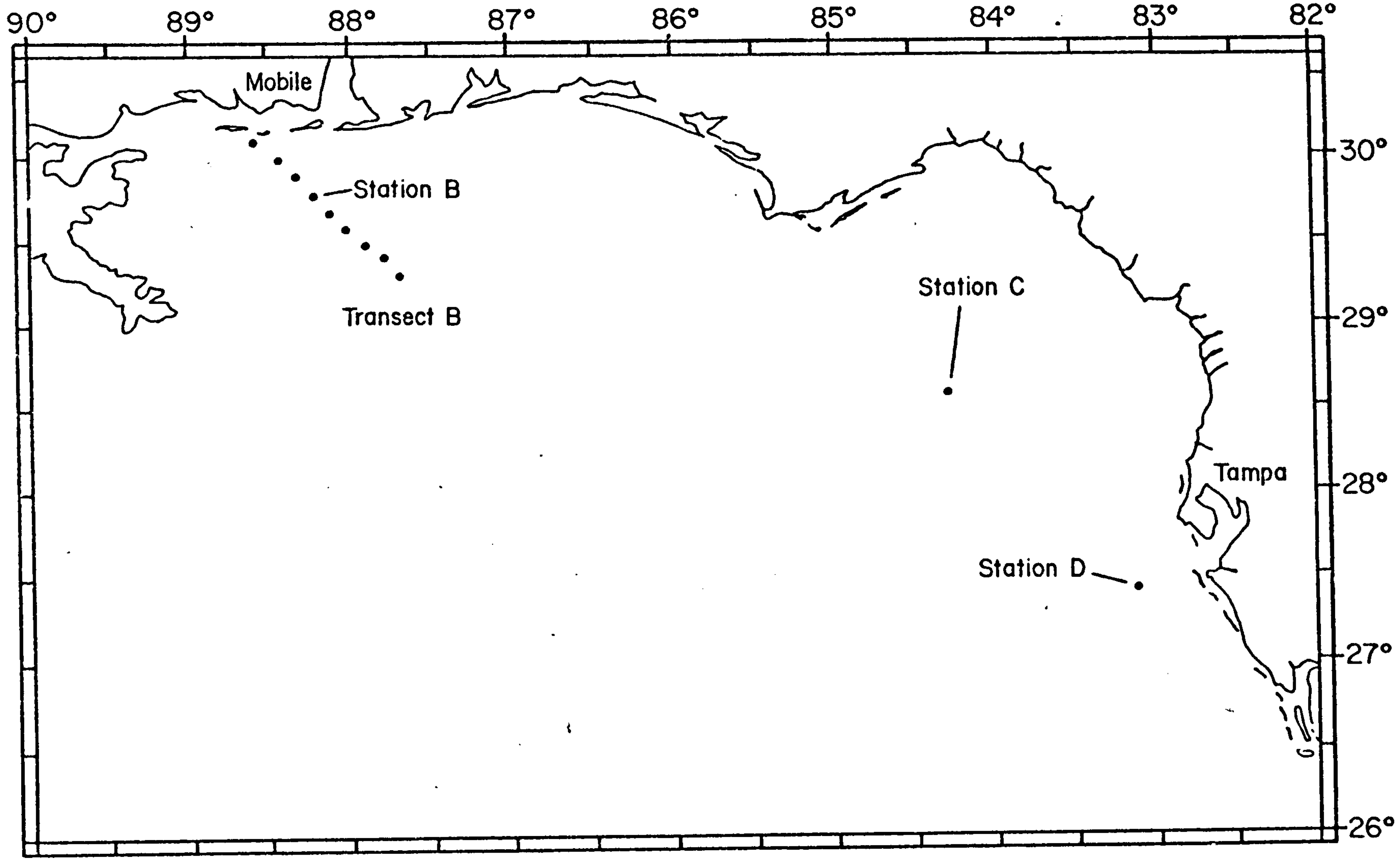

Figure 252 Station locations for summer 1976 time series stations and Transect B.

At Station D, vertical homogeneity of the particulate concentrations was the general rule except near the bottom. Extremely clear water ($c_p < .10$ m^{-1}) was usually present with aperiodic protrusions into the area of more turbid shelf waters ($0.3 \leq c_p \leq 0.60$). The patchy nature of the data at this station suggests either that oceanic water (probably Loop Current) had incorporated boluses of shelf water in its shoreward edge or that biological patchiness was present. Station D appeared to be just seaward of a summer transition zone between shelf and oceanic water types. Due to the meandering of the Loop Current during the summer, this boundary does move, however.

Fall 1977

A program of short time-series statons was conducted during fall 1977 on the first leg of DM II. Each of four stations were sampled for 12 hours with 2-hour sample intervals. Each series was too short to look for periodic causative mechanisms but could reveal a measure of temporal variability at certain stations. Surface values of c_p varied from 0.19 m^{-1} to 0.11 m^{-1} to 0.14 m^{-1} during the twelve hours at Station 2747. Below 9 m, the water was of oceanic clarity ($c_p \doteq .10$ m^{-1}) with a slight increase near bottom. Water turbidity increased by about 0.03 m^{-1} throughout the water column at the twelfth hour of the series.

The 12-hour time series at Station 0005 (Middle Grounds) revealed a profile similar to that at Station 2747 except that the entire water column was more turbid. Surface values varied from 0.17 m^{-1} to 0.37 m^{-1} to 0.13 m $^{-1}$ during the series, with bottom values ranging from 0.17 m^{-1} to 0.24 m^{-1} to about 0.10 m^{-1}. Intermediate-water turbidity first increased from 0.13 m^{-1} to 0.24 m^{-1} and then decreased to oceanic levels of 0.09 m^{-1} at the end of the series. The turbid lens (12 m thick) that occurred two hours into the series was gone two hours later. It may have been a patchy phytoplankton bloom. Bottom water temperatures increased toward the end of the time series, supporting the hypothesis that clear oceanic water was intruding into the region.

At Station 2529, casts 73, 75, and 77 produced transmissometry profiles where the surface, middle, and bottom water c_p values were 0.16 m^{-1}, 0.13 m^{-1}, and 0.26 m^{-1}, respectively. Cast 74 resulted in a nearly nearly homogeneous profile (0.17 - 0.21 m^{-1}) with bottom values increasing to 0.27 m^{-1}. That change was accompanied by a slight increase in mid and bottom water temperatures. Cast 76 produced lower values of c_p (0.14 - 0.21 m^{-1}).

The profiles at Station 2529 were more variable with time, due to its proximity to the Mobile Bay system. Surface values of c_p ranged from 0.19 m^{-1} to 0.18 m^{-1} without regard to changes in salinity. Bottom values varied from 0.45 m^{-1} to 0.69 m^{-1} from cast 73 to cast 76. Thickness of the bottom nepheloid layer increased from 8 m to about 14 m during the series. At the same time, winds increased from 10 - 15 kts to 18 - 25 kts, suggesting that wind-driven currents may have thickened the benthic boundary layer.

Winter 1978

During the winter time series cruise of 1978, several storm fronts passed through the northeast Gulf of Mexico. Plots of wind velocity versus time during each of the four stations are shown in the Appendix (see Figures A-15 through A-18). The winds were generally out of the north-northeast, except for Station 2639 when they were from the west-northwest. Wind speeds as high as 45 kts (mode=35) with sea states up to 5 were encountered at Station 2639, and speeds of 27 kts with sea states of 5 were observed at Station 2315.

Plots of the four 120-hour transmissometry time series stations are shown in the Appendix (Figures A-19 through A-22). At Station 2747, the water column was not stratified. The appearance of a clear water lens in mid-water column every 24 - 26 hours suggests that tidal or inertial currents brought clear oceanic water shoreward periodically. Sustained 15 to 20 kt northerly winds after February 4 apparently set up a seaward Ekman flow, preventing the reappearance of oceanic water after 0700 hours February 6. Small boluses of turbidity frequently appeared near the bottom, probably as a result of the turbulent suspension of bottom sediments. The periodicity of those events was not clear, so a power spectral analysis was applied to c_p versus time data taken just above the bottom. The results (see Figure 253) revealed that periods corresponding to half-seiche (10.6 hours) and twice-seiche (40 hours) pre-dominated the spectrum of c_p variations. Thus, periodic currents associated with the ebb and flood currents of co-oscillatory seiches (see Platzman, 1972) have enough speed to erode the generally coarse bottom sediments found at Station 2747. Data taken from the mid-water column (40 m) reveal c_p oscillations that are not affected by bottom erosion, but are simply oscillatory advection of turbidity features (e.g., gradients, turbid or clear water lenses) through the statin (see Figure 254). In this case, peaks were found at 13.3 hours, 20 to 22.7 hours, and 40+ hours. Since no peak at the inertial period (26.0 hours) was found, the 13.3 hur peak (about 1/2 the inertial period) is difficult to explain except as being the closest resolvable peak to the semi-diurnal tides. The 20 to 22.7 hour peak seems clearly (see Platzman, 1972) to match that of the fundamental (21.1 hour) co-oscillatory mode of the Gulf of Mexico in a seiche-type response to the winter storm fronts passing over the Gulf. No explanation of the 40 hour peak can be given.

At Station 2315, vertical homogeneity of c_p was the general case. The water column was considerably more turbid than Station 2747, perhaps due to its closer proximity to land. The turbidity did not appear to be of bottom origin since often the cleanest water found at the station was near the bottom. The patchiness of the data suggest that biological components may have been responsible for much of the turbidity. The clogging of zooplankton nets at this station was caused by an algae bloom. Our data show that the turbidity persisted at this station for the entire five days.

At Station 2528, a fairly homogeneous water column was found except in the near-bottom layer, where occasional turbid pulses of bottom sediment were observed. The entire water column was more turbid than at the southern stations. Power spectral analysis of the near-bottom data revealed that the

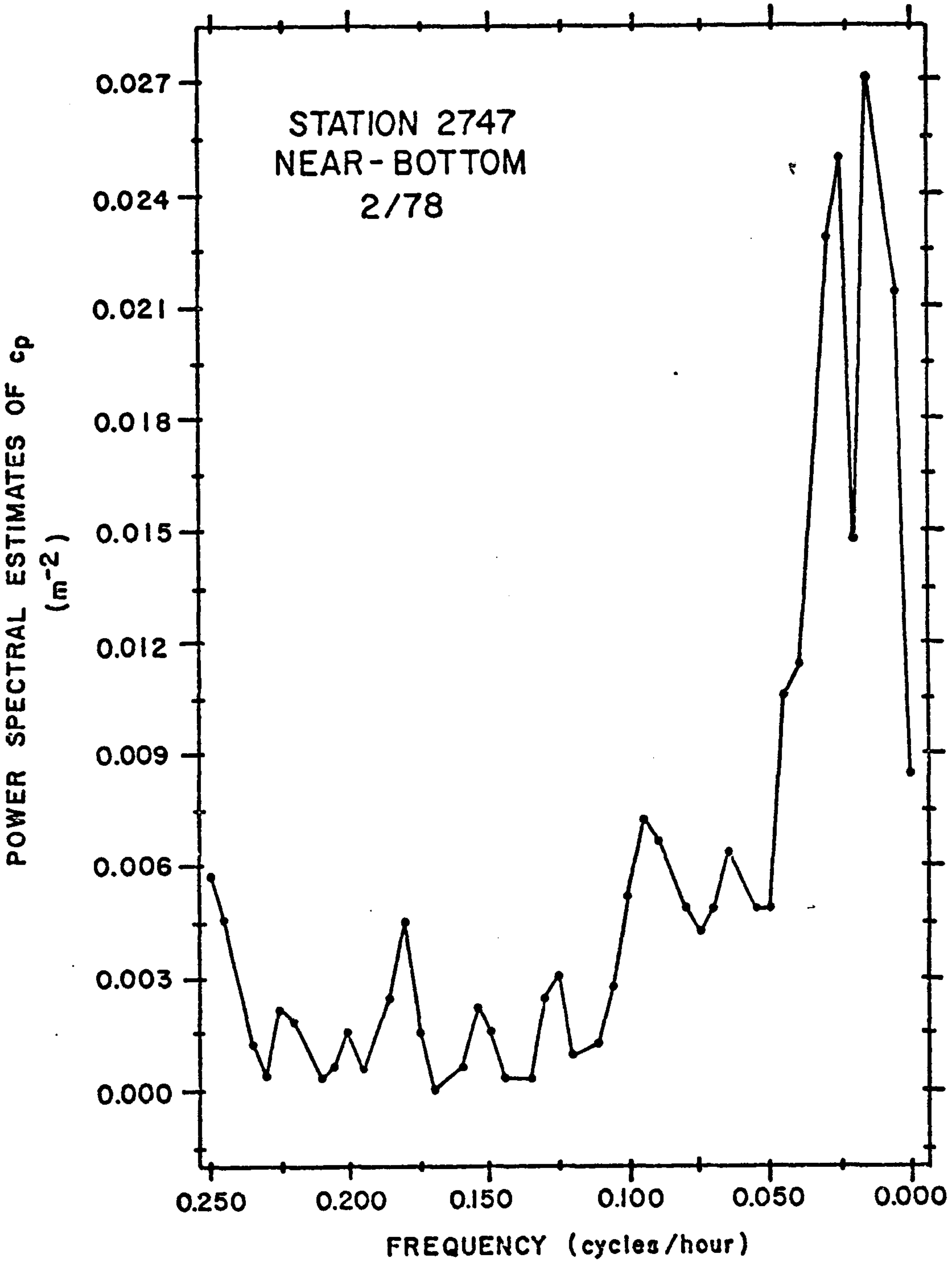

Figure 253 Power spectral estimates of the periodic variation of c_p values near the bottom at Station 2747.

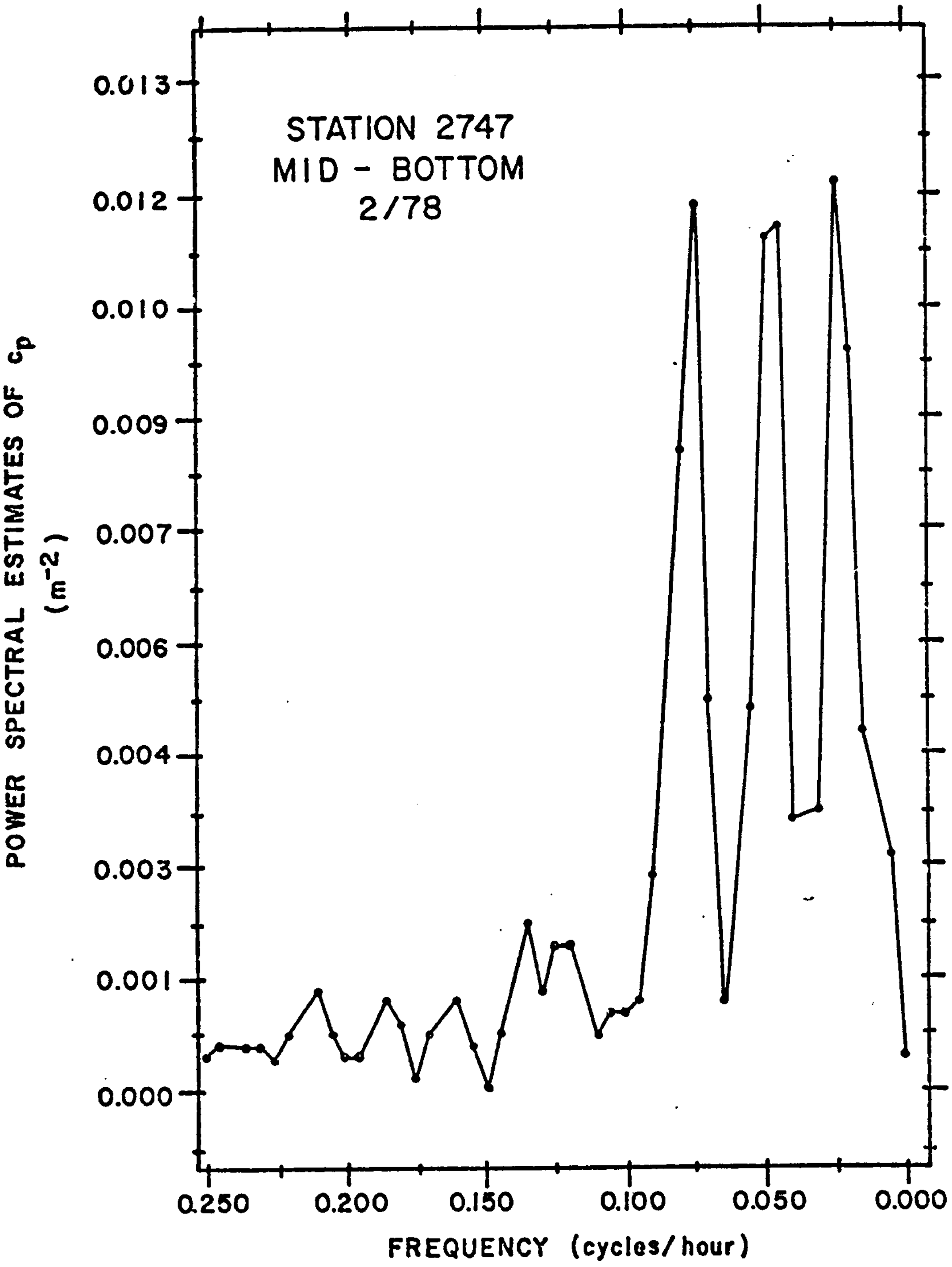

Figure 254 Power spectral estimates of the periodic variation of c_p values at mid-depth at Station 2747.

turbid pulses resulted from a mixture of oscillatory features with periods of 4.7, 6.7, 13.3+, 20.0 - 22.7, and 40 hours (see Figure 255). The 6.7 hour feature corresponds to the 6.68 hour "sloshing" mode of the Gulf of Mexico (Platzman, 1972), and the co-oscillatory mode (21.2 hours) is also present. Both of those modes could be driven by the storms associated with the passage of the warm and cold fronts over the Gulf. Again, the 40 hour and 13.3 hour periods are a puzzle.

At Station 2639, the strongly horizontally stratified summer turbidity regime became more vertically mixed, except near the bottom. The surface waters were fresher by 1 - 2% at times during the first three days of the time series, with river sources perhaps accounting for the lenses of high turbidity at the surface. Power spectral analysis of near-bottom data indicate that the variations of c_p were composed of oscillatory periods of 5.7 - 5.9, 7.6, 10.6 - 11.5, 14.5, and 27 hours (see Figure 256). A large peak at 84 hours occurred but is nearly meaningless in a 120-hour time series. Inertial, tidal, and co-oscillatory features were not existent at this station, whereas the 6.7 and 13.3 hour features found at earlier station were replaced by 7.6 and 14.5 hour periods, respectively. The 10.6 - 11.5 hour period is half the period of co-oscillatory tides, perhaps indicating erosion of bottom sediment on flood and ebb seiche, or twice during a 21.1 hour period. If this is the case, the lack of a 21.2 hour period would suggest that no significant horizontal gradient in c_p values occurred near the bottom to provide a change in signal due simply to advection. It also would suggest that the flood and ebb seiche current speeds were comparable in intensity.

If one ignores the part of each spectrum greater in period than 27 hours, the greatest oscillatory turbidity feature was found near the bottom of Station 2528 with a period of 13.3+ hours. Second in importance were the 4.7 and 22.7 hour features at the same station. These were followed closely in importance by the 10.6 - 11.5 and 7.6 hour peaks at Station 2639. While not all of the periods of the oscillations contributing to the variations in turbidity at the time series stations could be related directly to seiche periods, there is no question that storm-generated seiches play an important role in suspending and advecting sediment in the Gulf of Mexico in the winter. Any other seiche-generating phenomena (e.g., hurricanes) no doubt play similar roles.

SEASONAL COMPARISONS

During the 1975-76 transmissometry surveys of the MAFLA area, Manheim et al. (1976) reported c_p values that were generally less than 0.7 m^{-1}. Values exceeded that number in a nepheloid layer found after Hurricane Eloise and in a winter bottom nepheloid layer just off Mobile. In no case did the numbers exceed 1.5 m^{-1}. In the summer 1976 and 1977-78 sampling seasons, c_p values often exceeded 1.5 m^{-1} (see Figures 248 and A-4, and Table 93). However, since large ships were involved and high winds and seas were weathered during DM III, the large values are perhaps more indicative of being able to sample during high energy conditions than of whether or not winter 1978 was more energetic than winter 1976. Undoubtedly, if sampling had been possible during Hurricane Eloise, even larger c_p values would have been measured.

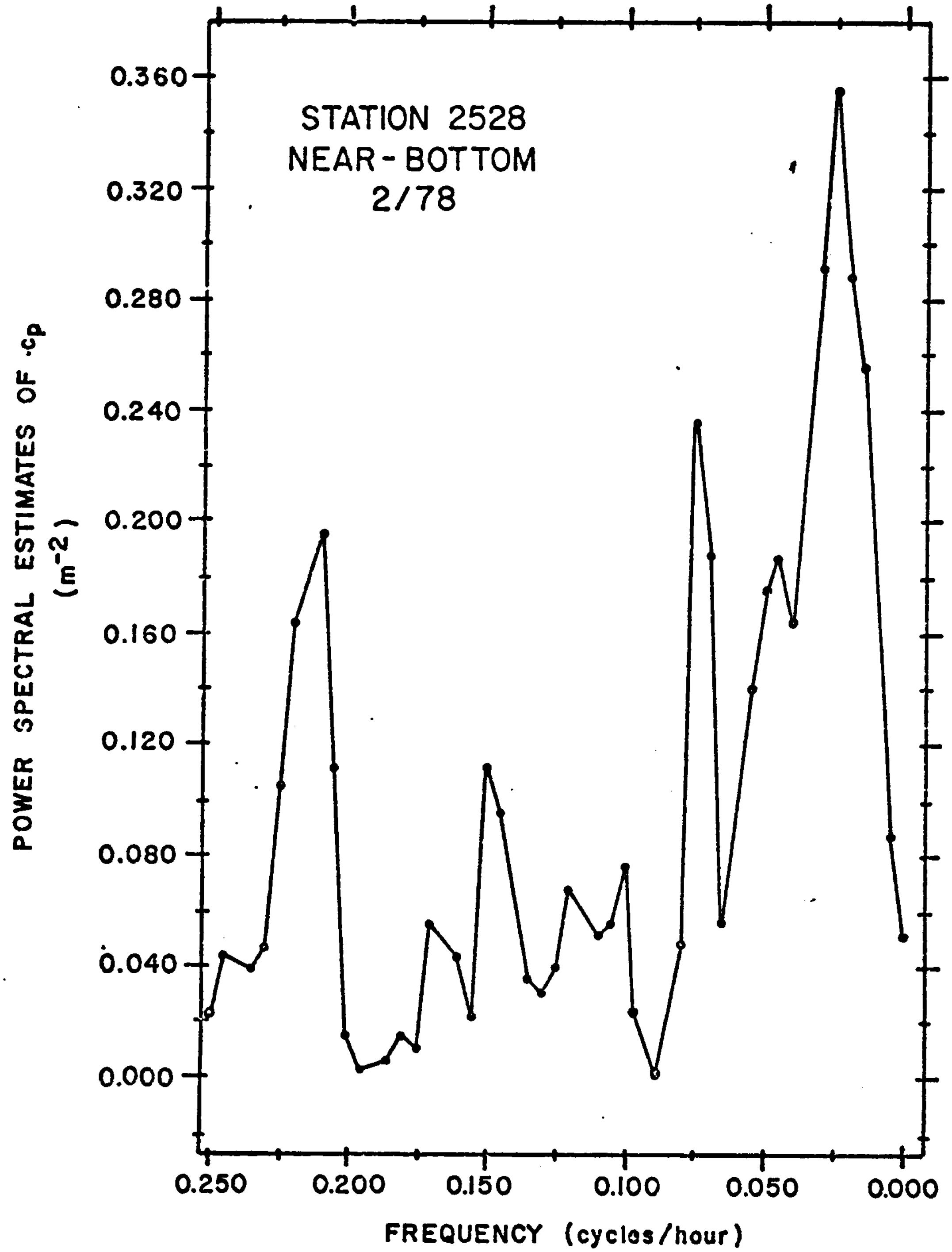

Figure 255 Power spectral estimates of the periodic variation of c_p values near the bottom at Station 2528.

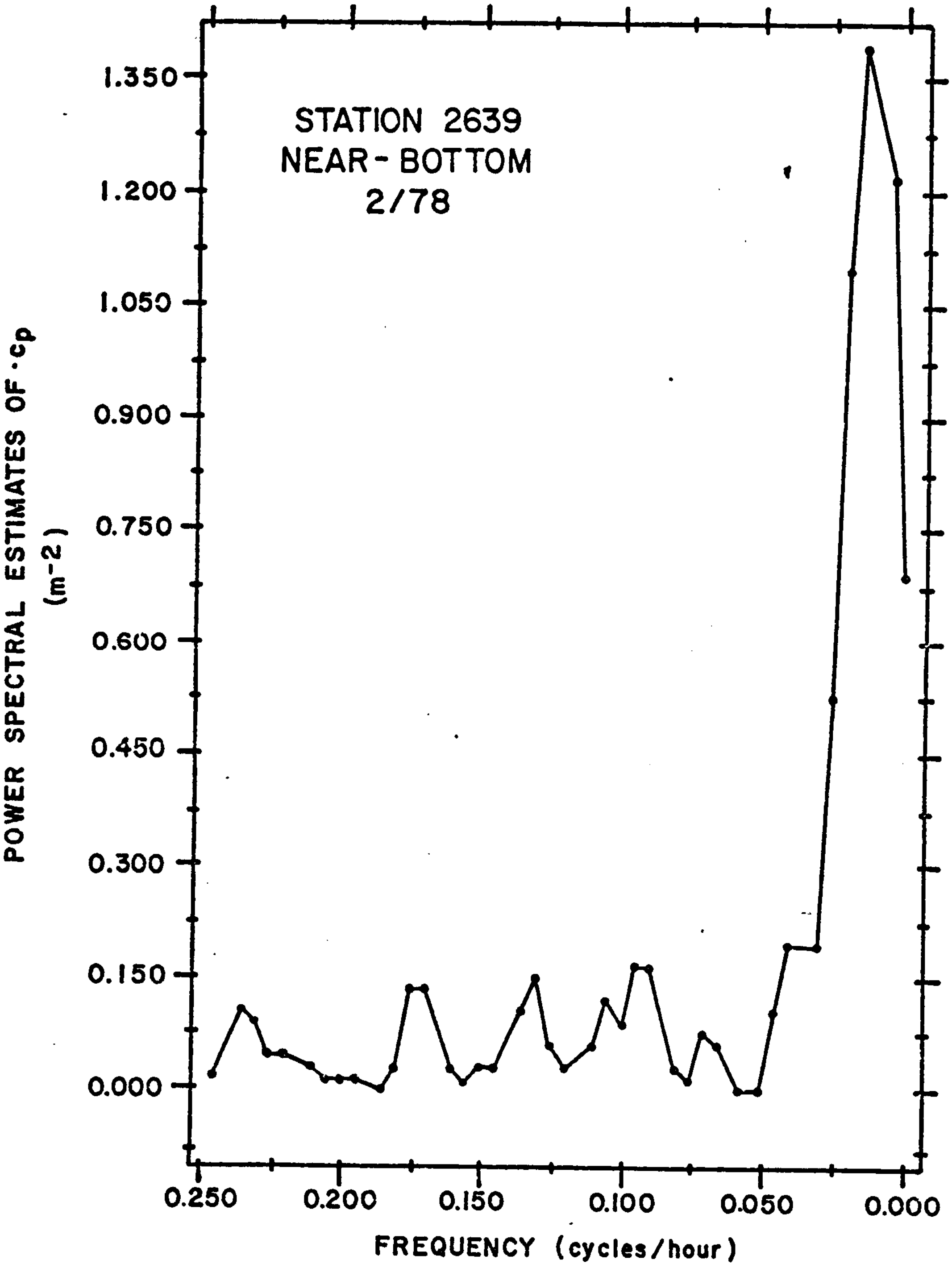

Figure 256 Power spectral estimates of the periodic variation of c_p values near the bottom at Station 2639.

TABLE 93

SUMMARY OF THE RANGE OF c_p (m^{-1}) VALUES FOUND DURING THE TIME SERIES STATIONS

STATION NUMBER	JULY 1976	STATION NUMBER	OCTOBER 1977	STATION NUMBER	FEBRUARY 1978
RIVER INFLUENCE					
B	0.07 - 1.29	2639	0.16 - 0.66	2639	0.37 - 3.30
		2529	0.08 - 0.24	2528	0.40 - 2.62
OCEANIC INFLUENCE					
C	0.09 - 0.58	0005	0.04 - 0.34	2315	0.34 - 0.67
D	0.06 - 0.54	2747	0.03 - 0.18	2747	0.05 - 0.50

One major particle source that was relatively subdued during the 1975-78 study was the Mississippi River. In summer 1973, its brackish water plume could be found over much of the west Florida Shelf (Rinkel, 1975), and it undoubtedly transported and deposited a sizeable sediment load into the MAFLA study area during that year. A brackish water river plume provided c_p values of about 1.0 m^{-1} in February 1978, at Station 2639, but such values would be small indeed compared to the expected Mississippi River plume numbers at flood stage conditions.

Major bottom erosional mechanisms have been seen during all sampling seasons. The impingement of the Loop Current onto the west Florida Shelf is especially likely during the summer and fall seasons. Internal wave effects were seen in summer 1976 data when the pycnocline was well defined. Seiche effects were observed in winter 1978 data and suspected by Manheim et al. (1976) after Hurricane Eloise.

The clearest water was usually found offshore, mid-depth, and on the southernmost transects. If Loop Current water was present and away from the bottom, it was always the cleanest. Since the Loop Current has a southern source and sink, the probability of its being found at the southern transects is greatest. However, it was present in summer 1976 and fall 1977 along the shelf break off Mobile and Panama City, providing a very sharp contrast to the usually turbid inshore waters found along Transects V and VI.

The summer water column was typically stratified in clarity with the productive surface layer usually overlying a clearer mid-layer. If turbulence was effective in eroding bottom material, a nepheloid layer resulted near the bottom. In the winter, the water column was usually more homogeneous except for the near-bottom layer.

Comparisons between summer and winter conditions during the time series stations can be made by referring to Table 93. The clearest water ($0.03 \leq c_p \leq 0.04$ m^{-1}) was found in the autumn at the southern stations, with winter Station 2747 providing c_p values (0.05 m^{-1}) nearly as low. Summer values for the northern stations were just as low (0.07 m^{-1}) when the Loop Current was present, as were the southern values (0.06 and 0.09 m^{-1}). The most turbid conditions were found in the winter nepheloid layers at the northern stations (seiche-derived) and in the summer nepheloid layer at Station B (internal wave-derived).

CONCLUSIONS

Water clarity in the eastern Gulf of Mexico increases away from vertical or horizontal interfaces, as one would expect. In the benthic boundary layer it increases with a decrease in turbulent energy (currents, seiches, internal waves, hurricanes) available to act on the bottom. In the surface layer, turbidity was largely relatable to runoff or biological productivity.

Water of a clarity comparable to Sargasso Sea water was measured in the Loop Current, which was found at times at the seaward ends of all transects. This water was 50 to 100 times as clear as water found at the northern winter stations in the nepheloid layer.

Near-bottom water clarity was affected by non-periodic (Loop Current) and periodic (internal waves, seiches, inertial currents) bottom currents, with nepheloid layers found at times in all regions of the study area. However, the rapidly shoaling, fine sediment-laden shelf off Mobile resulted in nepheloid layers during all sampling seasons. The Loop Current was energetic enough to produce massive nepheloid layers over even the coarsely sedimented southwest Florida Shelf.

The Loop Current is the primary transport mechanism for particles in the study area. The periodic current phenomena do not result in a net transport unless they are superimposed upon a current with a net directionality. However, they do provide significant erosional energy to the bottom which, coupled even with a slow (non-eroding) current, could result in a net sediment transport. In the summer and fall when the Loop current intrudes furthest into the Gulf of Mexico, a net southward transport of outer shelf sediments should result. The Loop Current also drives, at times, an eddy centered over the Middle Grounds.

During the winter, when northerly or northeasterly winds blow in conjunction with seiche activity, a general westward to northwestward transport of sediments should result. That may explain the presence of sediments suspended in the water column off Mobile, Alabama that were similar to those found on the bottom off Panama City, Florida during DM III (see L. Doyle's Final Report, Chapter 2 of the Volume).

There is no doubt that bottom sediments are moved considerable distances by currents in the MAFLA region. Any trace metals or petroleum hydrocarbons adsorbed onto such sediments will be transported with them. Transmissometers and current meters moored near the bottom at or near drill and production rigs could continuously monitor the local suspended sediment transport and help define the periodic bottom current mechanisms of the area. If an accidental oil spill occurred, this readily accessible information would help in the design of sampling strategies for assessment of the impact of the spill.

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APPENDIX A

This appendix contains additional figures which are not discussed in detail in the text.

LIST OF APPENDIX FIGURES

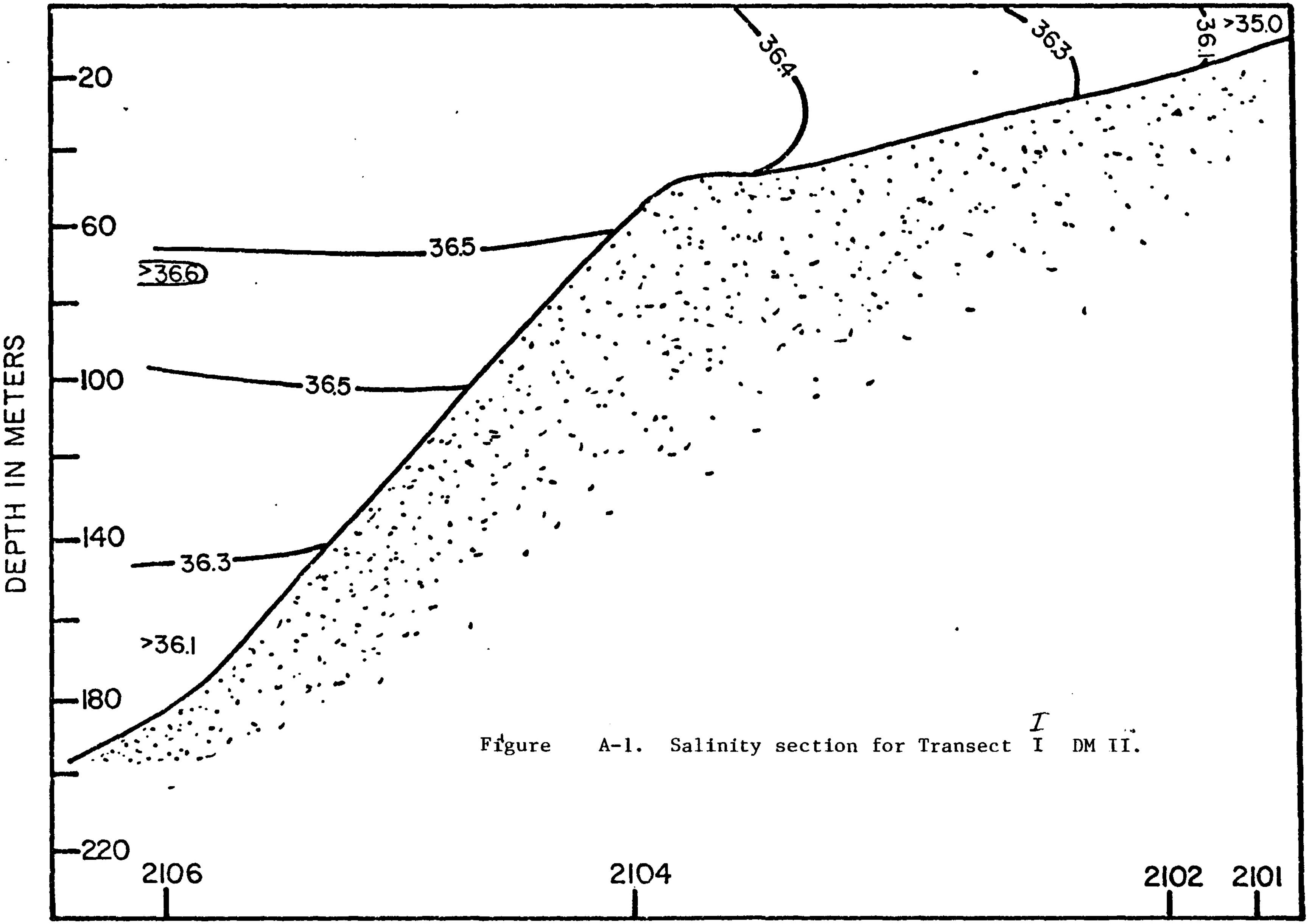


Figure A-1. Salinity section for Transect I DM II.

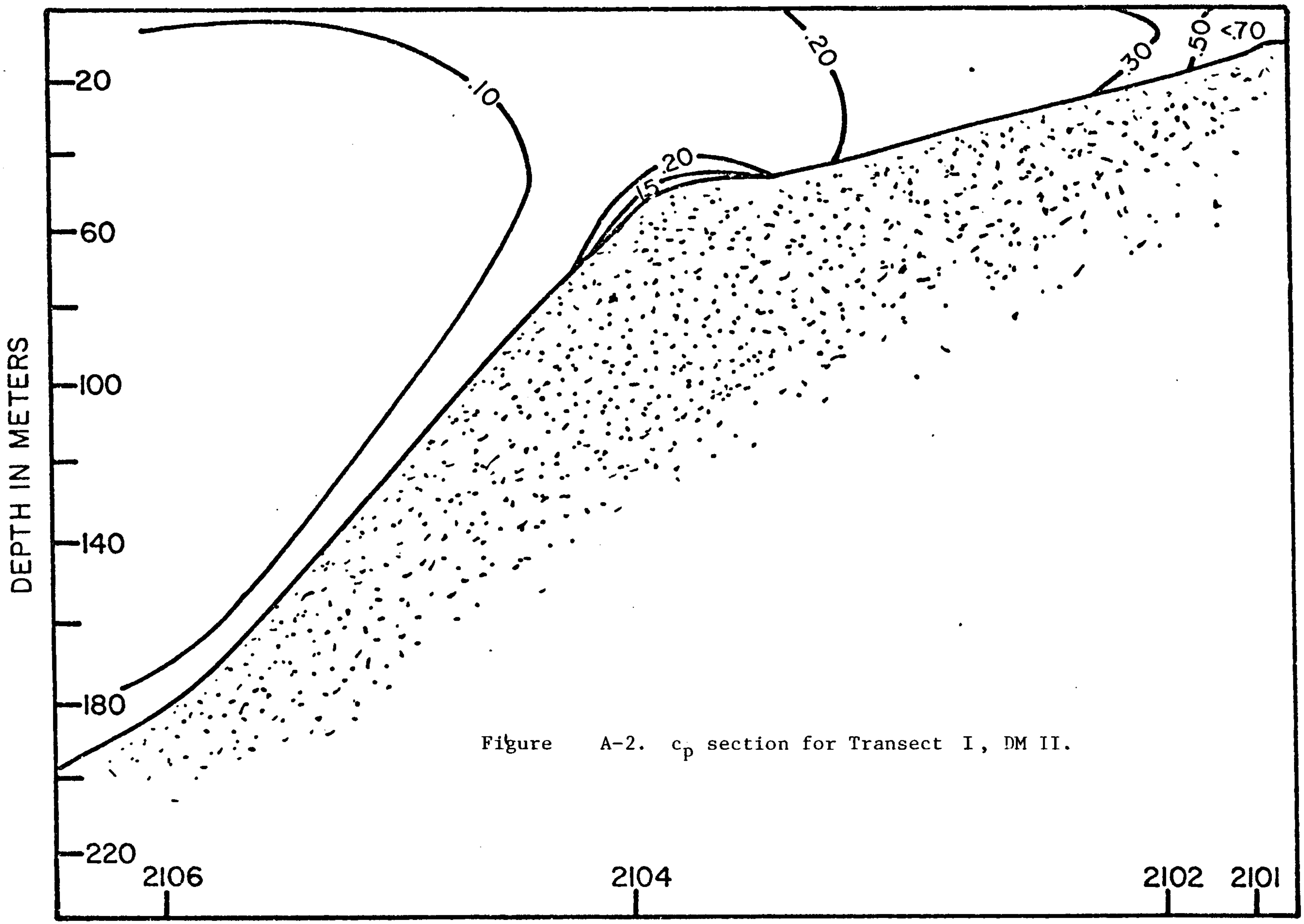


Figure A-2. c_p section for Transect I, DM II.

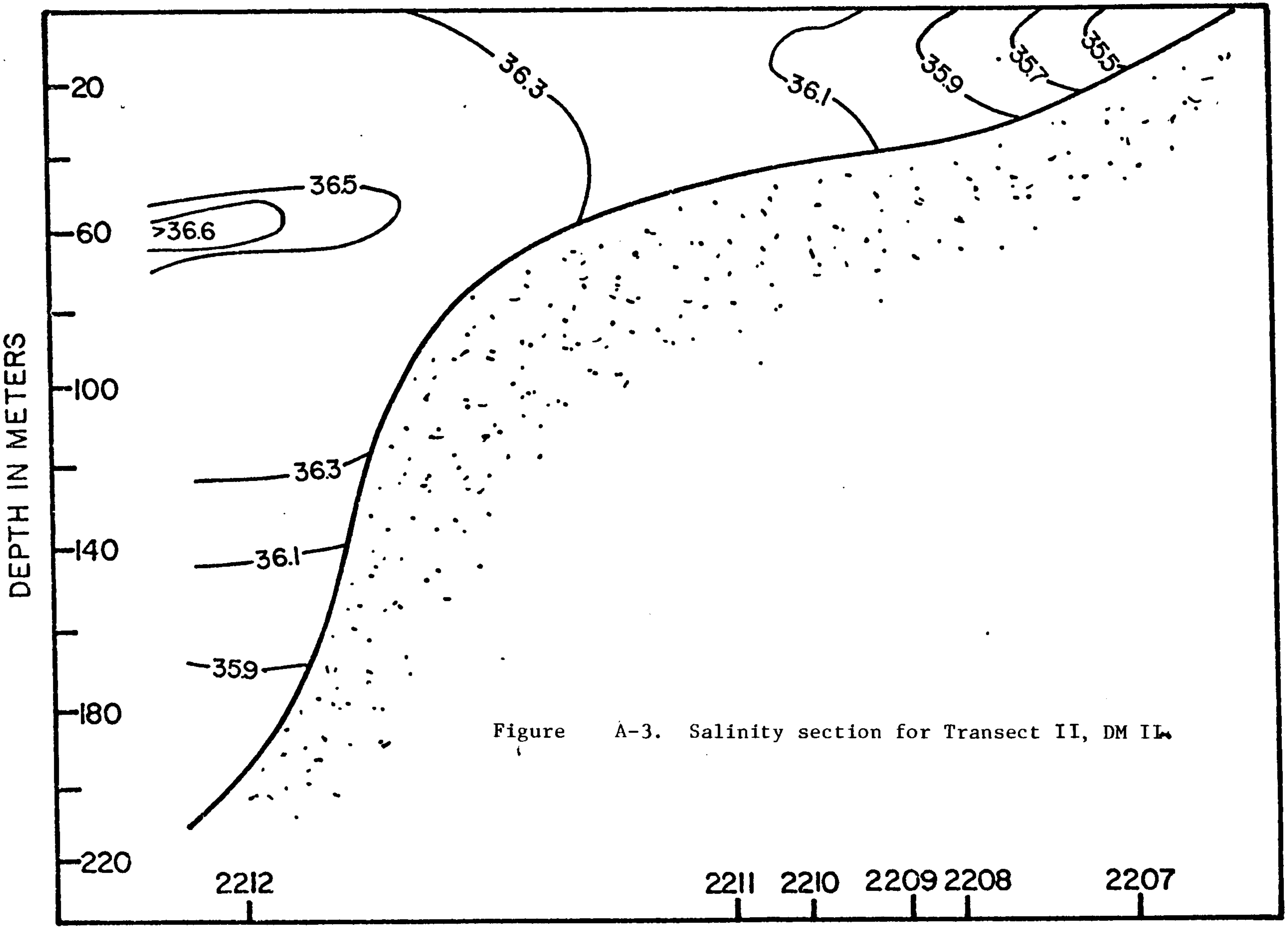


Figure A-3. Salinity section for Transect II, DM II.

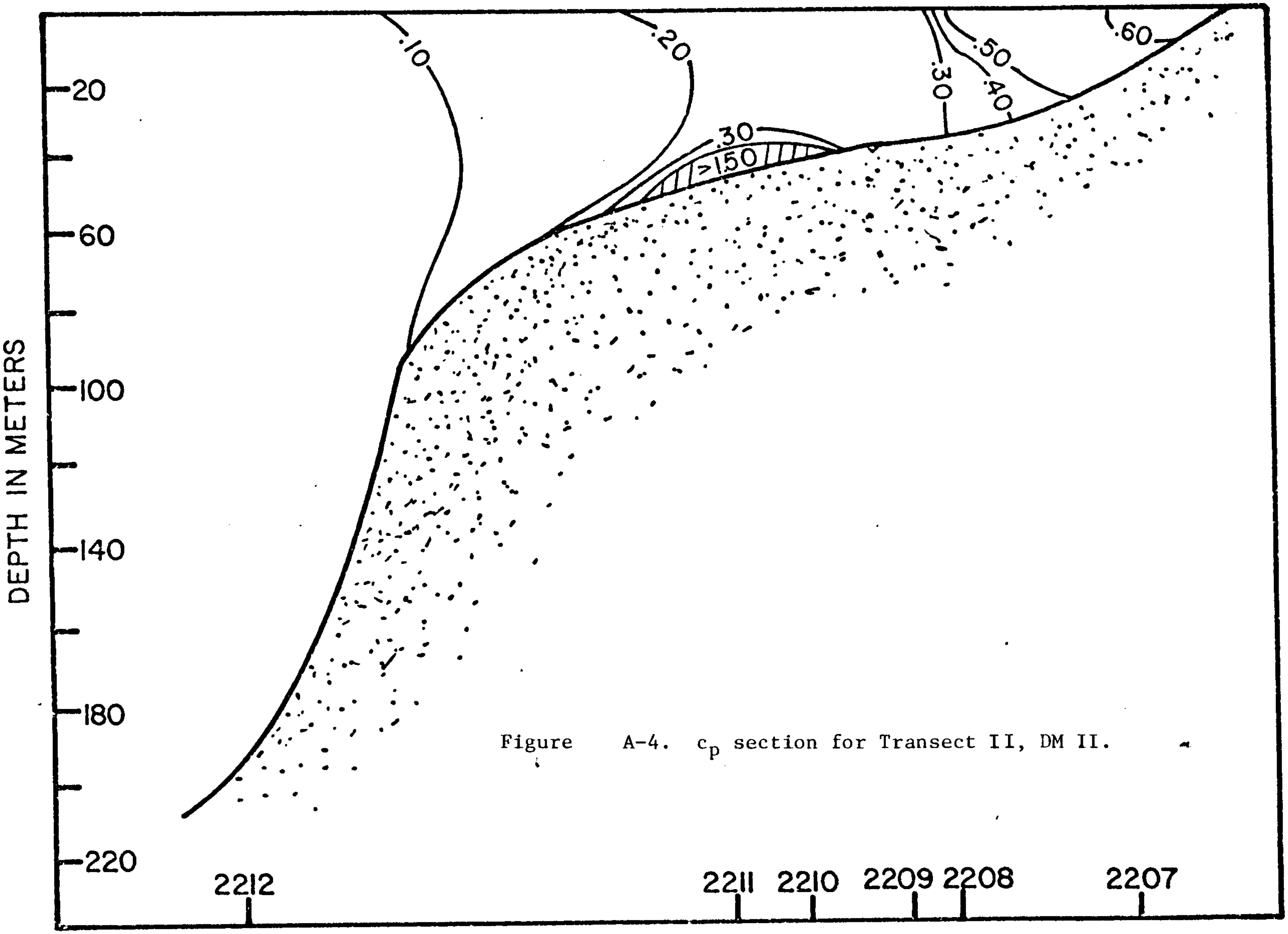


Figure A-4. c_p section for Transect II, DM II.

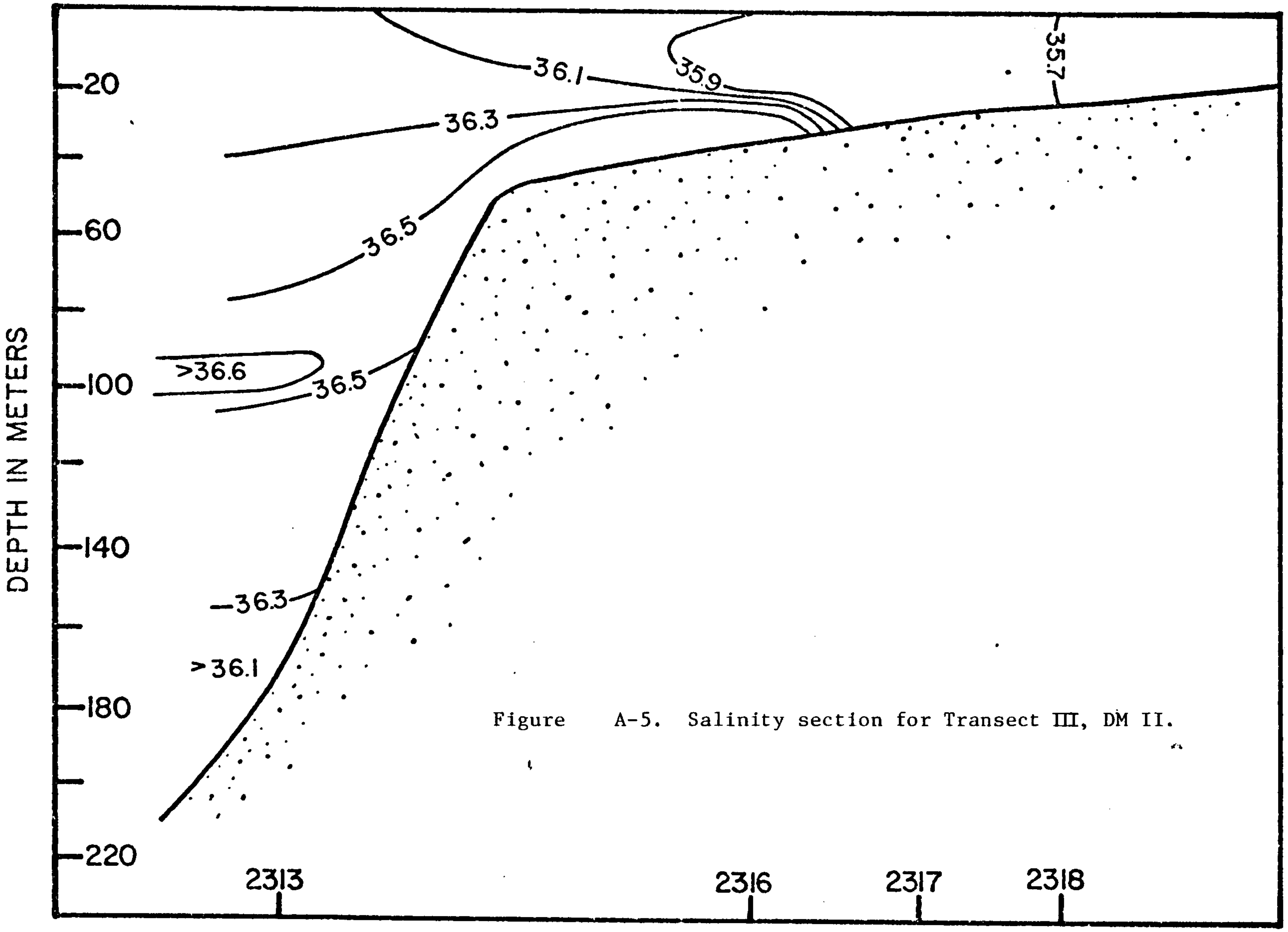


Figure A-5. Salinity section for Transect III, DM II.

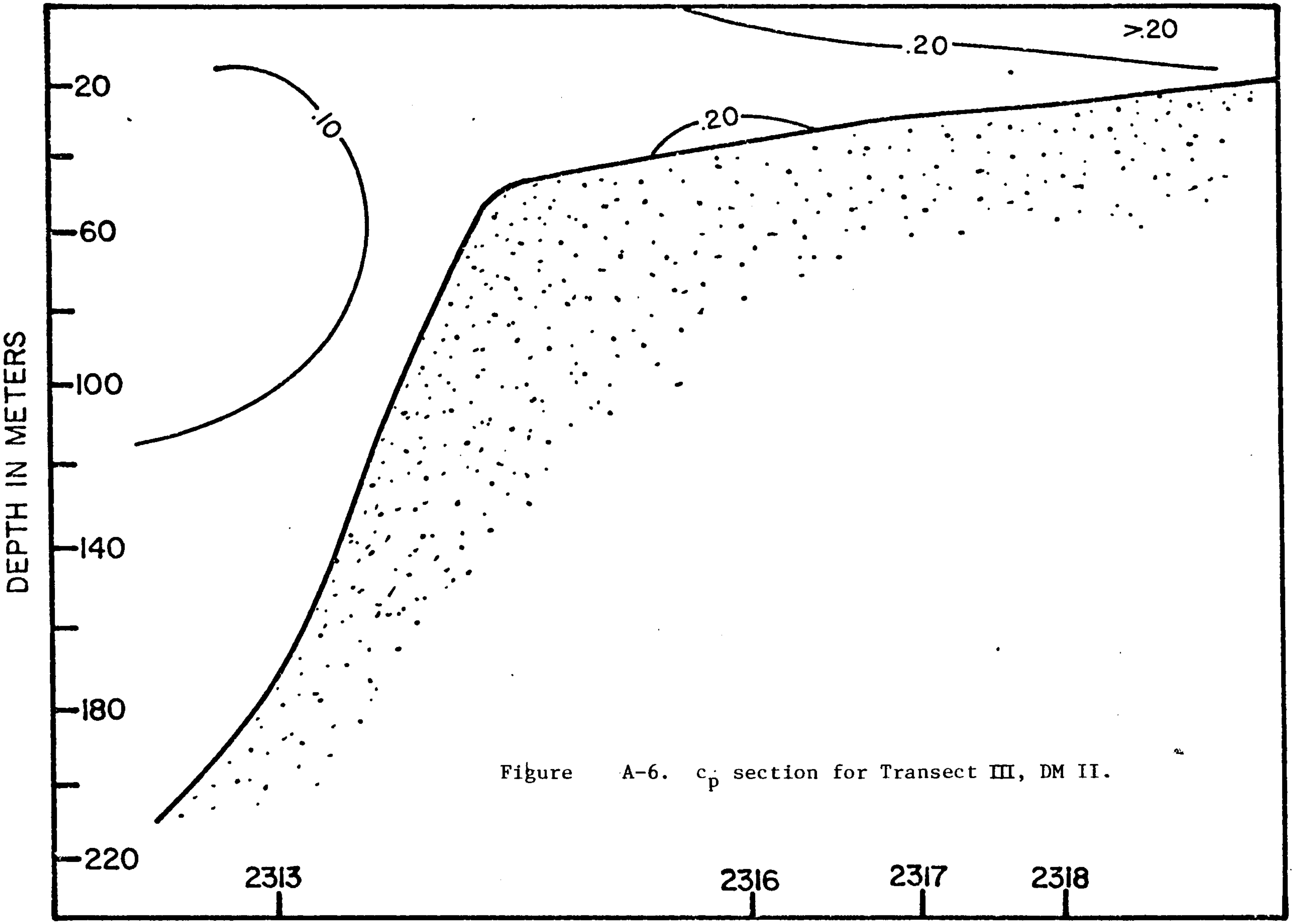


Figure A-6. c_p section for Transect III, DM II.

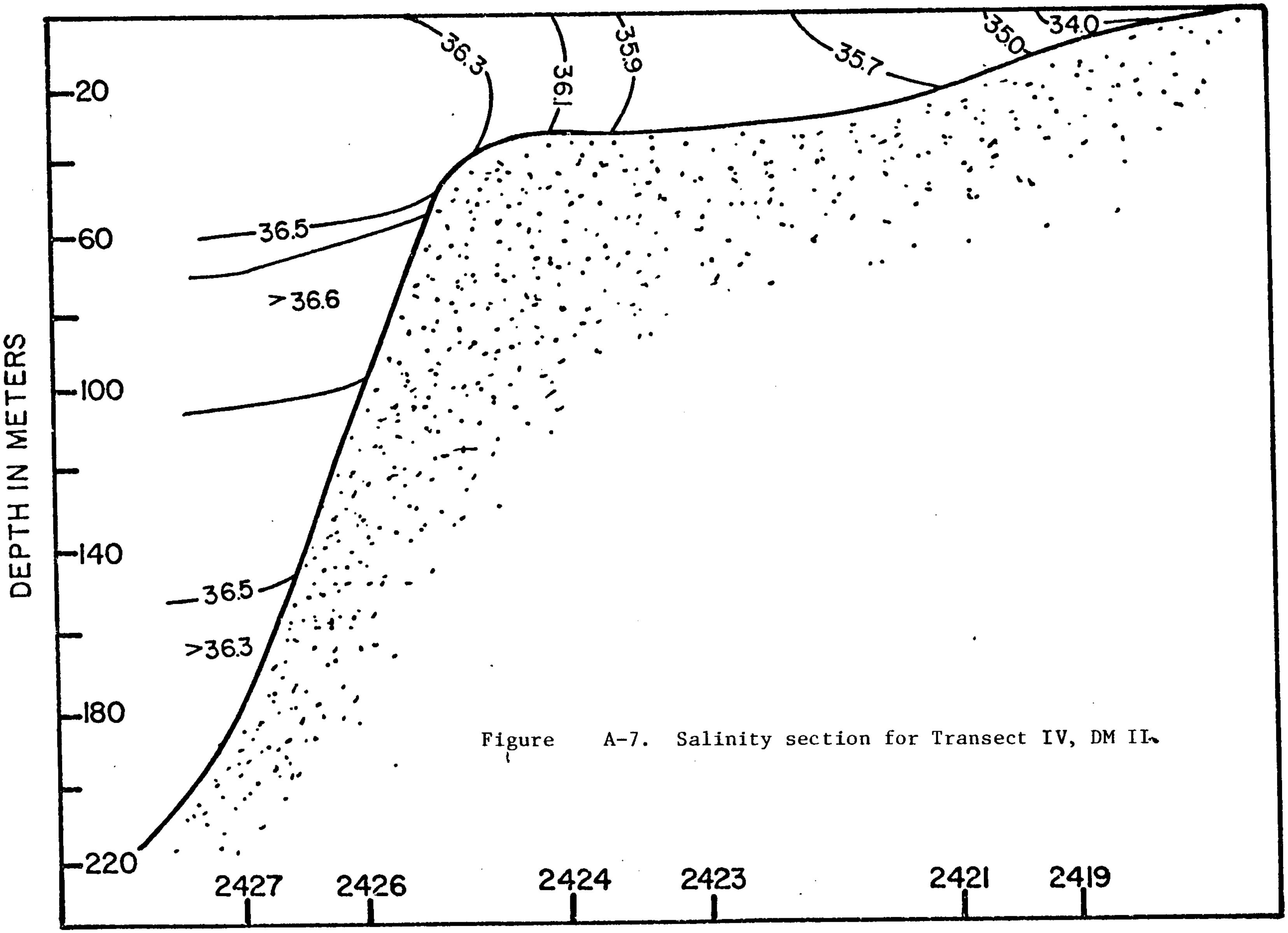


Figure A-7. Salinity section for Transect IV, DM II.

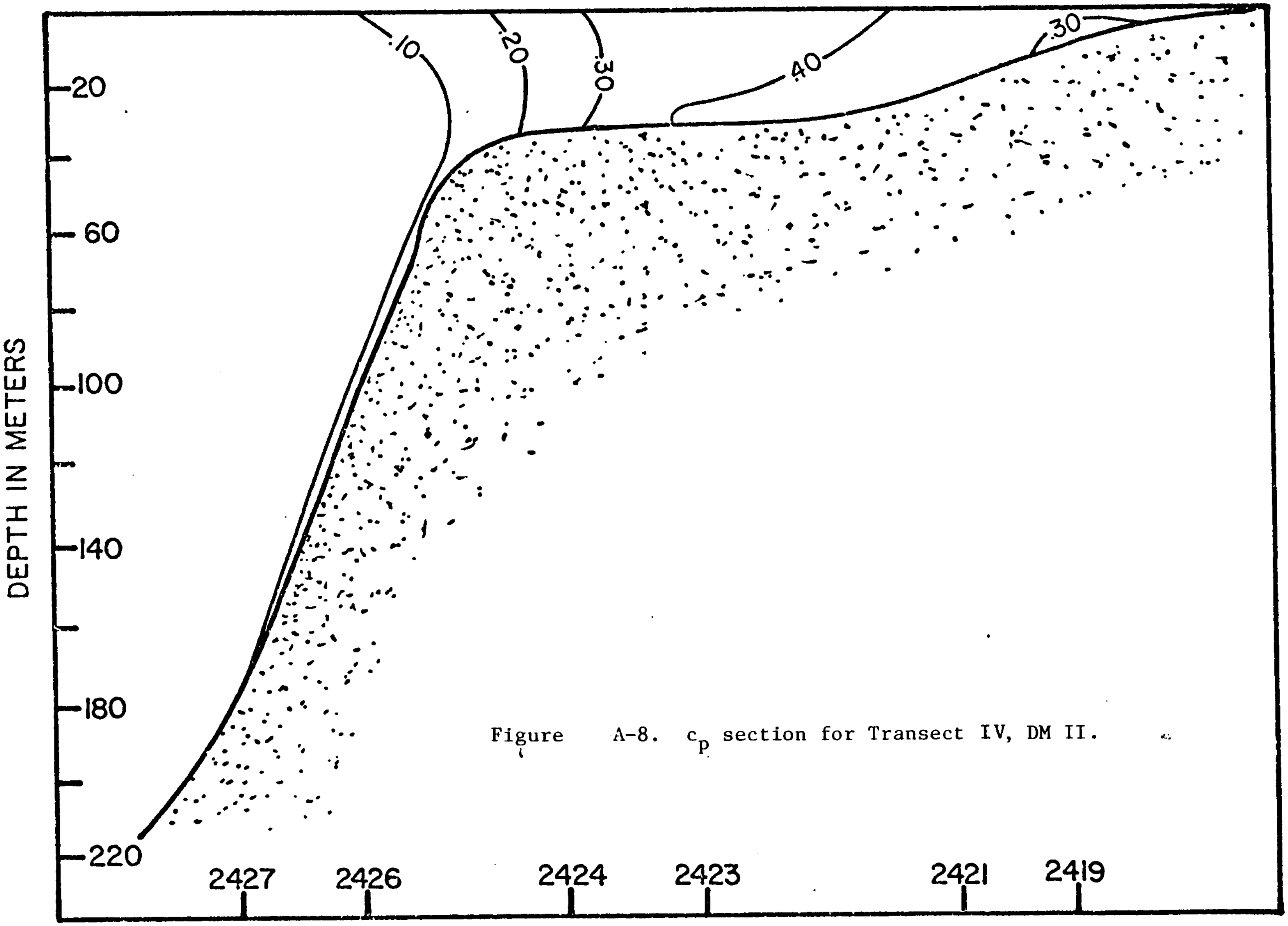


Figure A-8. c_p section for Transect IV, DM II.

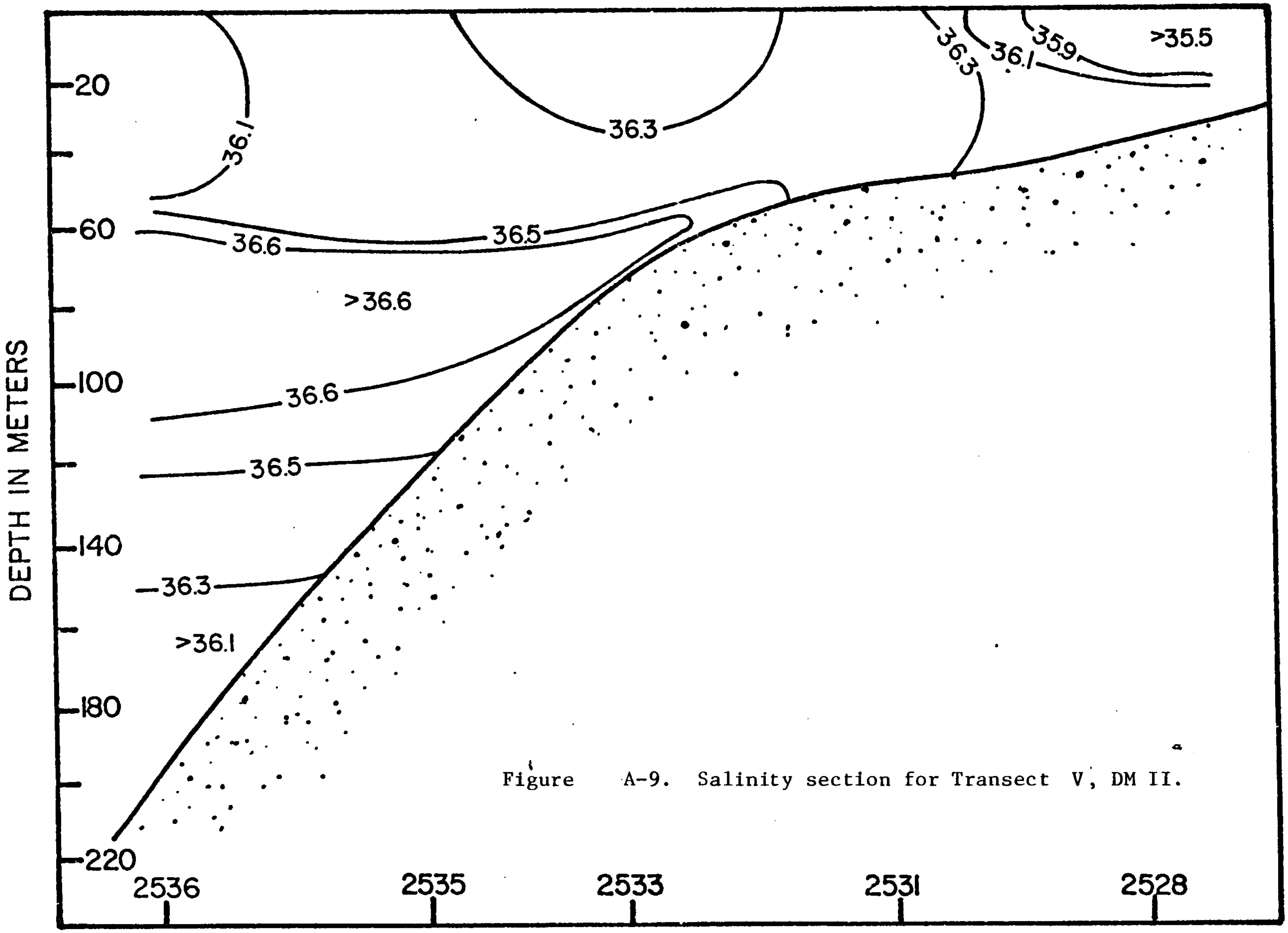


Figure A-9. Salinity section for Transect V, DM II.

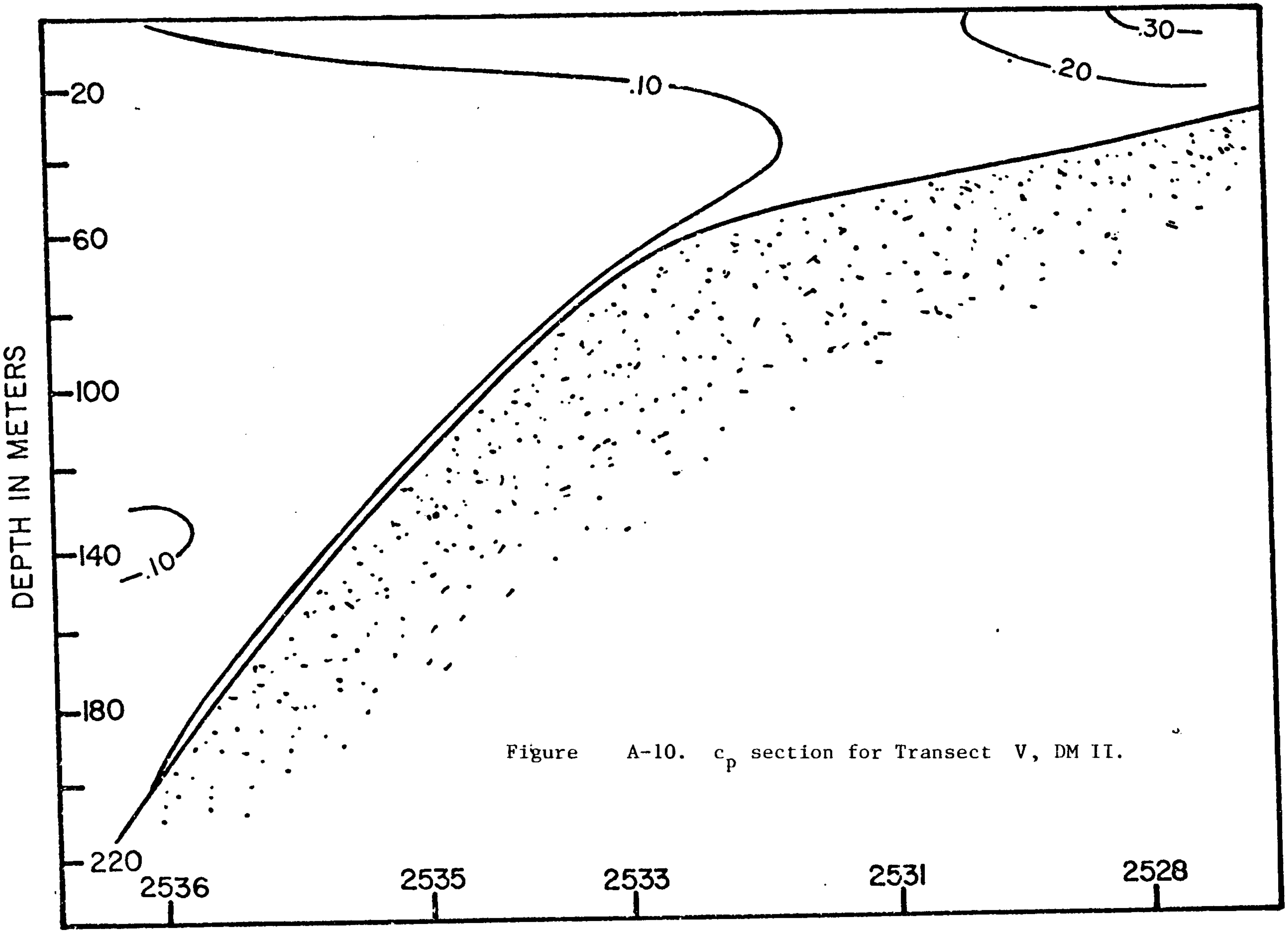


Figure A-10. c_p section for Transect V, DM II.

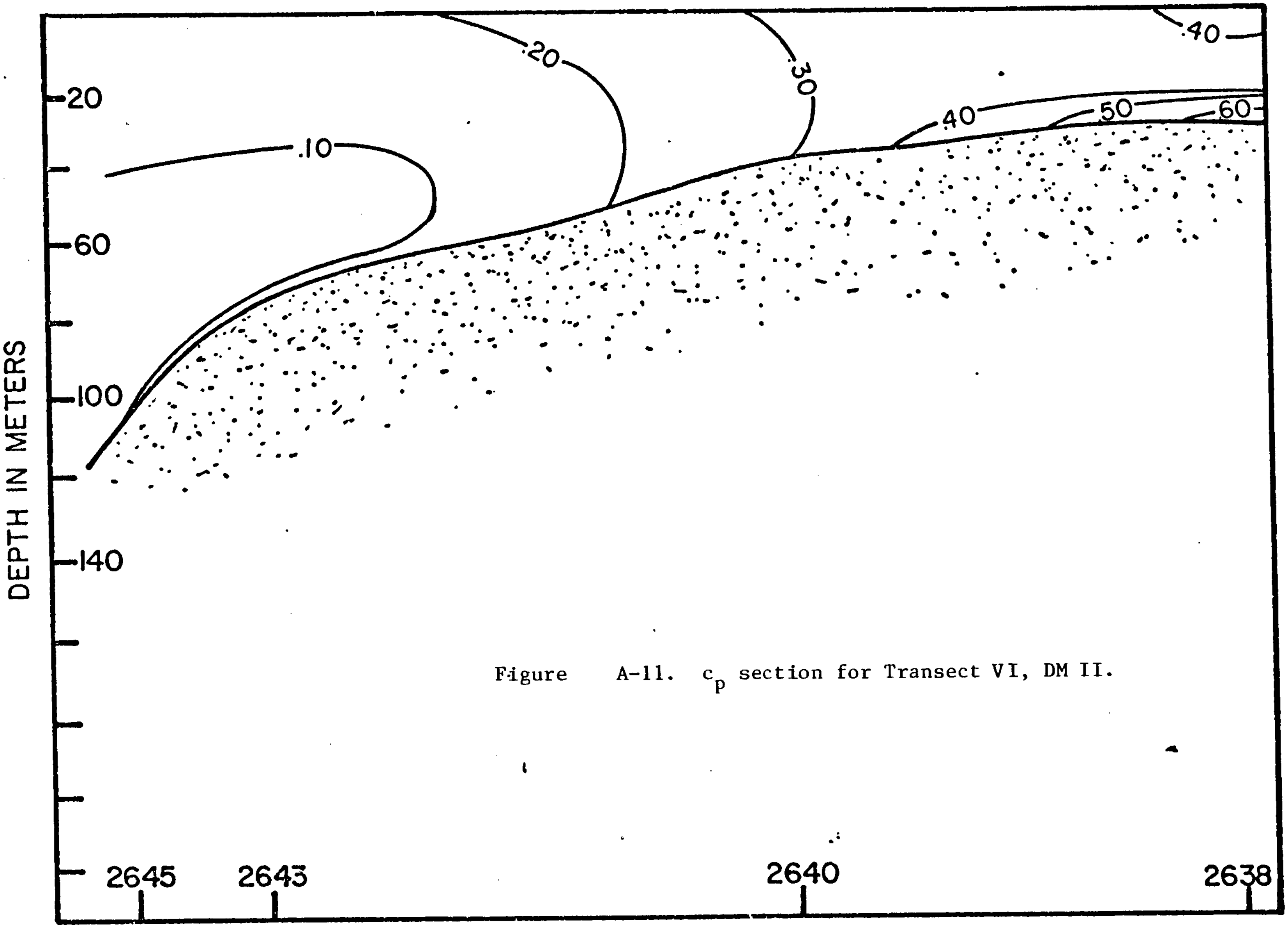


Figure A-11. c_p section for Transect VI, DM II.

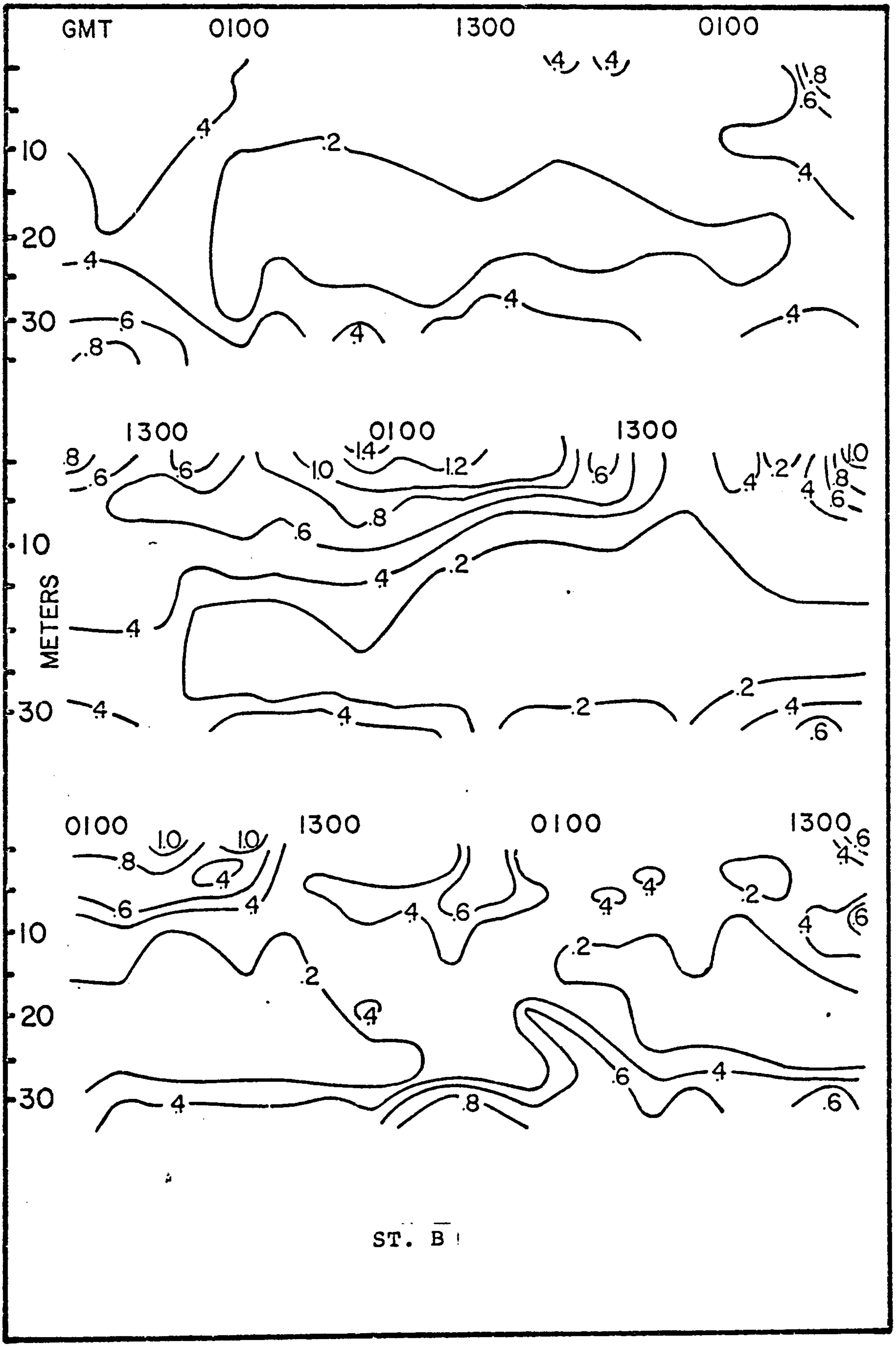


Figure A-12. Time series of c_p for Station B, summer 1976.

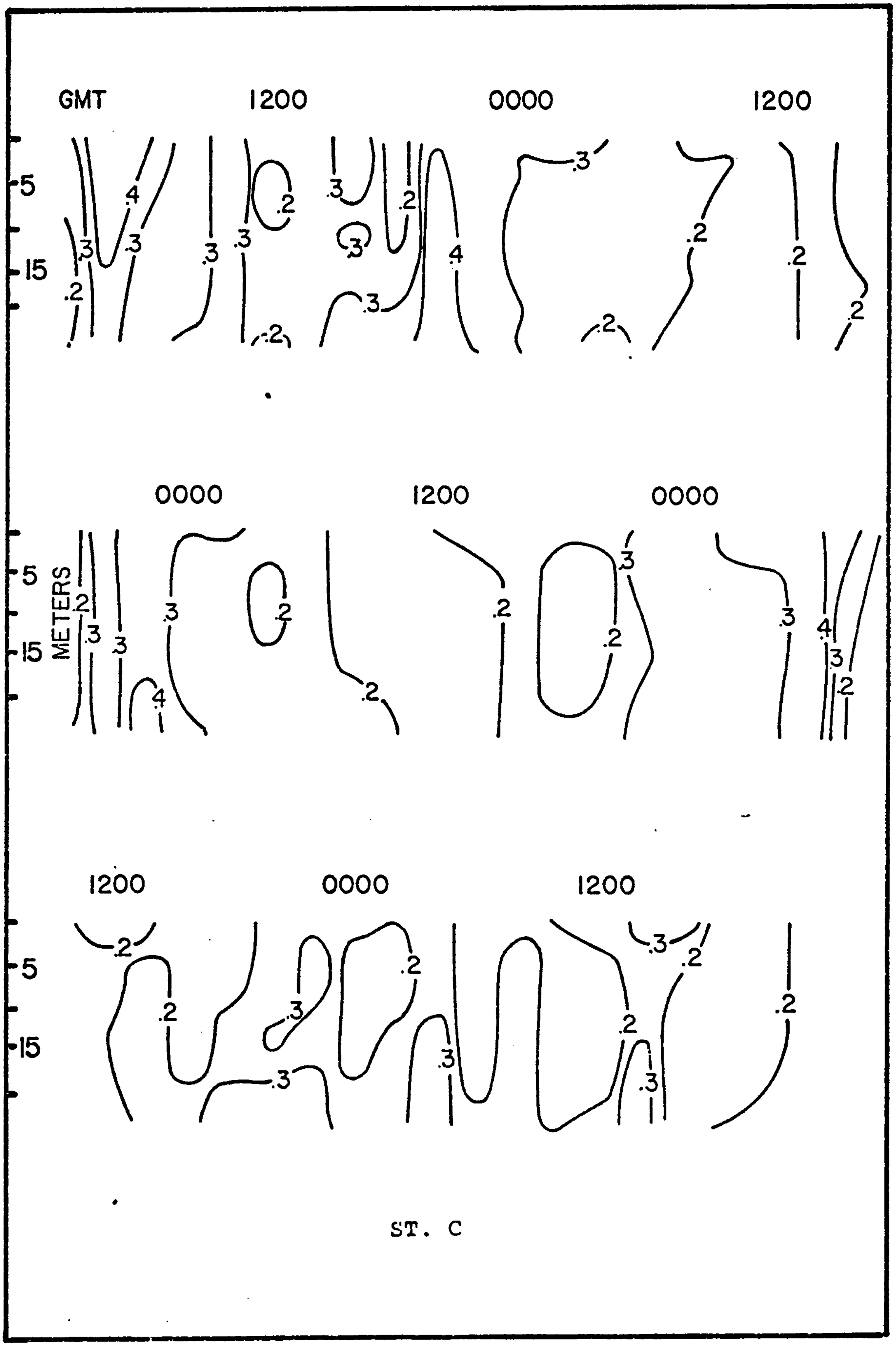
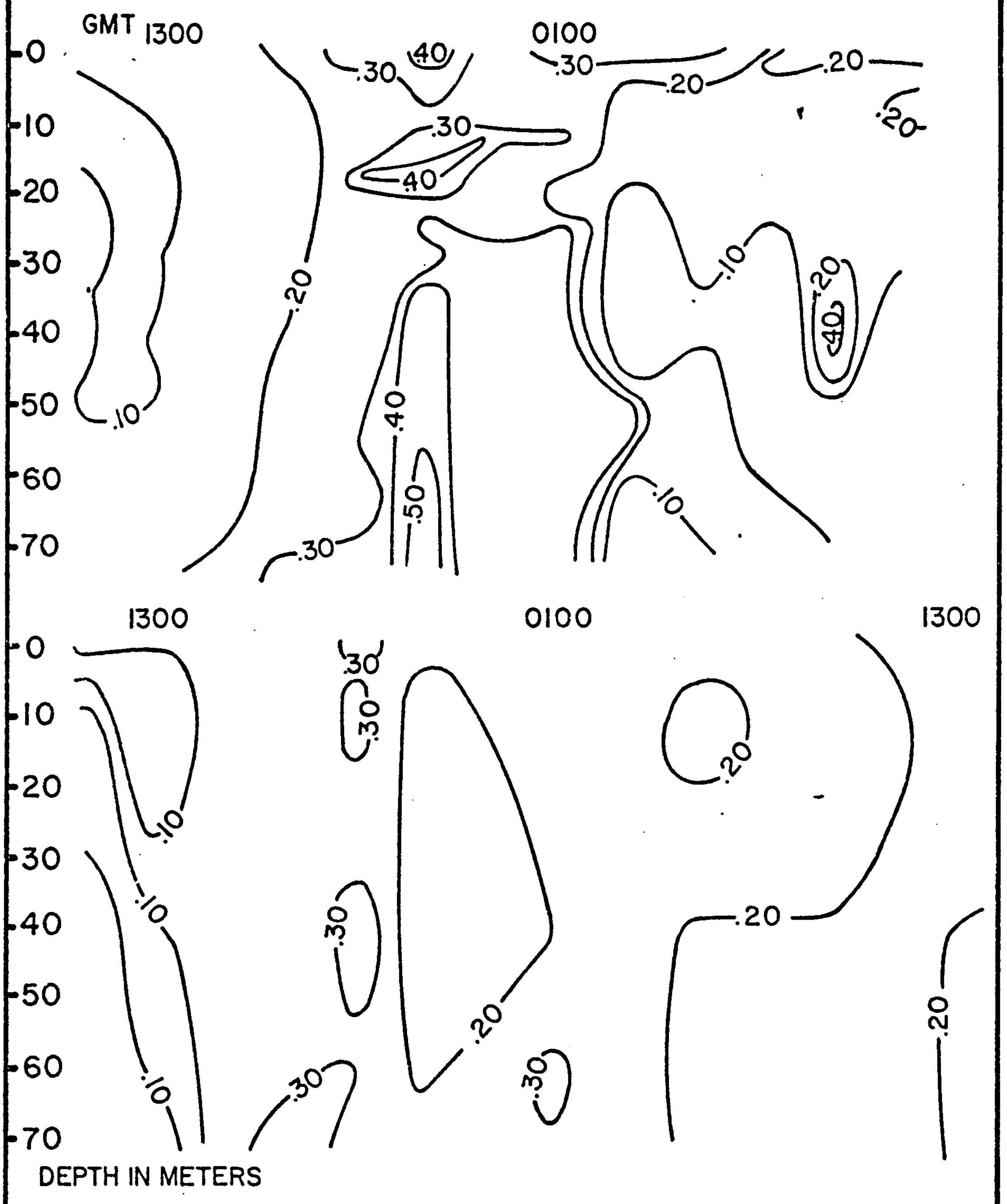


Figure A-13. Time series of c_p for Station C, summer 1976.



ST. D

Figure A-14. Time series of c_p for Station D, summer 1976.

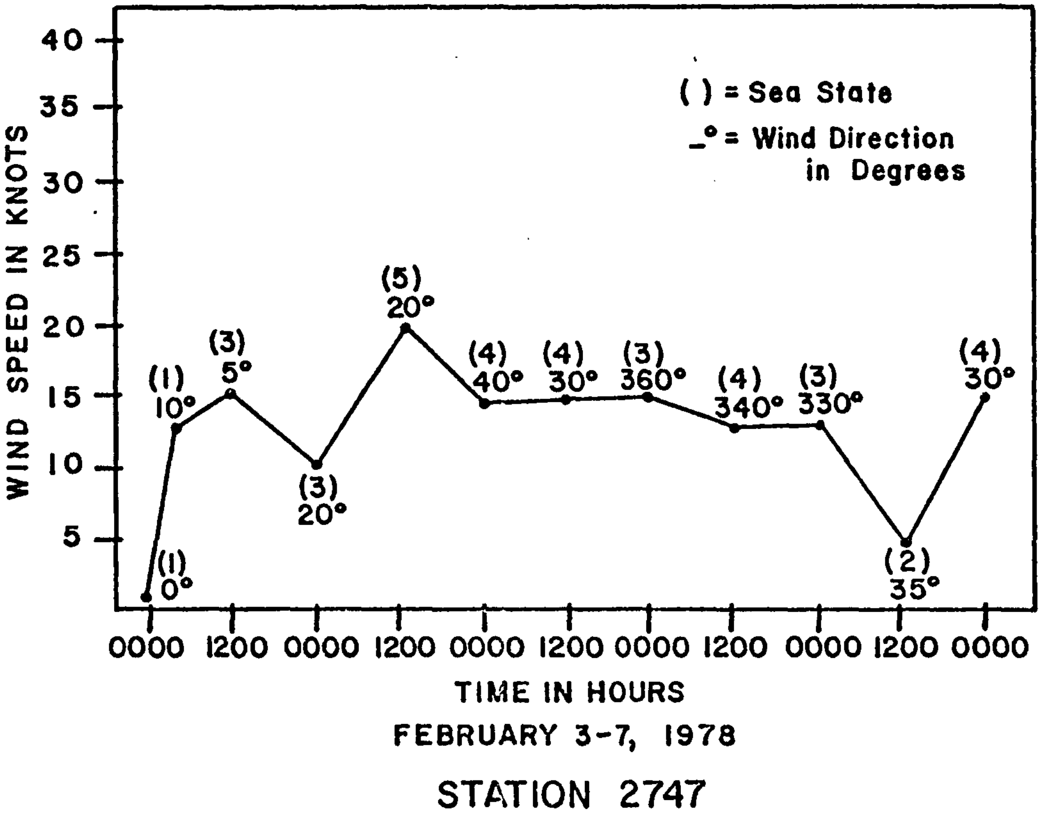


Figure A-15. Time series of wind velocities and sea state for Station 2747, winter 1978.

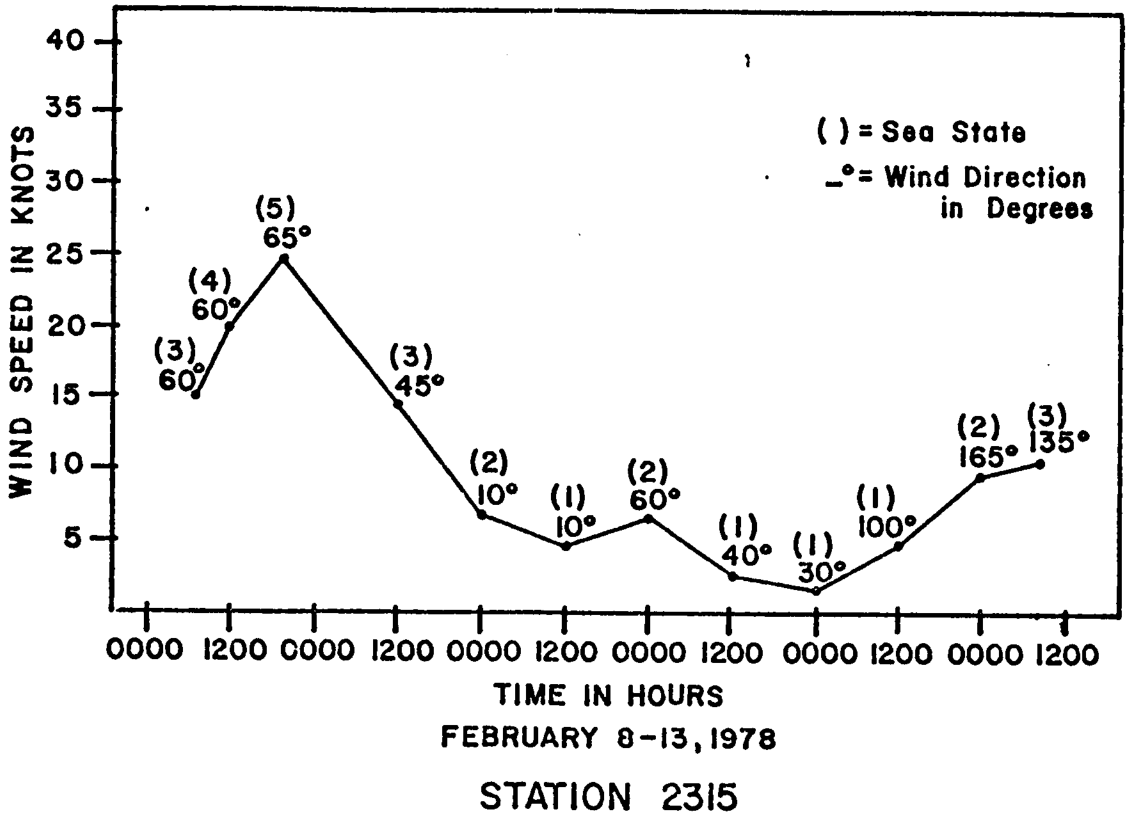


Figure A-16. Time series of wind velocities and sea state for Station 2315, winter 1978.

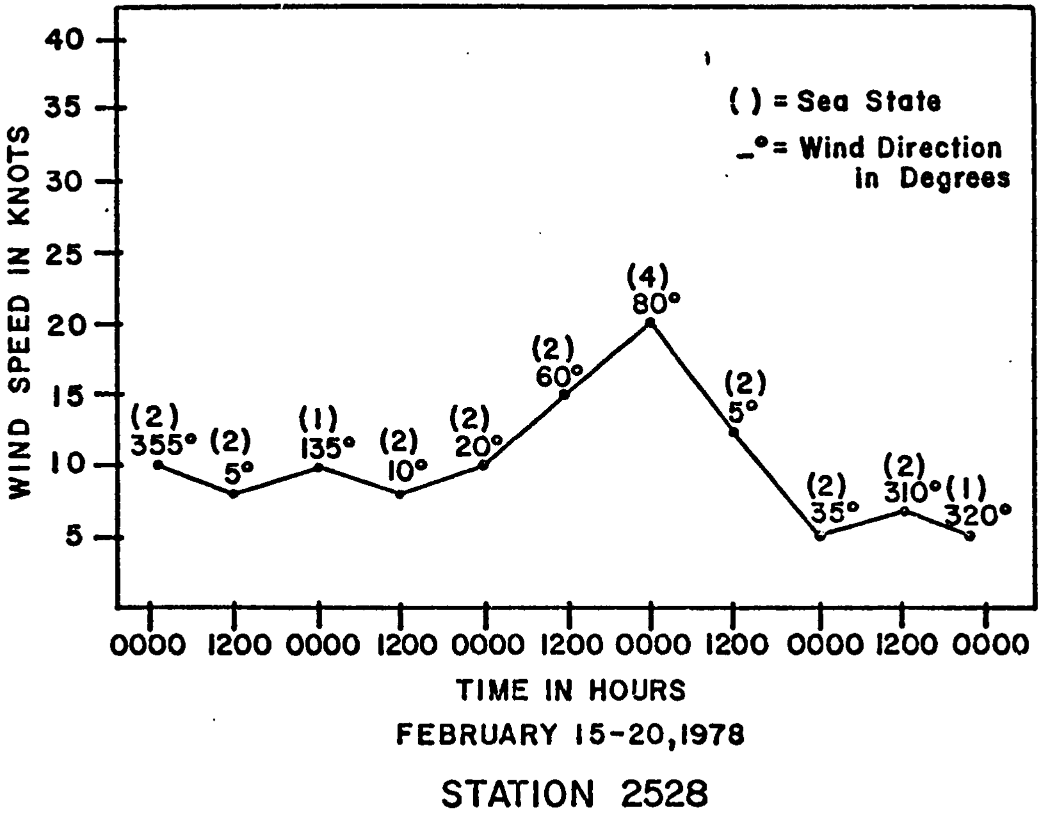


Figure A-17. Time series of wind velocities and sea state for Station 2528, winter 1978.

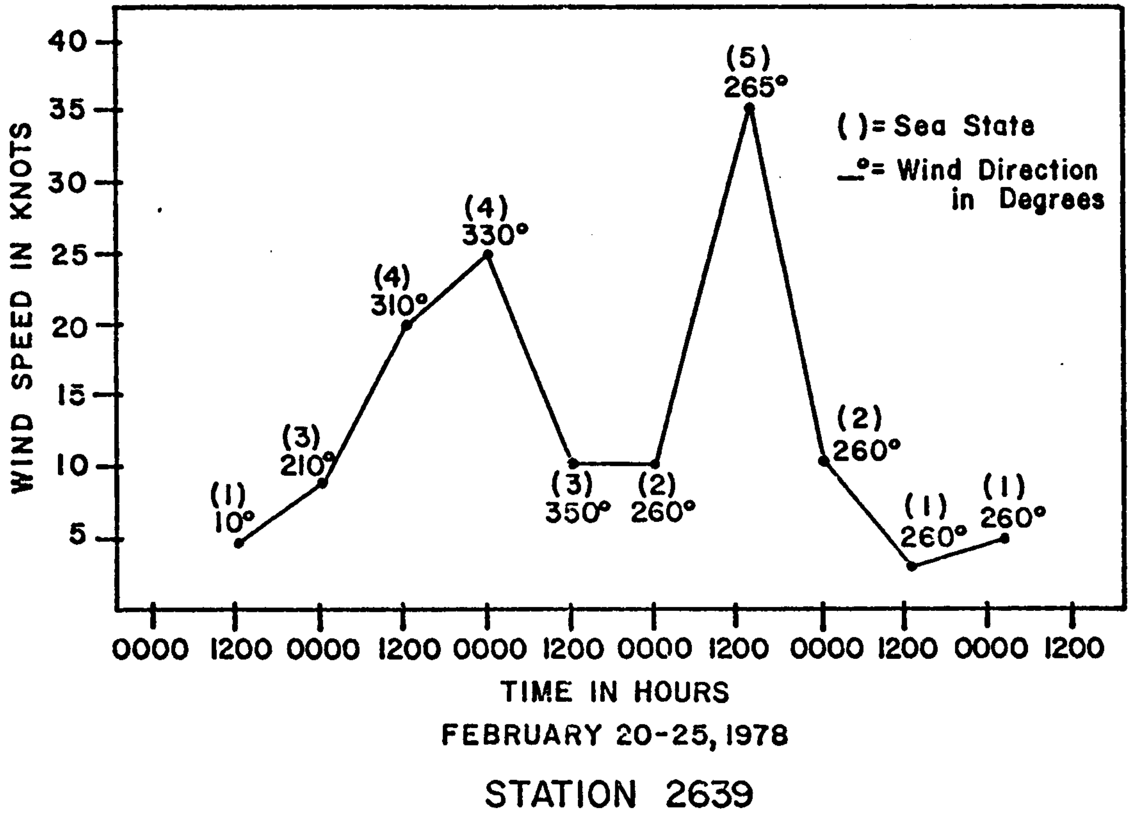


Figure A-18. Time series of wind velocities and sea state for Station 2639, winter 1978.

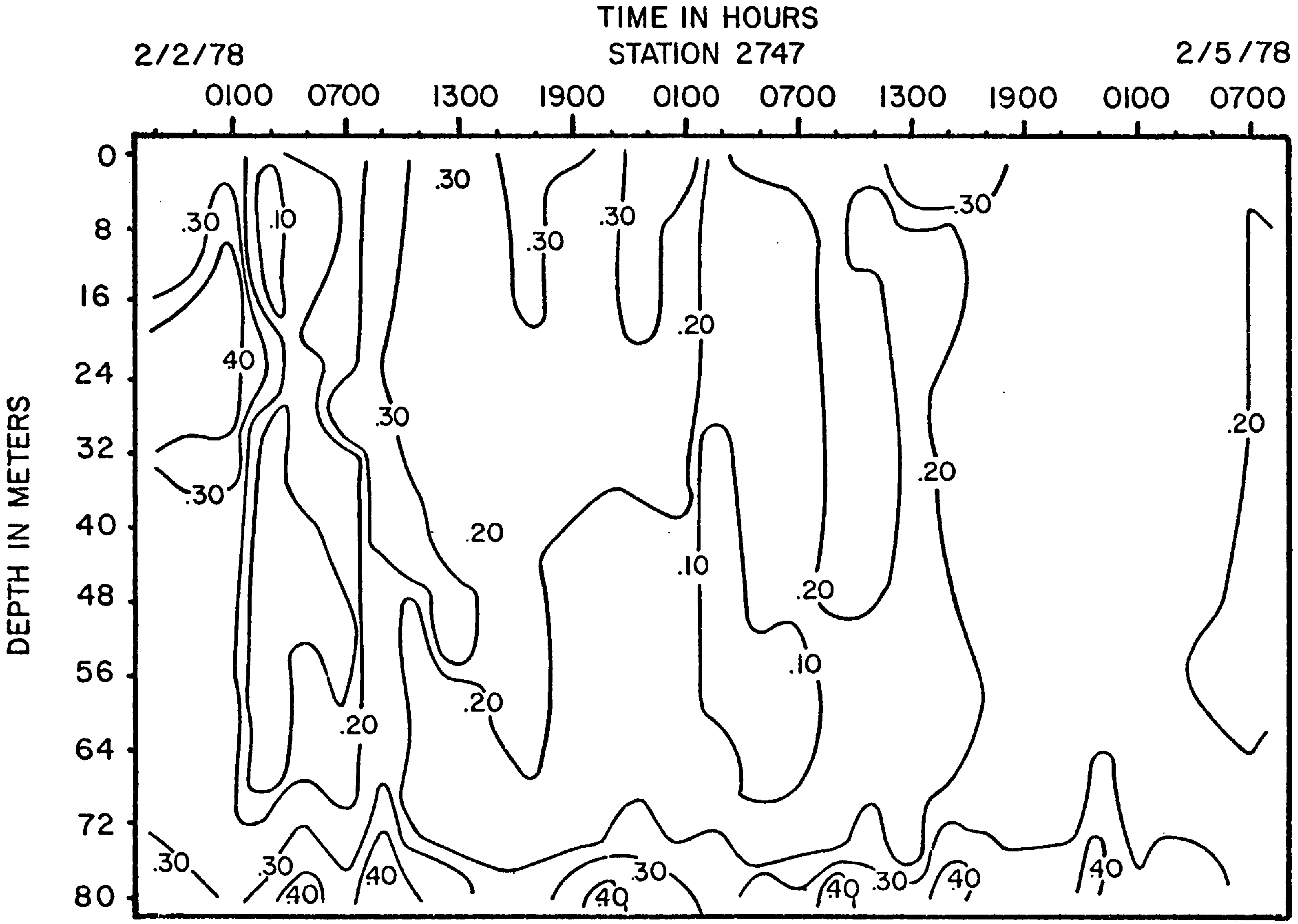


Figure A-19. Time series of c_p for Station 2747, winter 1978.

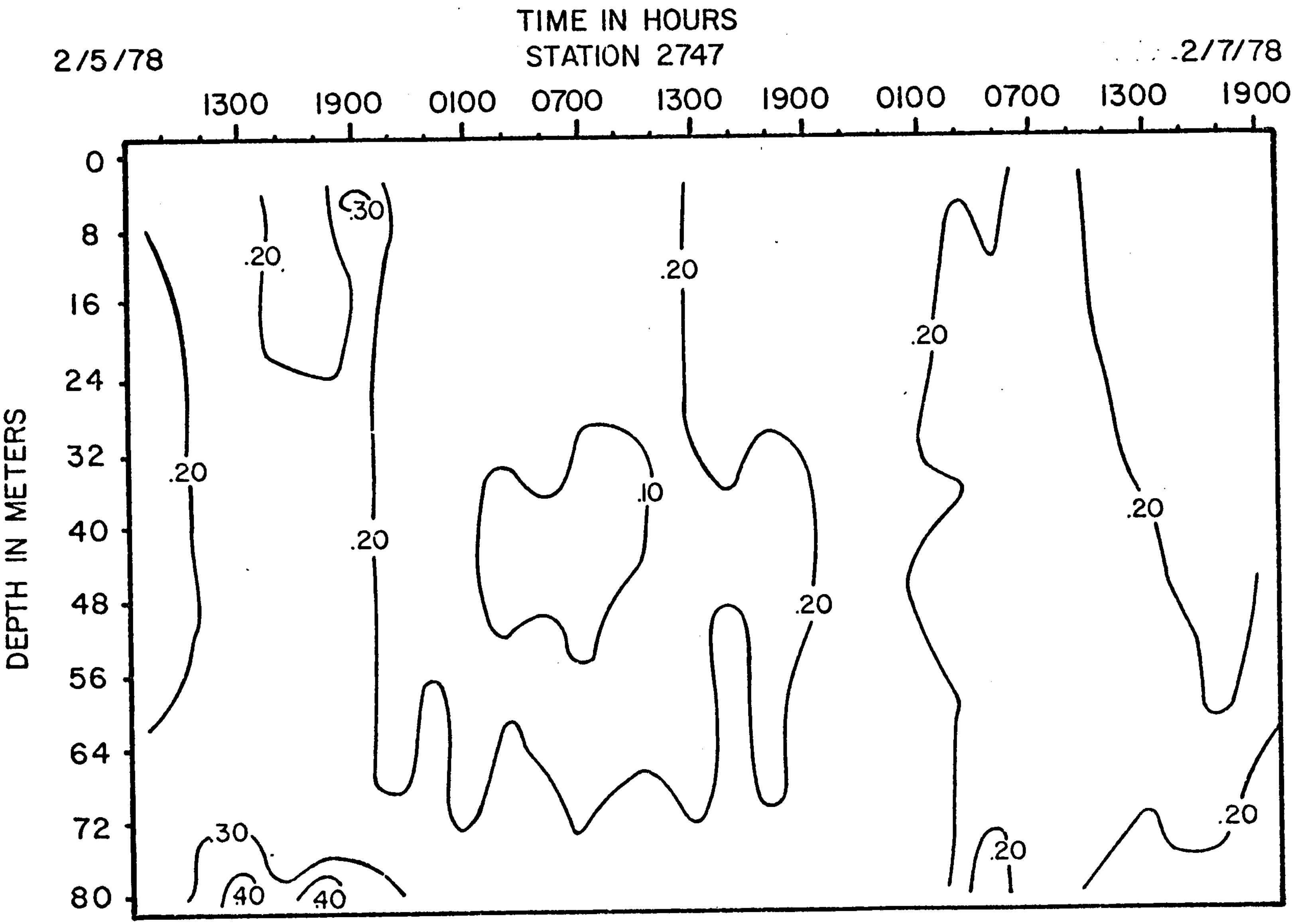


Figure A-19, continued. Time series of c_p for Station 2747, winter 1978.

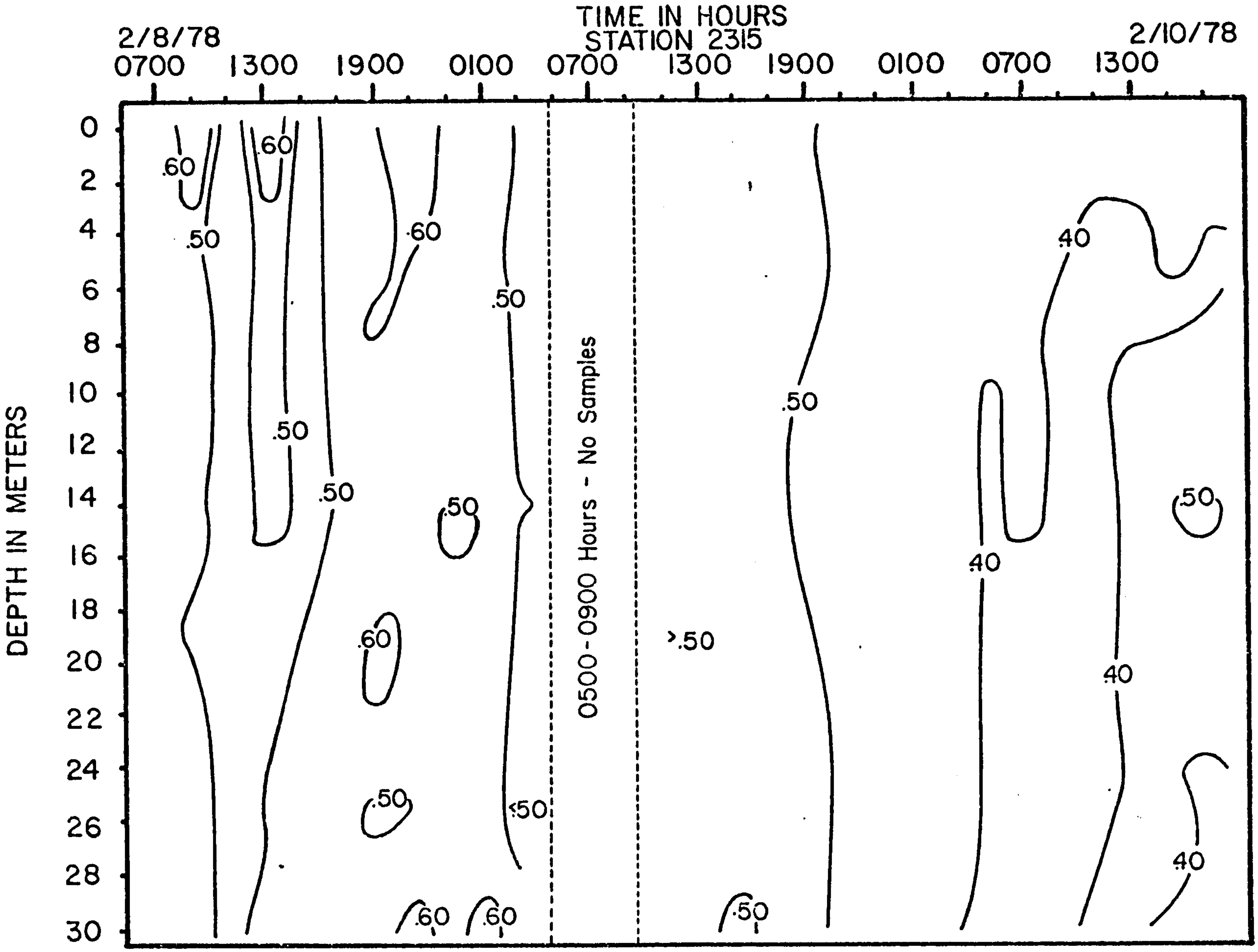


Figure A-20. Time series of c_p for Station 2315, winter 1978.

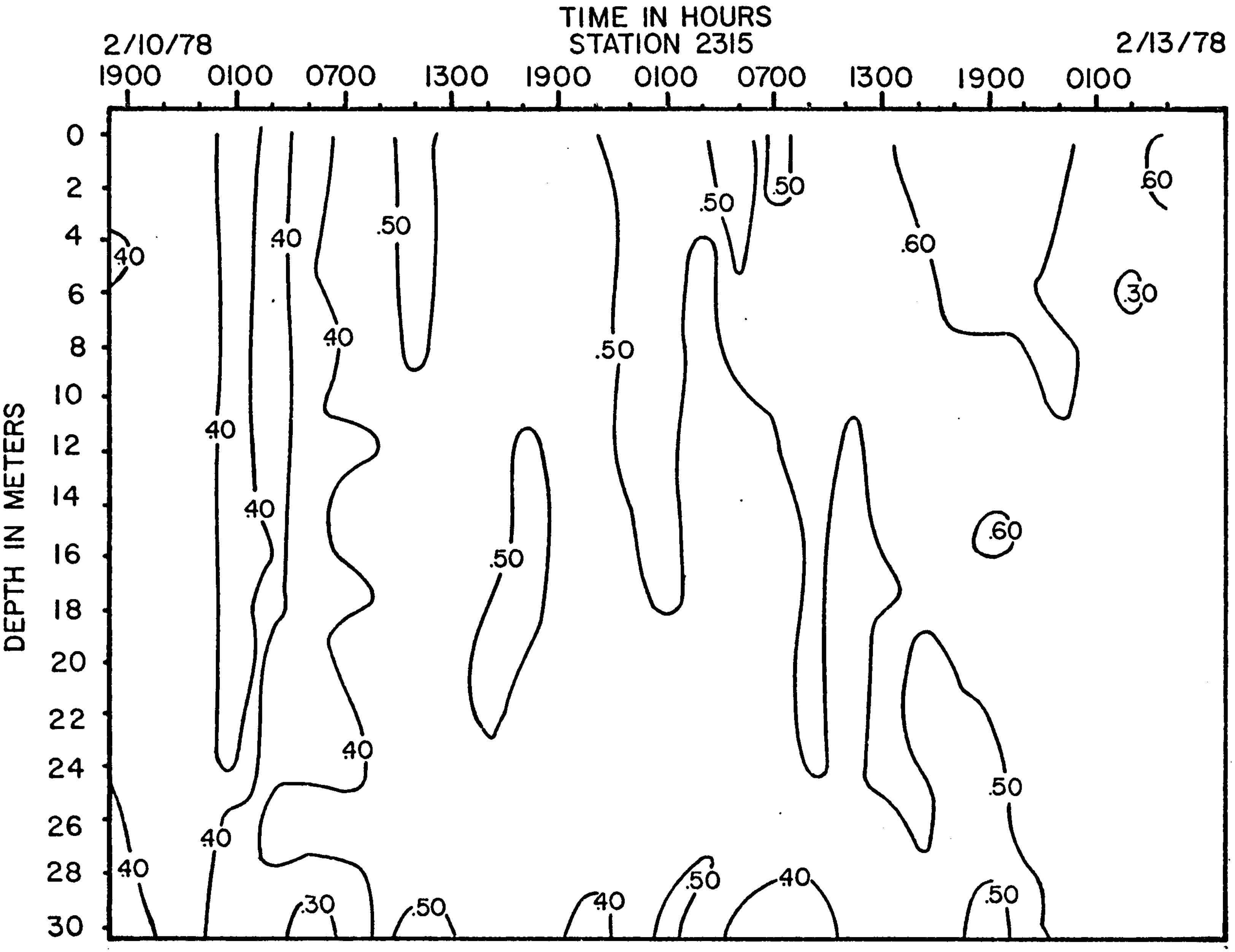


Figure A-20, continued. Time series of c_p for Station 2315, winter 1978.

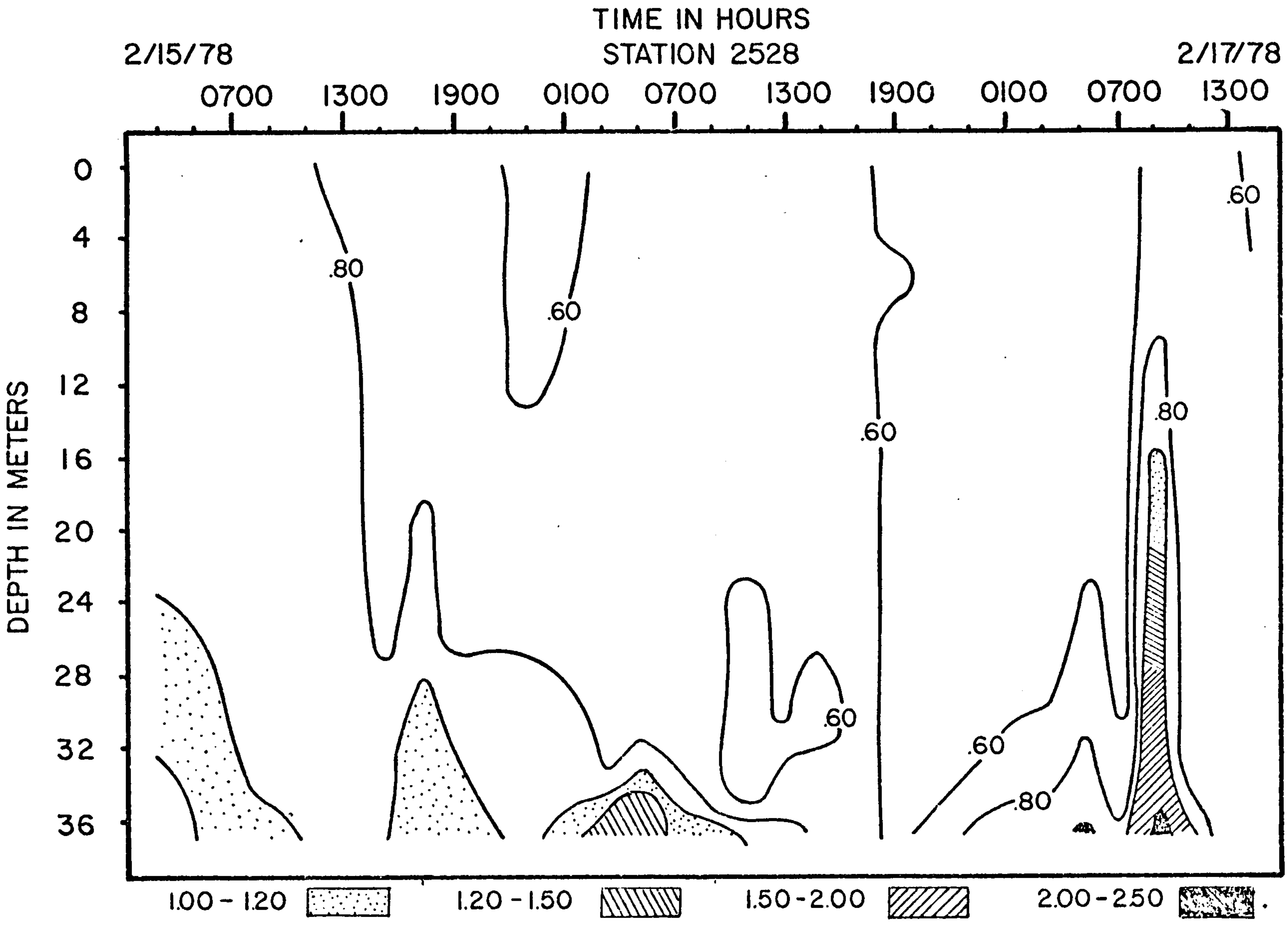


Figure A-21. Time series of c_p for Station 2528, winter 1978.

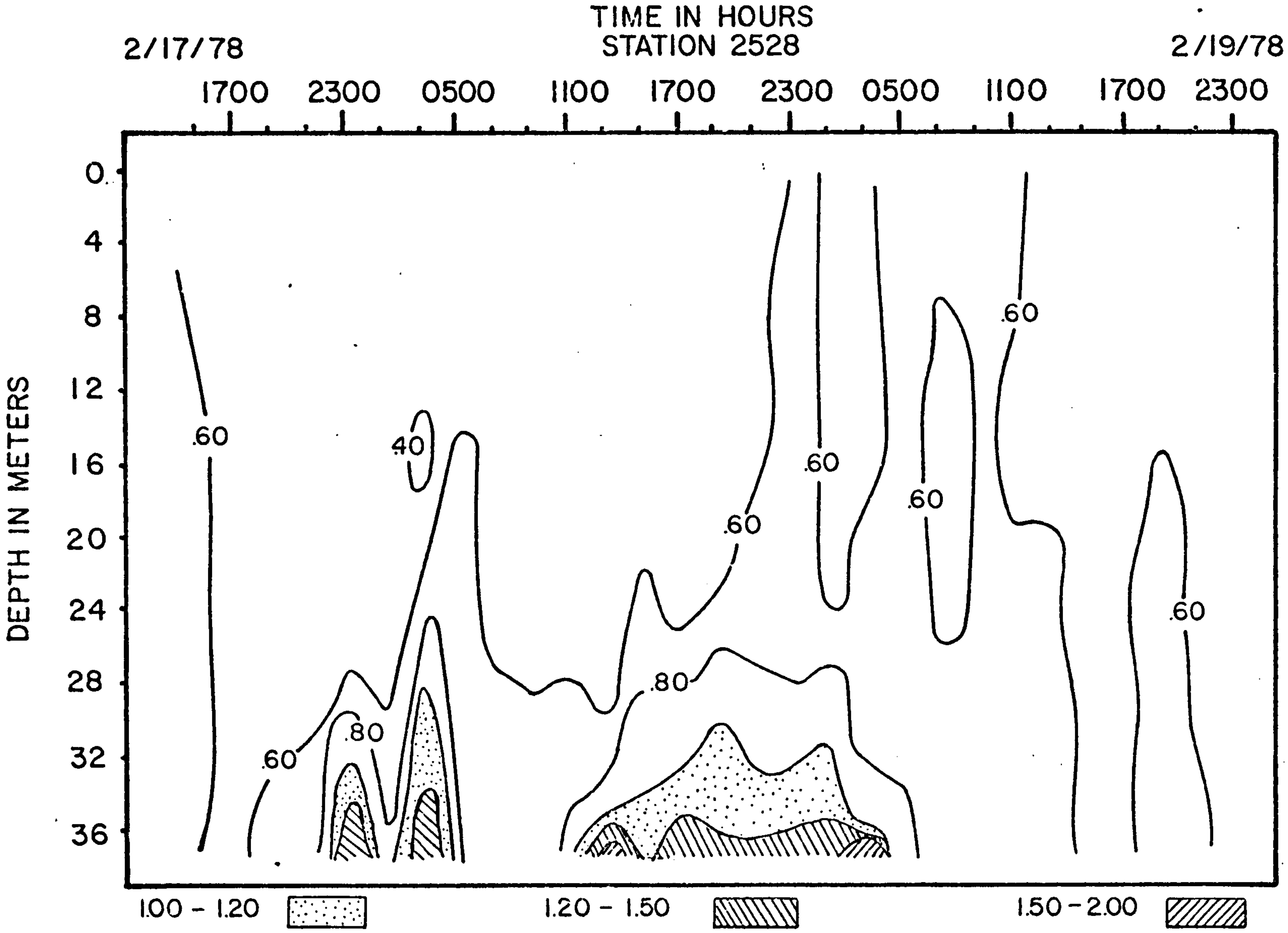


Figure A-21, continued. Time series of c_p for Station 2528, winter 1978.

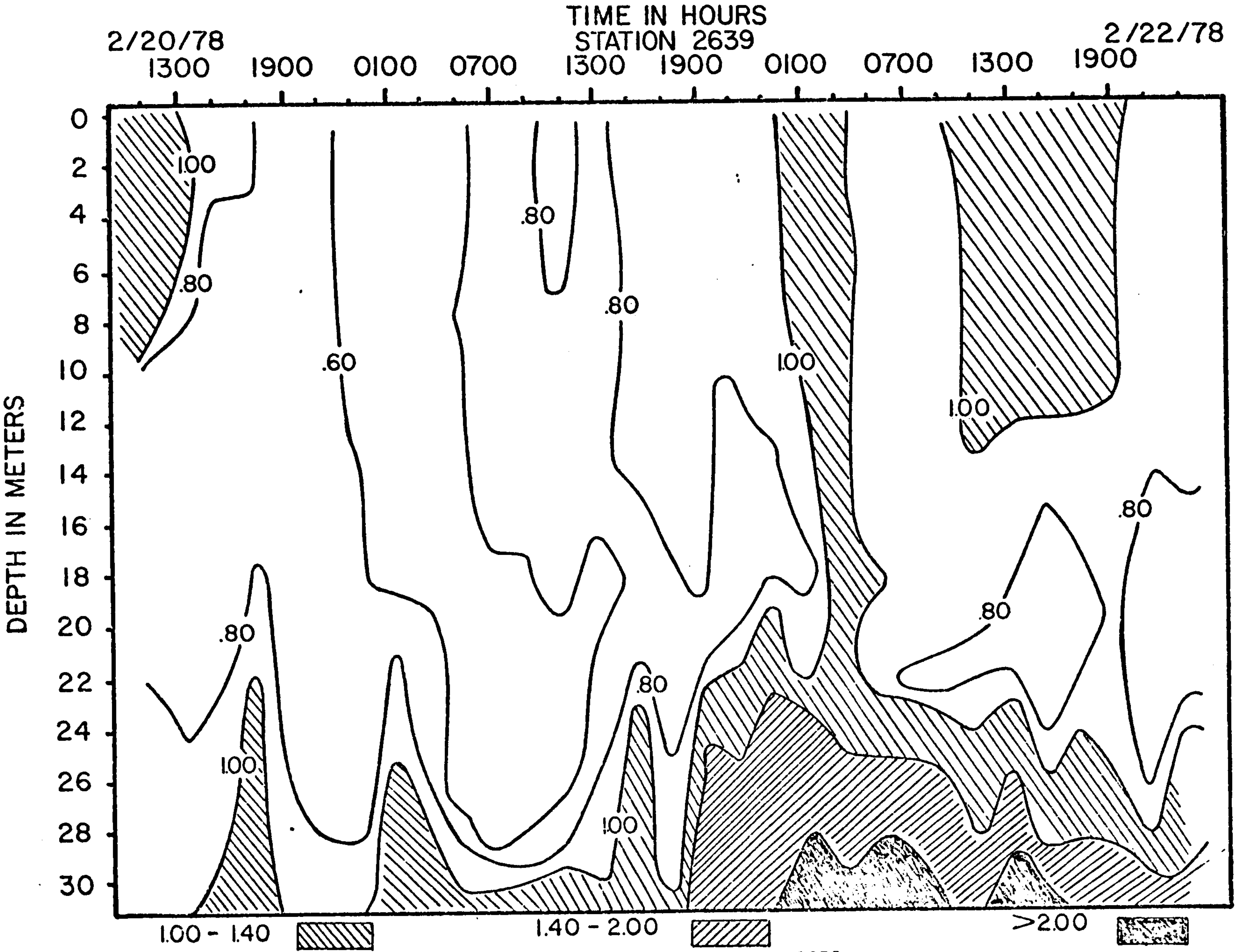


Figure A-22. Time series of c_p for Station 2639, winter 1978.

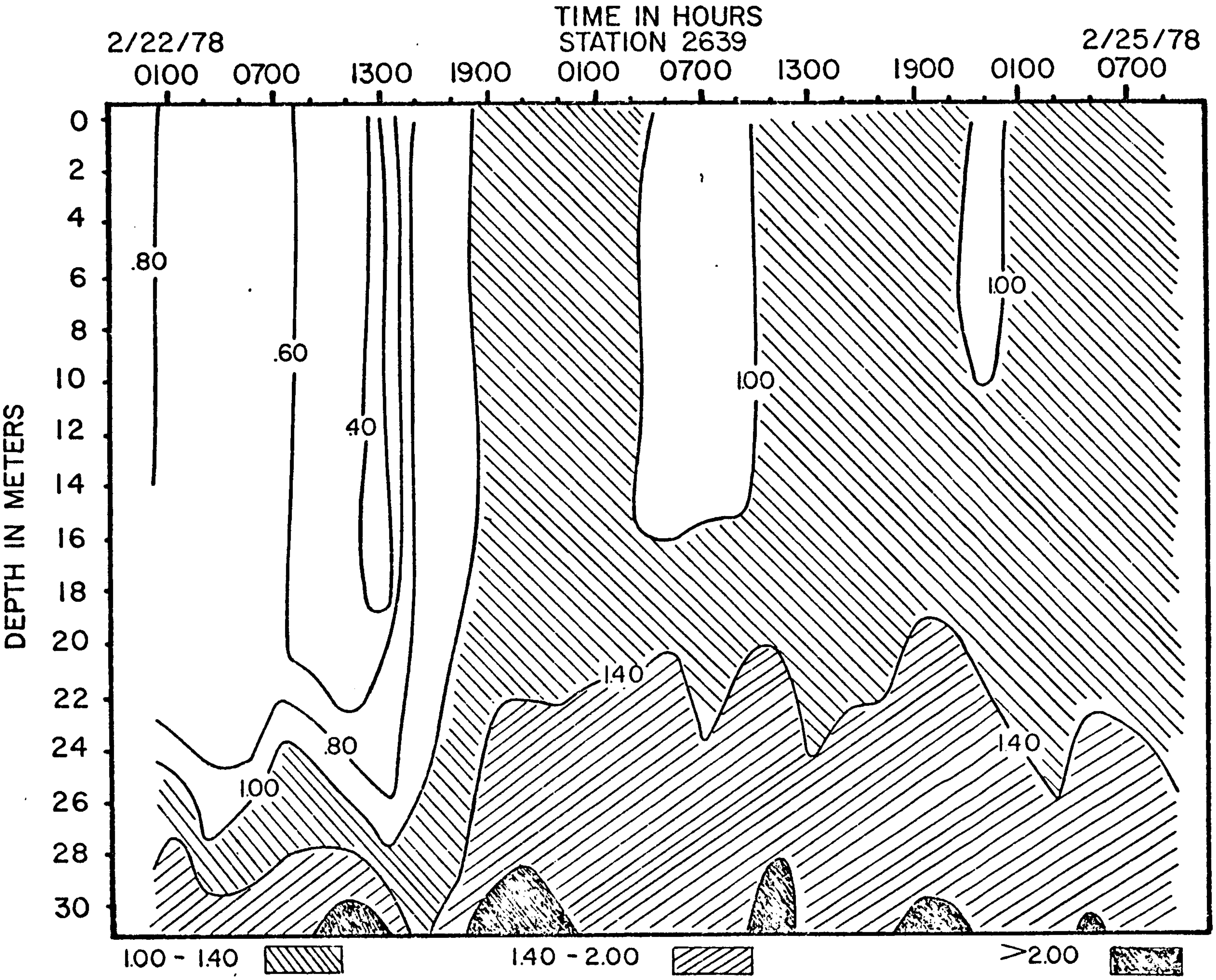


Figure A-22, continued. Time series of c_n for Station 2639, winter 1978.

VOLUME II

CHAPTER 22

WATER COLUMN TRACE METALS

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UNIVERSITY OF SOUTH FLORIDA
CONTRACT NO. AA550-CT7-34

TRACE METALS IN SUSPENDED MATTER AND ZOOPLANKTON OF THE NORTHEASTERN GULF OF MEXICO

PETER R. BETZER
MARTIN A.B. PEACOCK
ROBERT R. JOLLEY

INTRODUCTION

Interest in the impact of oil exploration and subsequent exploitation has provided the need to further explore and understand certain reactive constituents and their cycles within the oceans. These trace constituents of seawater can be excellent indicators of certain types of pollution, provided baseline levels have been established.

Trace constituents are concentrated and transported by suspended matter and zooplankton in a variety of ways. Zooplankton have been shown to transport trace elements through: vertical migrations across mixing barriers (Pearcy and Osterberg, 1967), moulting of exoskeletons (Fowler and Small, 1967), the sinking of skeletal structures after death (Arrhenius, 1963), and the incorporation of materials into fast-sinking fecal pellets (Osterberg, Pearcy and Curl, 1964). Suspended matter, both biogenic and terrigenous, may have elevated trace metal concentrations from chemical processes such as chelation, adsorption, precipitation, and flocculation. This material is often adsorbed to or ingested by small marine zooplankton who concentrate the metals and either transport them to the benthos or higher up the food chain.

The trace metal concentrations of different zooplankton populations may vary due to: the amount of element available (Goldberg, 1957), the temperature and salinity of surrounding waters (Duke et al., 1969), the population turnover rates (Martin, 1970), and the physiological state of the organisms (Haywood, 1970). Zooplankton populations will show further differences in elemental composition since each population can consist of up to twelve phyla of very different morphologies and trophic levels. Moreover, each species may exhibit vastly different chemical contents (Nicholls, Curl and Bowen, 1959).

Heavy metals, unlike the major constituents of seawater, are highly reactive, and much needs to be known about their transport in the marine environment. Suspended matter and zooplankton remove, concentrate, and transport trace metals, and thus, are important to understanding the fluxes of these heavy metals throughout the oceanic environment.

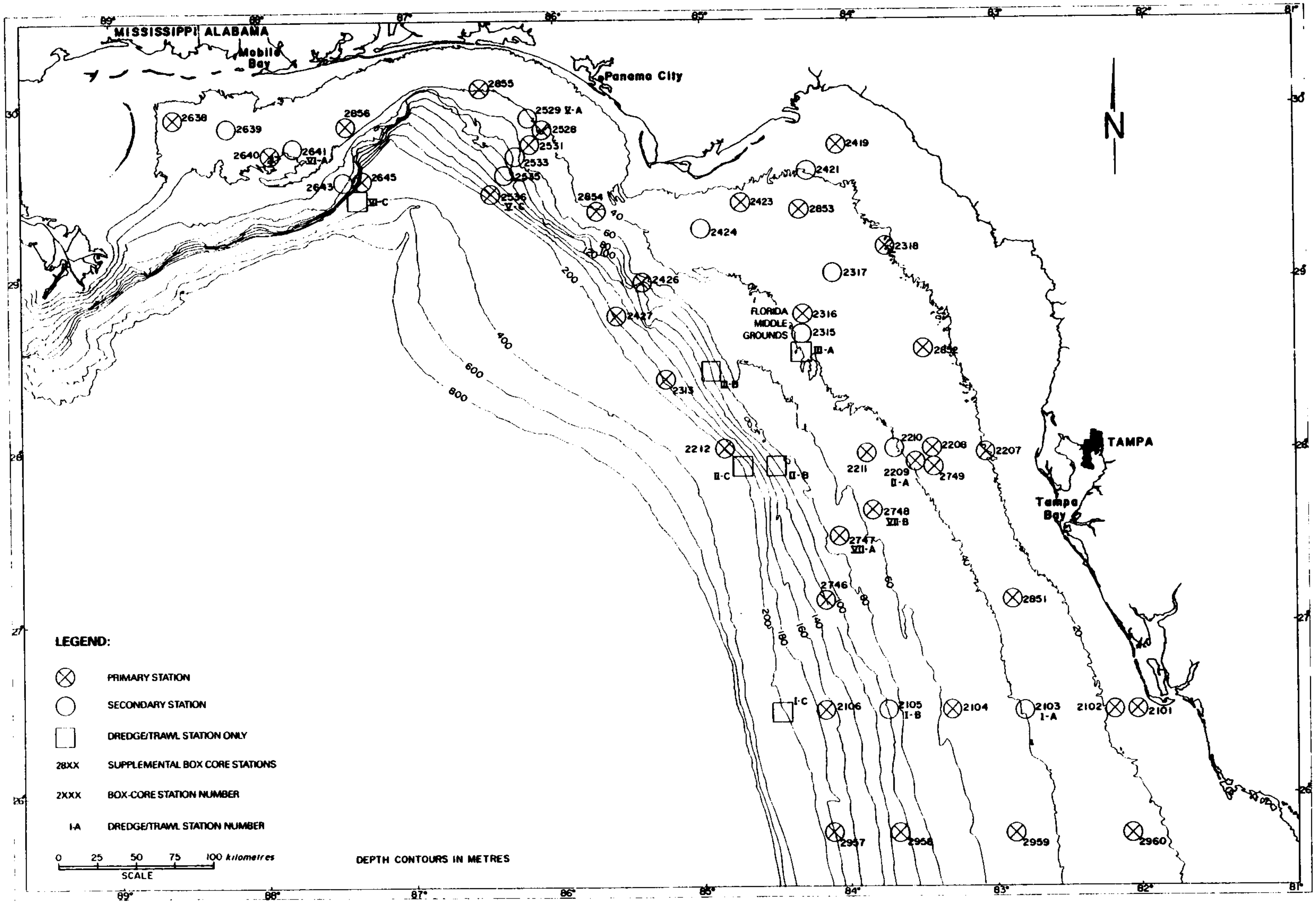
ZOOPLANKTON TRACE METAL COMPOSITION

Zooplankton, important members of marine food webs, are predominantly filter feeders utilizing suspended particulates for energy. They have been found to indiscriminantly utilize particles ranging in size from 1 to 50 μm and can effectively sweep water volumes ranging from 72 to >2,000 $m\ell \cdot 24\ hr^{-1} \cdot mg\ dry\ wt^{-1}$ (Jorgenson, 1966). Manheim et al. (1972) emphasized the importance of filter feeding zooplankton for the extraction of biogenic and terrigenous particles from the upper layers of the ocean to form larger, rapidly settling fecal aggregates. Other authors have also noted the potential importance that zooplankton fecal pellets and other metabolic products might have in transporting trace elements (Fowler, 1977), radioactive nuclides (Higgo et al., 1977), and other particulates both in and through the deep ocean to the sediment-water interface (Smayda, 1971; Schrader, 1971; Honjo, 1977). This evidence would indicate that zooplankton could be instrumental in affecting the distribution of suspended matter and, therefore, trace elements in the hydrosphere. Little work has been done, however, to evaluate whether changes in suspended matter composition affect the composition of zooplankton and/or their metabolic products.

To evaluate seasonal changes in their chemical composition, zooplankton were gathered on five cruises in the northeastern Gulf of Mexico. They were collected in stepped oblique trawls with 0.5-metre, 202-micron nets. During the first three cruises (June and September 1975, and January 1976), one sample was taken at each of the fifteen stations covering four transects of the continental shelf, including an extra sample at Station 1205 after the passage of Hurricane Eloise (September 1975). On the other two cruises (July 1976 and February 1978), zooplankton tows were made every six hours over a five-day period at a single station in the Florida Middle Grounds (Figure 257). These time-series stations were collected in order to evaluate the variability in zooplankton composition at one location, and also to establish some limits for the changes in composiiton from one location to the next, which might be considered significantly different.

The concentrations of iron (Fe), copper (Cu), cadmium (Cd), lead (Pb), zinc (Zn), chromium (Cr), nickel (Ni), and vanadium (V), in zooplankton from the northeastern Gulf of Mexico are presented in Appendices A-E. It is apparent that there are large variations in composition for materials collected on both the transects and the five-day time-series. Variation in elemental composition of zooplankton is not unexpected since different zooplankton species can have very different elemental contents (Nicholls et al., 1959) and each may have different means available for concentrating a particular element. The rates of uptake via these pathways will in turn depend upon the amount of a given element available for uptake (e.g., Goldberg, 1957), various physical factors such as temperature and salinity (e.g., Duke et al., 1969), population turnover rates (e.g., Martin, 1970), and the physiological state of the organisms (for example, the difference between senescent and growing diatoms; Gross and Zuethen, 1948 and Hayward, 1970).

The mean elemental composition of zooplankton from the northeastern Gulf of Mexico is presented in Table 94 and is compared with studies by other investigators. Our results compare most favorably to those reported by Martin and Knauer (1973) for the open Pacific and with some of other authors, although some discrepancies are noted. Our determination of lead and iron in zooplankton values are substantially lower than those reported by most other investigators. Possible explanations for this discrepancy include the proximity of their sampling areas to regions of high terrigenous input or from contamination. MAFLA samples taken during the winter of 1975 near the mouth of the Mississippi and Mobile Rivers (1,400 transect and Station 1308) illustrate the impact that terrigenous (clay) material can have on the iron content of zooplankton. Here, the mean iron content of the zooplankton ($\bar{x}$ = 1,297 ppm) was nine times greater than the winter mean (154 ppm) for the 1,100, 1,200 and 1,300 (partial) transects. Suspended material collected at the same stations as zooplankton trawls, were characterized by iron levels that were five times greater in the Mississippi-Mobile area than in the other areas sampled. Therefore, it would appear that inputs of terrigenous material with higher elemental levels can at times affect the composition of zooplankton.



BLM 77/78 MAFLA SURVEY STATION LOCATIONS

Figure 257

TABLE 94. Average metal concentrations of mixed zooplankton from BLM surveys (1975-1977) in northeastern Gulf of Mexico and comparisons with other studies (concentration in p.p.m. dry wt.)

Study/Element	Cd	Cr	Cu	Fe	Pb	Ni	Zn
N.W. Gulf of Mexico (Sims, 1975)	1.9	-	16.2	1,181	10.0	3.9	91.0
Monterey Bay (Cal.) (Martin and Knauer, 1973)	6.2	<1	5.4	344	6.9	3.9	88.5
Eastern Pacific and Hawaii (Martin and Knauer, 1973)	2.3	<1	11.5	100	2.1	8.4	180
Clyde Sea (Topping, 1972)	1.0	-	16.2	-	15.0	-	228
Puerto Rico (Martin, 1970)	-	-	41.0	1,200	49.3	42.0	428
Spring-Summer (1975) BLM-1	7.0	0.7	15.0	137	1.87	2.08	-
Fall (1975) BLM-2	8.5	0.9	22.4	92	2.44	3.76	-
Winter (1976) BLM-3	5.8	0.8	16.6	439	2.34	2.41	-
1st Time Series (July, 1976) BLM-4	1.9	0.8	29.3	102	5,27	2.76	80
2nd Time Series (February, 1976) DM III	2.5	0.8	42.3	191	2.60	3.70	71.1

The higher concentrations of lead found by other authors (Martin and Knauer, 1973, who sampled the open Pacific, are the single exception) might be related to their having sampled in nearshore areas where, in general, there are greater lead levels. Patterson et al. (1977) have noted that "excess" lead can be added to offshore waters by either aerosol transport or by storm runoff, but that the bulk of sewage lead was rapidly removed to nearshore sediments. This still does not explain why our nearshore lead concentrations taken in regions of high terrestrial runoff (1,300 and 1,400 transects) are less than one-half those reported by most authors. Therefore, unless there is greater aerosol deposition and/or storm runoff in the areas they sampled, sample contamination seems the most likely problem (Tatsumoto and Patterson, 1963; Chow and Patterson, 1966; Patterson et al., 1977).

The concentrations of copper and cadmium in zooplankton also showed interesting changes that are not so readily explained. Mean cadmium concentrations for the three transect cruises were more than twice those taken on the time-series cruises of July 1976 and February 1977 as well as those of other investigators (Table 94). Furthermore, a t-test demonstrated the difference between the means for the transect and time-series cruises was significant at the 99% confidence level. It is possible, of course, that the large standard deviations (Table 94) around the mean metal concentrations for the transect cruises of the MAFLA studies is related to the composition of the zooplankton living in oligotrophic versus more productive areas. There is some evidence from the zooplankton species composition that the inshore communities were distinct from those in offshore areas (Caldwell and Maturo, 1975). Then too, Martin (1970) has noted a similar change in zooplankton composition between shallow and deep water copepods in the Caribbean. He attributed the higher elemental trace metal levels in deep water (>100 m) zooplankton to slower population turnover rates because a reduced food supply allowed greater time for uptake and absorption of trace elements. The majority of high zooplankton cadmium concentrations in the eastern Gulf occur in offshore stations. This finding supports the hypothesis that slower turnover rates might be responsible for higher mean cadmium levels during the three transect cruises than during the time series work which was carried out in shallower, more productive waters. Since similar sampling techniques were used throughout, it is unlikely that contamination was responsible for the differences between the time-series and transect cruises.

Copper levels were the reverse of the cadmium concentration, as the mean concentations for the transects were lower than the time-series. The lower levels found during the transect cruises are in good agreement with those reported by other authors (Table 94). However, both time-series cruises show substantially greater mean concentrations and standard deviations. The extremely large standard deviations about the means (29.3 ± 21.4 ppm and 42.3 ± 62.4 ppm) and random high levels (Appendices C and D) indicate that contamination by copper-rich, anti-fouling paint might be a problem. Given the large amount of bilge pumping and garbage dumping that normally takes place at sea, contamination would seem more plausible during periods when a vessel remained in one area over an extended length of time. This is, of course, exactly what took place during the time-series work where the vessel drifted for as much as five days.

Chromium concentrations were similar for both transects and time-series and are close to the upper limit (<1 ppm) reported by Martin and Knauer (1973). Our results also compare favorably with those reported by Fowler (1977), although his study was specifically investigating the elemental composition of a Mediterranean euphausiid. In addition, he also analyzed microplankton (principally copepods, phytoplankton, chaetognaths, and detritus retained on a nylon netting of 76 μm aperture) which had a chromium concentration approximately five times greater (4.9 ppm vs. 0.8 ppm) than the mean we report.

Our means for nickel and zinc (2.94 ppm and 75.6 ppm, respectively) are in fair agreement with those of other authors (Table 94). In general, the zinc concentrations tend to be slightly less than other authors except Sims (1975).

In an attempt to evaluate temporal variations in zooplankton composition, two time-series cruises (five days) were initiated at the Florida Middle Grounds (Figure 257). Samples were collected every six hours and processed in the same way as those samples collected on the cruises made during the original MAFLA survey. In addition, in an effort to evaluate the validity of various laboratory procedures, several experiments were performed with the zooplankton from the first time-series. First, to determine if the subsample taken after the zooplankton were dried and ground was representative of the entire sample, four replicates of Samples C-4 and C-32 were taken. Each sample was ashed, digested and then analyzed. The results (Table 95) show good correlations for all elements except those from the first replicate of Sample C-32. This subsample remained in a chamber of the low temperature asher for about four days while seals on the asher were being replaced and appears to have been contaminated (probably by particles that entered the chamber). These results indicate that our grinding technique does produce representative subsamples. In addition, we also compared our techniques with those that use centrifugation to remove insoluble residues after digestion and prior to analysis of the zooplankton. One milliliter, each of an uncentrifuged sample was removed from five digestion bombs and brought to volume in a 25 mℓ volumetric flask. The remaining two milliliters of sample were transferred to acid-cleaned polypropylene centrifuge tubes and filled with approximately 10 mℓ of deionized water. These were spun at 20,000 rpm for 20 minutes and the supernatant decanted into a 50 mℓ volumetric flask which was brought to volume with deionized water. Analysis of the samples showed that the centrifuge step did not affect the final results (Table 96).

The statistical results for the elemental zooplankton composition from the time-series cruises indicate that, based on their variation about the mean, there are two groups of elements. The first group, Cd, Cr, Fe, Ni, and Pb have standard deviations less than 50% of the mean. The second group includes Cu and possibly Zn which have standard deviations greater than 50% of the mean. The large variance in copper concentations, as discussed previously, more than likely resulted from contamination by antifouling paint. This is particularly evident during the second time-series where the first nine zooplankton samples have copper concentrations of 11.2 ± 1.9 ppm, whereas, the last nine samples have concentrations of

TABLE 95. Replicate trace metal determinations made on sub-samples of ground zooplankton.+

Sample/Element	Cd	Cr	Cu	Fe	Ni	Pb	Zn
C-4-1	2.5	0.4	17.5	45.6	2.91	2.5	68.1
C-4-2	1.8	0.5	17.9	48.6	2.91	2.7	72.0
C-4-3	2.9	0.5	17.6	44.2	2.57	2.7	68.3
C-4-4	2.5	0.5	17.7	46.5	2.73	2.5	72.1
Summary Mean and Singles Standard deviation	2.4±0.4	0.5±0.05	17.7±0.2	46.2±1.8	2.78±0.2	2.6±0.1	70.1±2.2
*C-32-1	3.2	0.9	26.6	125.3	3.57	3.6	99.9
C-32-2	1.7	0.7	12.9	80.0	2.23	4.3	62.5
C-32-3	1.7	0.43	12.8	76.8	2.43	3.9	61.8
C-32-4	1.6	0.41	12.9	77.5	2.20	3.4	60.9
Summary Mean and Singles Standard deviation	1.7±0.06	0.51±0.16	12.9±0.06	78.1±1.7	2.29±0.12	3.9±0.4	61.7±0.8

+ Concentrations in ppm dry wt.

* Excluded from mean calculations because of possible contamination

C-4 sample taken in Florida Middle Grounds

C-32 sample taken in Florida Middle Grounds

TABLE 96. Comparison of trace metal analysis for centrifuged and uncentrifuged samples of nitric acid digested zooplankton.°

Sample/Element	Cd	Cr	Cu	Fe	Ni	Pb	Zn
*C-2	1.0	0.6	28.5	62.6	2.01	2.2	50.8
+C-2 (25 ml)	0.4	0.3	14.1	27.0	1.02	0.8	29.4
C-6	1.9	0.3	15.9	35.6	1.69	2.7	42.7
C-6 (25 ml)	0.95	0.15	8.3	19.4	0.61	1.4	27.5
C-14	1.7	0.6	16.7	46.3	2.02	4.64	48.4
C-14 (25 ml)	0.9	0.3	7.8	22.1	0.84	2.42	21.8
C-30	1.3	0.6	10.2	81.8	1.89	3.4	47.1
C-30 (25ml)	1.1	0.25	5.1	39.0	0.61	1.5	22.7
C-40	1.8	0.68	12.5	80.9	1.75	5.5	43.0
C-40 (25 ml)	0.9	0.3	6.2	37.4	0.80	2.0	21.0

Note: Concentrations in (25 ml) sample should be one-half concentration in above sample. Total sample concentration is the sum of both fractions (ex. C-2 conc. = C2 + C2 {25 ml})

* Samples C-2, C-6, C-14, C-30 and C-40 were subjected to centrifugation prior to atomic absorption analysis.

\+ Samples followed by 25 ml in brackets are those which were analyzed immediately after digestion by atomic absorption without being centrifuged.

° Concentration in p.p.m. dry weight.

73.4 ± 78.1 ppm.* Zinc concentrations also increased markedly after the first seven samples had been collected during the second time-series (February 1977). The mean zinc concentration of the first seven samples ($\overline{x}$ = 45.3 ± 19.6 ppm) is one-half the mean concentration of the last 11 samples ($\overline{x}$ = 98.4 ± 54.2 ppm).* Therefore, these results indicate that copper and zinc in zooplankton (in this case the zooplankton nets were dominated by phytoplankton) were readily contaminated during time-series sampling. Contamination of the net plankton was most readily observed during the second time-series where phytoplantkon comprised the bulk of material (visual inspection). During the first time-series, this phenomenon was not observed since zooplankton, organisms that would have to assimilate copper and zinc from phytoplankton, dominated the net collections. The zooplankton from the first time-series did, however, display somewhat elevated levels of copper indicating that some contamination may even have occurred during the first time-series.

The other elements analyzed, including Cd, Cr, Fe, Ni and Pb, did not increase during the course of the time-series. Thus, the output from the ship did not perceptibly affect the metals during this experiment even though other careful workers have shown that paint and other metallic-rich materials from ships can markedly affect metal levels in zooplankton (Martin and Knauer, 1973).

In summary, the trace metal composition of zooplankton from the northeastern Gulf of Mexico show: 1) good agreement with previous reports for trace metals in oceanic zooplankton populations, 2) seasonal and regional changes in trace metals content which, in part, might explain the higher iron and lead concentrations found by most other investigators and, 3) evidence for copper and zinc contamination of zooplankton samples by the prolonged presence of an oceanographic vessel.

SUSPENDED PARTICLE LOADS

Suspended particle loads can be valuable indicators of the various processes affecting their horizontal, vertical and seasonal distribution. The mean and single standard deviations for surface and bottom suspended loads in the four regions (Sarasota, Middle Ground, Panama City and Mississippi-Mobile area) sampled during July 1976 (BLM-4), November 1977 (DM II), and February 1978 (DM III) are presented in Table 97. Seasonal and regional trends are evident and consistent with previous investigations in the MAFLA area (Betzer and Peacock, 1976). In general, the elevated suspended loads for the winter sampling appear related to storms which result in substantial sediment-water interactions and subsequent resuspension of fine-grained bottom materials. Thus, in three areas (Mobile, Panama City, Middle Grounds) the suspended particle loads are significantly higher (at the 95% confidence level) during the winter than the other seasons. In addition, there are also marked regional differences in suspended particle loads. For the most part, the regional differences reflect their nearness to the major particle source for the Gulf of Mexico and the Mississippi

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*The difference between the means is significant at the 95% confidence level.

TABLE 97. Seasonal averages for suspended particle loads (μg/l) at four Continental Shelf stations in the eastern Gulf of Mexico.

	July, 1976		Nov., 1977		Feb., 1978	
Location/Cruise	BLM-4		DM II		DM III	
	sfc*	bot+	sfc	bot	sfc	bot
SARASOTA 27°23'N,84°07'W (Bottom Depth 79m)	61.7 ±30.1	41.8 ±16.3	12.3 ±3.2	48.3 ±22.5	40.1 ±19.4	46.3 ±42.2
MIDDLE GROUNDS 28°40'N, 84°21'W (Bottom Depth 31m)	70.4 ±30.1	61.9 ±17.0	14.2 ±6.2	11.3 ±3.0	172.6 ±78.7	149.1 ±78.8
PANAMA CITY 29°56"N, 85°59"W (Bottom Depth 33m)	54.1 ±13.0	52.1 ±11.6	23.9 ±17.3	29.7 ±27.6	170.0 ±134.2	240.0 ±119.0
MISSISSIPPI - MOBILE AREA 29°47'N, 88°13'W (Bottom Depth 29m)	191.9 ±78.7	170.5 ±103.9	48.3 ±23.6	382.6 ±227.5	492.4 ±109.5	1072.0 ±910.0
	Summer		Fall		Winter	

*Surface samples gathered between 3 and 10 metres.

+Bottom samples taken 5 metres above the bottom.

River. Thus, the data for the Mobile-Mississippi region always have much higher suspended loads than those for Panama City, Middle Grounds or Sarasota. There are, however, other inputs which are important determinants of the concentration of suspended particles, including biological productivity, river input, sediment-water interactions, and water masses, but these require chemical data for resolution and will be discussed later.

During the winter of 1978 (February DM III) increased suspended loads were evidenced in three of the four sampling areas (Table 98). Our time-series data for DM III show suspended loads that were more than twice those found at other times (fall and summer) of the year in the Florida Middle Grounds, off Panama City, and near the Mississippi-Mobile areas. These values were significantly different at the 95% confidence level from those in the other areas. The highest mean suspended load (1,072 ± 910 μg/l) was found in the bottom samples near the mouth of Mobile Bay during the winter. These data are consistent with those collected during the previous MAFLA sampling (Betzer and Peacock, 1976). Here, suspended loads during the winter were more than twice those collected during the spring-summer (June) and the fall (September) of 1975. This seasonal difference was significant at the 95% confidence level (Betzer and Peacock, 1976).

It is noteworthy that the winter samples from the Sarasota area did not have increased suspended loads, as significant increases were noted in the Tampa Bay area during the MAFLA project. It is possible that the water depth (79 m) and the lack of any significant atmospheric forcing prior to this winter sampling were enough to provide the contrast with the other three regions.

The region with the greatest suspended particle loads was the Mississippi-Mobile area. During all three time-series, there were high suspended loads in bottom waters. In surface waters, high suspended loads were present during the July (1976) and February (1978) sampling. As evidenced by the low surface salinities (<29 $^{o}/oo$) at Station B, the increased suspended loads during July of 1976 probably resulted from river input (Figure 258)

During the fall of 1977 (November, DM II) there was a near-bottom nepheloid layer in the Mississippi-Mobile area. Mean suspended loads in bottom (29 m) waters near the mouth of the Bay were eight times those present in surface waters (384 versus 48 μg/l). The difference between the means was significant at the 95% confidence level. This distribution could have resulted from the accumulation of materials in a salt wedge such as has been reported by Meade (1972). However, the salinity difference of approximately 0.5 $^{o}/oo$ noted between surface and bottom waters does not support this hypothesis. Rather, the large amounts of suspended material probably resulted from an interaction of bottom currents with sediments in this area or the horizontal advection of material from the Mississippi area. Near-bottom increases in suspended load were also found at Station 2747 near Sarasota in November of 1977 (DM II) and might also be indicative of sediment-water interactions. Here, the near-bottom suspended loads are four times those in surface waters (48 versus 12 μg/l). Compositional data will be required to determine whether significant amounts of bottom materials were resuspended and added to bottom waters.

TABLE 98. Mean Elemental Concentrations (ppm) of Suspended Particulate Matter From Northeastern Gulf of Mexico.

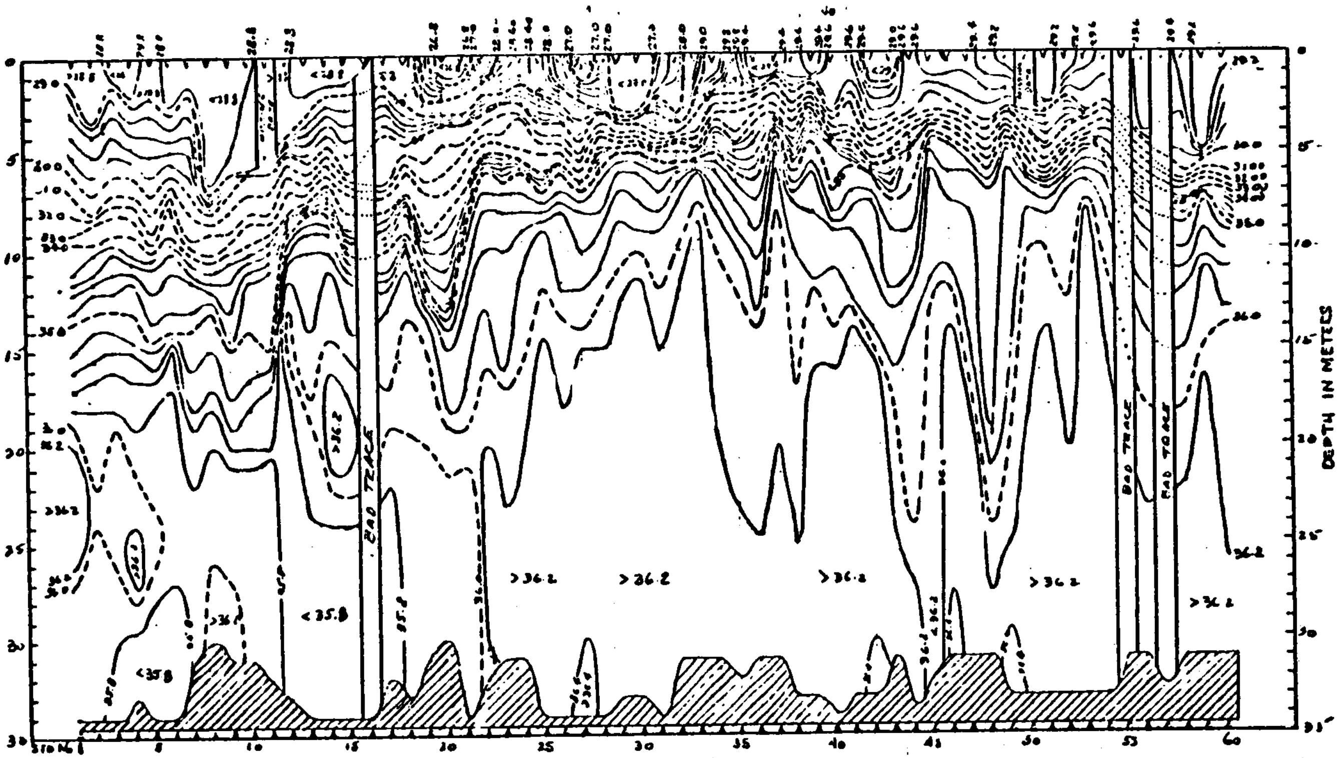
Cruise BLM-4 (Summer, 1976)
Refractory

Station	Sarasota "D"		Middle Grounds "C"		Panama City "A"		Miss. Delta "B"	
Element	sfc	bot	sfc	bot	sfc	bot	sfc	bot
Al	2181 ± 3653	3984 ± 3716	1268 ± 980	3408 ± 2528	2123 ± 634	6660 ± 3949	12078 ± 7696	42076 ± 23155
Cd	1.08 ± 1.11	1.19 ± 1.35	I.D.*	I.D.	0.21 ± 0.47	BDL+	1.47 ± 0.59	0.84 ± 0.78
Cr	2.11 ± 5.58	16.7 ± 37.4	I.D.	I.D.	695 ± 213	487 ± 556	64 ± 74	44 ± 60
Cu	24.9 ± 16.8	6.1 ± 8.4	32.3 ± 56.8	32.2 ± 58.9	133 ± 239	3.13 ± 4.30	23.9 ± 19.5	32.3 ± 14.0
Fe	2911 ± 2364	2253 ± 1325	1758 ± 3951	1742 ± 1224	1042 ± 733	2867 ± 1396	7561 ± 4918	23887 ± 10990
Pb	20.9 ± 16.2	10.1 ± 10.2	20.3 ± 28.2	17.6 ± 26.6	22.3 ± 33.4	17.3 ± 21.1	100.7 ± 96.1	83.1 ± 33.8
Si	41252 ± 24755	33417 ± 12751	39321 ± 20457	48762 ± 16387	31022 ± 5123	46232 ± 19139	61579 ± 18736	142749 ± 51493
n =	5	5	19	19	5	5	4	5

* I.D. Insufficient data points to calculate mean and standard deviation.

\+ BDL Below detection limits.

Note: All ± are one standard deviation.



Salinity Distribution Time Series Station "B" 29°47'N 088°13'W – 9060 STD Data – 1900 July 10 – 1500 July 15, 1978 — BLM-41

Figure 298

During the fall (DM II) time-series cruise, surface suspended particulate loads were extremely low, approaching those found in open ocean waters (e.g., Betzer et al., 1974; Lal, 1977; and Brewer et al., 1977). These particle loads were significantly different (95%) from surface suspended loads during the summer (BLM-4) and winter (DM III) time-series. Hydrographic data (see Figure 259) for the fall (Dames & Moore) showed high salinity waters covered the entire West Florida Shelf. Thus, it would appear that an incursion of the Loop Current had significantly reduced surface suspended loads on the continental shelf. In addition, the high near-bottom suspended loads, previously noted at the Mobile (2639) and Sarasota (2787) stations during the fall (DM II), probably resulted from interactions of this water mass with fine-grained bottom sediments.

In summary, seasonal and regional differences were found in suspended loads from the MAFLA shelves during the three time-series. As noted during previous MAFLA studies (Betzer and Peacock, 1976), the large suspended loads found over this extensive continental shelf during the winter are probably the result of intense sediment-water interactions during storms. Also, the Mississippi River dominates the particle budget for the Gulf of Mexico and is the primary reason suspended loads in the Mississippi-Mobile area are elevated over those near Panama City, in the Middle Grounds, and off Sarasota. The four major sources for suspended material in this area are: 1) sediment-water interactions, 2) river inputs, 3) biological productivity, and 4) Loop Current incursions. It is evident, however, that gravimetric data can only be used to infer a probable source for any suite of particles. Rather, chemical analysis is needed to discriminate the most important sources for particle suites.

SUSPENDED PARTICULATE COMPOSITION

The elemental composition of suspended particulate matter can provide valuable insight into the various sources (Joyner, 1964; Atkinson and Steffanson, 1969; Betzer and Pilson, 1971) and the transport of this material through the marine environment (e.g., Eggimann, 1975; Bolger, 1976). In addition, by separating these elements into weak acid soluble and refractory fractions one can partition trace elements into available and unavailable forms.

The chemical analysis of suspended particulate samples collected during three time-series cruises (July 1976, October 1977, and February 1978) in the northeastern Gulf of Mexico demonstrates interesting seasonal and regional differences in composition (Appendices F and G). Although some major differences were noted, these patterns are similar to those observed during the initial MAFLA study (Betzer and Peacock, 1976). Temporal changes in suspended particulate composition result from the various hydrologic, biologic, chemical, and depositional processes occurring in this region. For the purpose of discussion, however, a more convenient classification of the processes has been adopted. These data will be discussed as they relate to sediment-water interactions (resuspension), river inputs, Loop Current incursions onto the continental shelf, and the impact of the biosphere on the seasonal and regional composition of suspended matter.

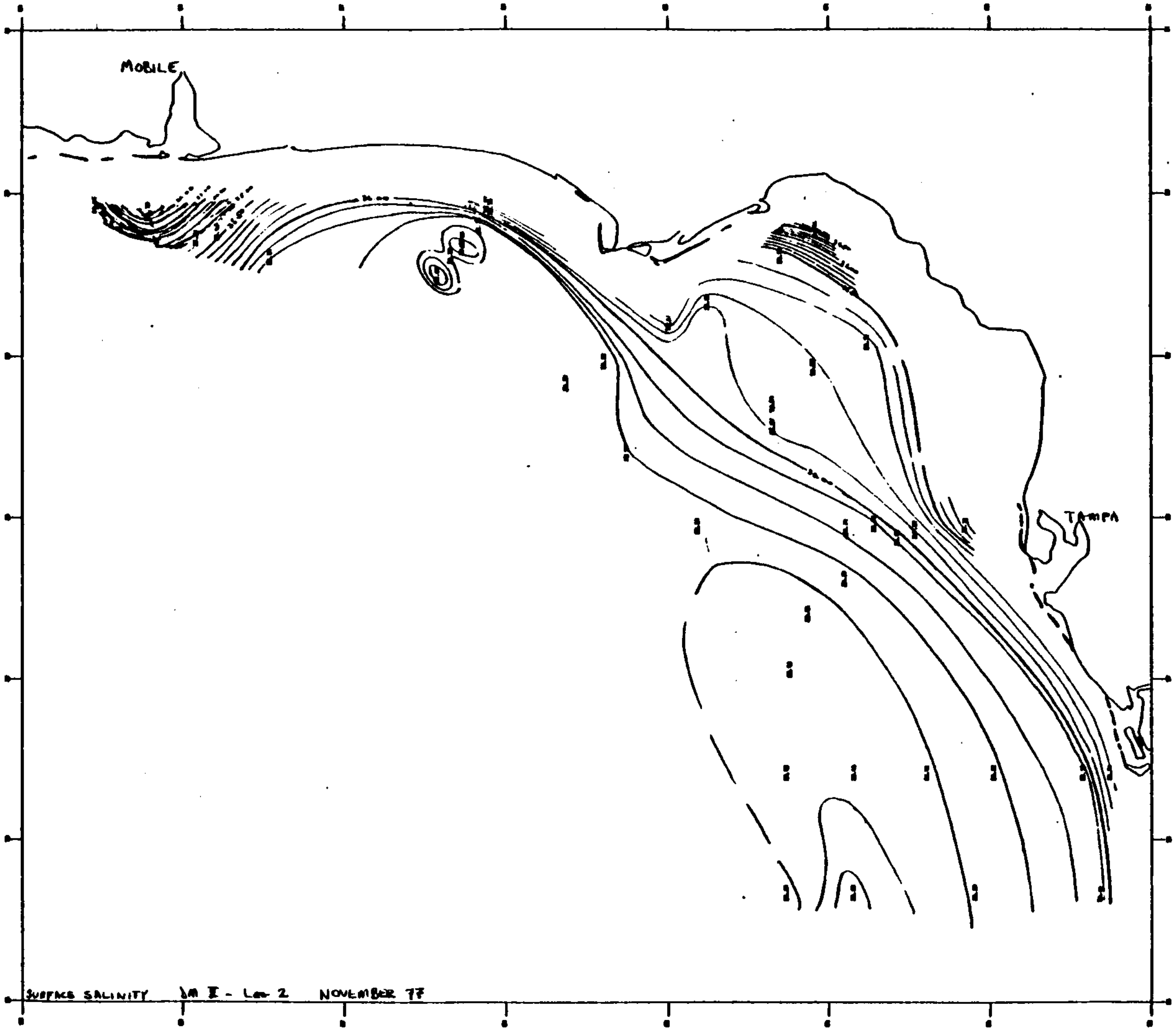


Figure 259

Sediment-water interactions were found to be an important control over suspended particulate composiiton during the winter season of both the Dames & Moore (DM III, February 1978) and SUSIO studies (January 1976) of the MAFLA area. In addition, sediment-water interactions were noted during the fall at the Sarasota (2747) and the Mobile (2639) stations where bottom currents interacted with underlying sediments. As noted earlier, suspended loads on cruise DM III were significantly larger during the winter (except the Sarasota station, 2747) than the other two cruises (BLM-4; DM II) during the summer and fall, respectively. The mean refractory silica and aluminum concentrations in both surface and bottom waters at the Middle Grounds (2315) and Panama City (2528) stations during the winter (DM III) are elevated between two to six times over their previous levels during the two earlier time-series cruises (BLM-4; DM II) (see Tables 98 through 100). In addition, the standing crop of these two elements was much greater during the winter, averaging 28.9 and 2.70 μg/l for silica and aluminum, respectively, compared to summer (2.46 μg/l and 0.20 μg/l) and fall (0.61 μg/l and 0.09 μg/l). Mean silica-to-aluminum ratios at these two stations range from 9.6 to 11.7 indicating that a substantial part of the silica is not of alumino-silicate origin. The clay mineralogy of these samples which were collected concurrently with ours (Doyle et al., 1978) indicate that the Si/Al ratios in suspended matter should vary from 1.1 to 1.3. The excess refractory silica (that which is unrelated to clay or quartz) is probably biologically precipitated diatom frustules. The suspended material from the Middle Grounds also had a high mean % $CaCO_3$ (6.71%-sfc, 5.41%-bot) during the winter time-series, when compared to fall and summer time-series. Given the preponderance of carbonates in bottom sediments (~66%) at this location, this is not an unexpected result (Presley et al., 1976).

The concentrations of silica, aluminum, and iron in suspended matter near Mobile provide a marked contrast with the rest of the areas in the northeastern Gulf and are essentially a reflecton of this location's proximity to the major particle source for the Gulf of Mexico, and the Mississippi River. Therefore, during all seasons a substantial portion of the suspended particle suites in surface and bottom waters are composed of suspended clays. There were, however, major seasonal changes in the standing crop of suspended clays which reflect the increased sediment-water interactions which took place during the winter. Particulate aluminum levels during the winter were 27 μg/l and 54 μg/l for surface and bottom, respectively, compared to 2.4 μg/l and 33 μg/l for fall and 2.3 μg/l and 7.2 μg/l for summer. The low mean silica-to-aluminum ratios for the winter at this station (3.58 - surface; 3.99 - bottom) demonstrate that most of the material in suspension (~40%) is alumino-silicates. The suspended particulates collected during the fall (DM II) at this same station had very high bottom suspended loads (eight times greater than surface) indicative of some local sediment-water interaction and/or horizontal advection. The mean ratio of silica to aluminum, 5.7 for near-bottom samples, indicates that the greater portion of this material is alumino-silicate, whereas, the surface ratios ($\bar{x}$ = 14.4) are evidence for a much greater biological contribution to surface particle suites.

Possibly, the most interesting occurrence of sediment-water interactions was observed during the fall cruise (DM II) at the Sarasota station (2747). Mean near-bottom suspended loads were four times greater (48 μg/l vs. 12 μg/l) than those in surface waters. Carder et al. (1978) have noted

TABLE 99. Mean Elemental Concentrations (ppm) of Suspended Particulate Matter From Northeastern Gulf of Mexico.

Cruise DM II (Fall, 1977)
Refractory

Station	Sarasota 2747		Middle Grounds III A		Panama City 2529		Mobile 2629	
Element	sfc	bot	sfc	bot	sfc	bot	sfc	bot
Al	10204 ± 7794	12936 ± 6690	3424 ± 2107	3532 ± 1601	2599 ± 1571	7919 ± 6650	49219 ± 13709	89000 ± 16700
Cd	19 ± 19	2 ± 2	I.D.*	I.D.	3 ± 2	16 ± 29	10 ± 8	4 ± 4
Cr	415 ± 510	33 ± 36	BDL+	BDL	37 ± 38	BDL	145 ± 81	95 ± 11
Cu	304 ± 213	33 ± 17	165 ± 72	412 ± 537	69 ± 44	160 ± 288	60 ± 41	32 ± 22
Fe	6164 ± 3101	4330 ± 1920	8740 ± 4947	1419 ± 1018	1971 ± 412	2472 ± 1455	16742 ± 3396	36218 ± 9181
Pb	I.D.	I.D.	60 ± 50	71 ± 63	BDL	BDL	65 ± 94	25 ± 90
Si	42817 ± 34909	33808 ± 15404	17603 ± 11554	22313 ± 16212	37557 ± 10843	45387 ± 29022	124682 ± 24148	206452 ± 12282
n =	5	5	4	5	5	5	5	5

* I.D. Insufficient data points to calculate mean and standard deviation.

\+ BDL Below detection limits.

Note: All ± are one standard deviation.

TABLE 100. Mean Elemental Concentrations (ppm) of Suspended Particulate Matter From Northeastern Gulf of Mexico.

Cruise DM III (Winter, 1978)
Refractory

Station	Sarasota 2737		Middle Grounds 2315		Panama City 2528		Mobile 2639	
Element	sfc	bot	sfc	bot	sfc	bot	sfc	bot
Al	3820 ± 1168	6505 ± 903	15480 ± 6293	17195 ± 7773	12446 ± 4032	13918 ± 5969	55384 ± 7884	50477 ± 15203
Cd	0.10 ± 0.13	0.53 ± 1.07	0.22 ± 0.29	0.54 ± 1.64	0.20 ± 0.38	0.28 ± 0.36	0.10 ± 0.13	0.31 ± 0.29
Cr	120 ± 111	BDL+	30.7 ± 43.2	30.8 ± 64.9	91.2 ± 74.0	79.4 ± 72.8	129 ± 43	152 ± 13
Cu	19 ± 12	15 ± 14	15.6 ± 10.8	19.8 ± 34.6	9.4 ± 8.0	13.9 ± 17.4	19.0 ± 7.8	21.4 ± 9.6
Fe	26783 ± 48772	2667 ± 2166	5764 ± 2169	5725 ± 2350	5850 ± 2317	6572 ± 2805	30524 ± 4932	31598 ± 9169
Pb	2.2 ± 30.6	BDL	8.0 ± 11.6	3.9 ± 7.6	2.1 ± 4.5	8.4 ± 10.3	18.1 ± 18.0	16.7 ± 23.4
Si	99954 ± 29483	112105 ± 20593	157739 ± 26204	165111 ± 20736	145580 ± 23125	163308 ± 19586	198573 ± 19667	201907 ± 25681
n =	5	5	18	18	5	5	5	5

+ BDL - Below detection limits.

Note: All ± are one standard deviation.

the presence of a near-bottom nepheloid layer at this station caused by the movement of Subtropic Underwater onto the shelf at the same time our samples were collected. The percent suspended calcium carbonate ($\bar{x}$ = 48 ± 32%) was the highest observed during all time-series cruises. Also, the mean aluminum concentrations in both surface and bottom waters (1.02% and 1.29%, respectively) were more than twice the concentrations during the summer (BLM-4; 0.22% and 0.67%) and winter (DM III; 0.38% and 0.65%). The marked seasonal changes in standing crops of $CaCO_3$ and aluminum also support the idea that there were substantial sediment-water interactions during the fall. Al and $CaCO_3$ in near-bottom waters during the fall were 0.62 μg/l and 23 μg/l, respectively, compared to 0.17 μg/l and 4.2 μg/l for the summer, and 0.30 μg/l and 2.5 μg/l for the winter. Mean silica-to-aluminum ratios at this station during the fall were 8.0 ± 4 (surface) and 2.7 ± 0.33 (bottom). These data suggest that the near-botom incursion of Subtropic Underwater was resuspending both fine calcium carbonate and clays at this time of the year.

In addition to altering the standing crop and concentration of suspended silica, aluminum, and calcium, the resuspension of bottom sediments also affects the concentrations of other metals. Iron is the most readily observed since it is an important constituent of alumino-silicate minerals (Degens, 1962), and biological systems (Lewin and Chen, 1971). Also, soluble iron from rivers and terrestrial runoff readily precipitates upon mixing with seawater to form hydroxides, oxides and coatings on terrestrial material, as well as scavenging a variety of other trace elements (e.g., Krauskopf, 1956; Murray and Gill, 1978). It is therefore of interest to see how the iron content of suspended particulate matter changes with resuspension and how the quantities of weak-acid soluble and refractory (poorly oxidized or available vs. well oxidized) iron change.

The regions of high terrestrial input (rivers), sources of iron, are found in the northern portion of our sampling area (Griffin, 1962). Samples collected in this area (Mobile, Station 2639) during the winter and fall indeed had much greater mean refractory iron concentrations (Tables 99 and 100) than those in the other three regions (Sarasota, Middle Grounds, Panama City). During the winter cruise (DM III) to the Mobile area, mean refractory iron concentrations were similar in both surface and bottom waters (30,524 ppm vs. 31,958 ppm), whereas, during the fall (DM II) bottom water concentrations (36,218 ppm) were twice those present in surface waters (16,742 ppm). This was not unexpected since a near-bottom "nepheloid" layer was present at this station (2639) during the fall. During the winter and fall at Mobile (Station 2639), the mean weak-acid soluble (WAS) iron concentration followed the same trends as refractory iron. However, the ratio of WAS Fe/Ref Fe during the fall was substantially greater in near-bottom than in surface waters (0.10 vs. 0.18, respectively). This would indicate that, at this time, surface and bottom waters had different sources of particulate iron. The much higher levels of WAS iron in near-bottom waters probably resulted from a resuspension of reducing bottom sediments with iron-rich pore waters, whereas, surface particulate iron was probably of fluvial and/or biogenic origin.

It was remarkable that the winter sampling of the Panama City (2528) station showed no significant increase in mean refractory and weak-acid soluble iron concentrations over the Middle Grounds station (2315), as this station (2528) is in a region of greater terrestrial input (Griffin, 1962). Mean refractory and weak-acid soluble iron concentrations at these stations were essentially the same in both surface (5,764 ppm vs. 5,850 ppm, and 236 ppm vs. 320 ppm) and near-bottom waters (5,725 ppm vs. 6,572 ppm, and 241 ppm vs. 307 ppm). The standing crops of refractory iron for the Middle Grounds and Panama City, although similar in surface waters (1.0 μg/l vs. 1.0 μg/l, respectively) were substantially greater for the near-bottom waters of the Panama City station (0.85 μg/l vs. 1.6 μg/l). With the exception of the surface stations at the Middle Grounds during the fall (discussed later), the refractory iron concentrations at these stations during the winter (DM III) were elevated over the concentrations found in surface and bottom waters during the fall (DM II) and summer (BLM-4). Similarly, standing crops of refractory iron at these stations was much greater during the winter than at other times of the year.

The resuspension noted in near-bottom waters off Sarasota (2747) in the fall (DM II) evidenced lower means for refractory and weak-acid soluble iron concentrations than those present in overlying surface waters (see Tables 99 and 102). This resulted from the dilution of the iron present in clay minerals (low Si/Al ratio) by the substantial quantities ($\bar{x}$ = 48%) of iron-poor calcium carbonate. If one considers standing crops, there is more refractory iron (0.21 μg/l vs. 0.08 μg/l) present in near-bottom waters, whereas, weak-acid soluble iron concentrations are still significantly greater in surface than in near-bottom waters (0.01 μg/l vs. 0.02 μg/l). This implies that the clay fraction, elevated in near-bottom waters over that in surface waters, controlled the distribution of refractory iron, whereas the larger standing crop of weak-acid soluble iron in surface waters was, in large part, related to the increased concentration of organic matter with exchangeable iron.

Other elements (Cd, Cu, Pb) also showed changes which could be related to resuspension. In the three regions (Mobile, Panama City, Middle Grounds) where sediment-water interactions were noted during the winter, the weak-acid soluble concentrations of Cd, Cu, and Pb were much less in both surface and bottom waters (see Tables 101 and 103) than at other times of the year (summer, fall). This resulted from the dilution of background levels in metal-rich organic matter by bottom-derived, metal-poor inorganic suspensates. When compared to the other seasons, weak-acid soluble iron concentrations were also reduced during the winter at Panama City and the Florida Middle Grounds. Since these regions have neither direct fluvial input nor reduced sediments to increase the concentration of WAS iron, the same dilution mechanism probably also applies for iron. As pointed out earlier, this was not the case at the Mobile station.

Refractory elements (Cd, Cu, Pb) do not exhibit as clear-cut a relationship to resuspension as do the weak-acid soluble elements, although they tend to be less concentrated during the winter at the Mobile, Panama City, and Middle Grounds stations. This trend probably also results from the dilution of a relatively metal-rich, organic-dominated particle assemblage with metal-poor resuspended bottom material. Chromium shows no readily discernible trends in both the refractory and weak-acid soluble phase.

TABLE 101. Mean Elemental Concentrations (ppm) of Suspended Particulate Matter From Northeastern Gulf of Mexico.

Cruise BLM-4 (Summer, 1976)
Weak-acid Soluble

Station	Sarasota "D"		Middle Grounds "C"		Panama City "A"		Miss.-Mobile "B"	
Element	sfc	bot	sfc	bot	sfc	bot	sfc	bot
Ca	37865 ± 57447	39626 ± 41676	4429 ± 1371	5137 ± 1891	4177 ± 1802	4412 ± 776	7598 ± 4653	3554 ± 199
Cd	6.1 ± 4.9	1.8 ± 2.8	30 ± 75	14 ± 22	10.6 ± 12.1	3.5 ± 5.5	19 ± 19	8 ± 9
Cr	BDL+	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	105 ± 107	39 ± 27	111 ± 137	65 ± 44	138 ± 85	31.9 ± 36.3	151 ± 102	52 ± 23
Fe	121 ± 115	643 ± 1143	472 ± 693	1212 ± 3409	514 ± 124	587 ± 325	312 ± 327	1679 ± 1077
Pb	99 ± 32	59 ± 33	82 ± 50	76 ± 63	32 ± 21	39 ± 39	148 ± 64	94 ± 64
n =	5	5	19	19	5	5	4	5

+ BDL - Below detection limits.

Note: All ± are one standard deviation.

TABLE 102. Mean Elemental Concentrations (ppm) of Suspended Particulate Matter From Northeastern Gulf of Mexico.

Cruise DM II (Winter, 1978)
Weak-acid Soluble

Station	Sarasota 2747		Middle Grounds III A		Panama City 2529		Mobile 2639	
Element	sfc	bot	sfc	bot	sfc	bot	sfc	bot
Ca	3942 ± 770	193492 ± 128666	4872 ± 2016	12910 ± 12047	22486 ± 13204	13529 ± 7487	7758 ± 6516	11149 ± 9318
Cd	I.D.*	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.	I.D.
Cr	153 ± 53	71 ± 33	152 ± 74	203 ± 66	116 ± 53	143 ± 116	56 ± 10	18 ± 12
Cu	183 ± 90	51 ± 71	98 ± 51	19 ± 14	82 ± 41	63 ± 41	32 ± 17	8 ± 5
Fe	1283 ± 836	209 ± 124	1361 ± 217	405 ± 248	449 ± 160	4169 ± 7422	1778 ± 617	6598 ± 1172
Pb	362 ± 220	85 ± 72	223 ± 123	81 ± 43	184 ± 102	181 ± 129	121 ± 84	94 ± 43
n =	5	5	5	5	5	5	5	5

* I.D. - Insufficient data points to calculate mean and standard deviation.

Note: All ± are one standard deviation.

TABLE 103. Mean Elemental Concentrations (ppm) of Suspended Particulate Matter From Northeastern Gulf of Mexico.

Cruise DM III (Fall, 1977)
Weak-acid Soluble

Station	Sarasota 2747		Middle Grounds 2315		Panama City 2528		Mobile 2639	
Element	sfc	bot	sfc	bot	sfc	bot	sfc	bot
Ca	3685 ± 2811	22623 ± 35216	26828 ± 22589	23514 ± 9777	10454 ± 18007	8344 ± 14047	1720 ± 124	2597 ± 1144
Cd	11 ± 21	11.5 ± 20.7	3 ± 3	5 ± 7	1 ± 1	8 ± 14	1 ± 1	6 ± 12
Cr	BDL+	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Cu	39 ± 13	27 ± 12	18 ± 12	13 ± 6	17 ± 12	10 ± 4	13 ± 5	10 ± 10
Fe	561 ± 474	72 ± 33	241 ± 107	236 ± 165	320 ± 128	307 ± 181	3641 ± 147	2285 ± 668
Pb	90 ± 24	71 ± 55	29 ± 17	15 ± 10	22 ± 17	11 ± 3	14 ± 4	9 ± 1
n =	4	4	18	18	5	5	5	5

+ BDL - Below detection limits.

Note: All ± are one standard deviation.

The two stations (Sarasota, Mobile) during the fall (DM II), which showed evidence for resuspended sediments near the bottom from the fall incursion of the Loop Current, had reduced concentrations of weak-acid soluble Cd, Cr, Cu and Pb in bottom waters when compared to surface waters. Also, the mean weak-acid soluble iron concentrations in near-bottom waters were suppressed at the Sarasota (2747) station but not the Mobile (2639) station. It is apparent therefore, that with the exception of iron over-reducing sediments, sediment-water interactions tend to dilute weak-acid soluble metal concentrations. If however, one considers standing crops of these weak-acid soluble metals (i.e., micrograms/liter) then one finds metal levels are essentially the same year round. Although refractory Cd, Cr, Cu and Pb display a similar dilution trend with resuspension, interpreting their distributions is complicated by the fact that these elements have both biogenic (diatoms, etc.) and inorganic (clays, quartz, etc.) sources.

Previous work in the study region (MAFLA) had shown resuspended bottom sediments were the primary source of surface (10 m) particulates (Betzer and Peacock, 1976) in the winter. Subsequent work in this area during the Dames & Moore time-series cruises has shown a similar situation occurring at three (Mobile-Mississippi, Panama City, Middle Grounds) of the four areas. The lack of resuspension at the Sarasota station is unusual since we previously found an abundance of resuspended carbonates all the way from the inner shelf to the 200 m contour off Tampa Bay in the winter (Betzer and Peacock, 1976). The composition of winter suspended particulates mirrors that of the underlying sediments, with clays dominating the Mobile-Mississippi and Panama City areas (Griffin, 1962), whereas clays and carbonates dominate the Middle Grounds area (Griffin, 1962; Gould and Steward, 1955).

Normally, one might expect the composition of resuspended bottom material would be the same as that of the underlying sediments. Table 104 shows a comparison between the mean refractory metal composition of surface and near-bottom suspended particulates compared to surface sediments (Presley et al., 1976) of the West Florida Shelf. In all cases, the trace metal concentrations in resuspended material are generally much higher than the concentration in bulk sediment. The important difference here is the amount of resuspended calcium carbonate; it is generally much less than the amount present in the sediments. This suggests that bottom currents tend to preferentially erode the very fine material leaving the larger calcium carbonate fragments behind. Baker and Feely (1978) have noted a similar situation in the eastern equatorial Pacific where chemical mass balance calculations suggested that the increase in elemental concentrations in the benthic nepheloid layer was due to resuspension of the very fine fraction (1 micrometer or less) from local bottom sediments.

The biosphere exerts an important influence upon the composition of offshore suspended loads. For example, Manheim et al. (1971) have noted that beyond the innermost 10 km of the southeastern Atlantic coast, suspended particulate loads are almost entirely organic. In addition, Honjo (1976) has noted the preponderance of coccolithophorids in open ocean waters, and Betzer and Peacock (1976) have noted high Si/Al ratios in offshore waters in the northeastern Gulf of Mexico indicative of diatom productivity. Since our chemical techniques allow for a differentiation of

TABLE 104. Comparison Between Mean Trace Metal Composition of Suspended Particulate Material and Surface Sediments of the West Florida Shelf.

Station	BLM-4 B (Miss. Delta) River Input			DM II 2639 (Mobile) Nepheloid Layer			DM III 2528 (Mobile) Winter Resuspension			DM III 2528 (P. City) Winter Resuspension			DM III 2315 (Middle Grounds) Winter Resuspension		
Element	sfc	bot	sed	sfc	bot	sed	sfc	bot	sed	sfc	bot	sed	sfc	bot	sed
Fe(%)	0.73	2.39	2.31	1.67	3.62	2.31	3.05	3.16	2.31	0.58	0.66	0.45	0.58	0.57	0.12
	±0.49	±1.10	±0.42	±0.34	±0.92	±0.42	±0.49	±0.92	±0.42	±0.23	±0.28	±0.15	±0.22	±0.24	±0.06
Pb(ppm)	100.7	83.1	16.0	65	25	16.0	18.1	16.7	16.0	2.1	8.4	7.7	8.0	3.9	7.1
	±96.1	±33.8	±1.4	±94	±90	±1.4	±18.0	±23.4	±1.4	±4.5	±10.3	±0.1	±11.6	±7.6	±2.6
Cd(ppm)	1.47	0.84	0.80	10	4	0.80	0.10	0.31	0.80	0.20	0.28	0.11	0.22	0.54	0.12
	±0.59	±0.78	±0.02	±8	±4	±0.02	±0.13	±0.29	±0.02	±0.38	±0.36	±0.04	±0.29	±1.64	±0.02
Cr(ppm)	64	44	41.20	145	95	41.20	129	152	41.20	91.2	79.4	4.3	30.7	30.8	4.0
	±74	±60	±0.02	±81	±11	±0.02	±43	±13	±0.02	±74.0	±72.8	±1.5	±43.2	±64.9	±2.9
Cu(ppm)	23.9	32.2	9.1	60	32	9.1	19.0	21.4	9.1	9.4	13.9	2.0	15.6	19.8	1.4
	±19.5	±14.0	±1.1	±41	±22	±1.1	±7.8	±9.6	±1.1	±8.0	±17.4	±0.0	±10.8	±34.6	±0.8
$CaCO_3$(%)	1.90	0.89	12.0	1.94	2.79	12.0	0.43	0.65	12.0	0.70	2.09	70.8	6.71	5.42	65.8
	±1.17	±0.05	±3.8	±1.63	±2.33	±3.8	±0.03	±0.29	±3.8	±0.21	±3.51	±10.6	±5.65	±2.48	±4.5

Note: All ± are one standard deviation.

carbonate and siliceous secreting organisms, it was of interest to evaluate seasonal and regional changes in the biosphere.

Previous work in the northeastern Gulf of Mexico (MAFLA) found the summer and fall were periods when standing crops of coccolithophores were greatest, with fall averaging 7.9 μg/l compared to 1.9 μg/l in the summer. If one assumes that cell numbers are a function of productivity, then fall was a more productive period. The summer (July 1976) and fall (October 1977) time-series cruises, however, did not follow this pattern. Rather, summer had the highest overall productivity compared to fall in three (Sarasota, Middle Grounds, and Mobile-Mississippi) of the four sampling areas. One problem in comparing these data is that the summer samples were collected in 1976, whereas, the fall samples were collected over one year later in 1977. It is possible, therefore, that we are not justified in making any comparisons. However, the lack of a sufficient data base necessitated such an attempt.

With the exception of the near-bottom samples at Sarasota and Mobile, which were discussed earlier, surface and near-bottom suspended loads during the fall were significantly (95%) less than those of the summer. The mean calcium carbonate concentrations for surface waters during the summer were 12 times greater than the fall at the Sarasota station and were approximately equal at the Mobile-Mississippi and Middle Grounds stations (Tables 101 through 103). However, when this is converted to μg/l, it is evident that there is much more calcium carbonate in the water column (from 4 to 64 times as much) at all three stations during the summer than the fall. Silica-to-aluminum ratios similarly support the hypothesis that the summer of 1976 was a period of increased productivity compared to the fall of 1977. Even though they incorporate minor amounts of aluminum in their frustules (Bennekom and Gaast, 1976), diatoms which utilize silica in their frustules would upon analysis show a high silicon/aluminum ratio (>5). The mean surface silicon/aluminum ratios for the summer (18/1) are over twice those for the fall (7.5/1) indicating there was substantial seasonal difference in diatom numbers.

What caused the suppressed suspended loads and productivity during the fall? Examinations of Figures 259 and 260 show high salinity (>36.6 $^{o}/oo$) water (possibly Loop Current) present on the shelf at the Sarasota, Middle Grounds, and Mobile stations. This open-ocean water, which is probably low in nutrients, would account for both the low suspended loads and productivity on the shelf at this time. In addition, as previously noted, it is this same high salinity water that has been implicated in resuspending bottom materials at the Sarasota and Mobile stations in the fall (DM II).

Station 2529 at Panama City was the only station that had higher productivity during the fall time-series (DM II) than the summer time-series (BLM-4). This station had a greater standing crop of calcium carbonate (1.25 μg/l vs. 0.56 μg/l) in the fall than the summer. Surface Si/Al ratios were similar during the summer ($\bar{x}$ = 15.7) and fall ($\bar{x}$ = 14.4) indicating that the percentage of diatoms was essentially the same during both seasons.

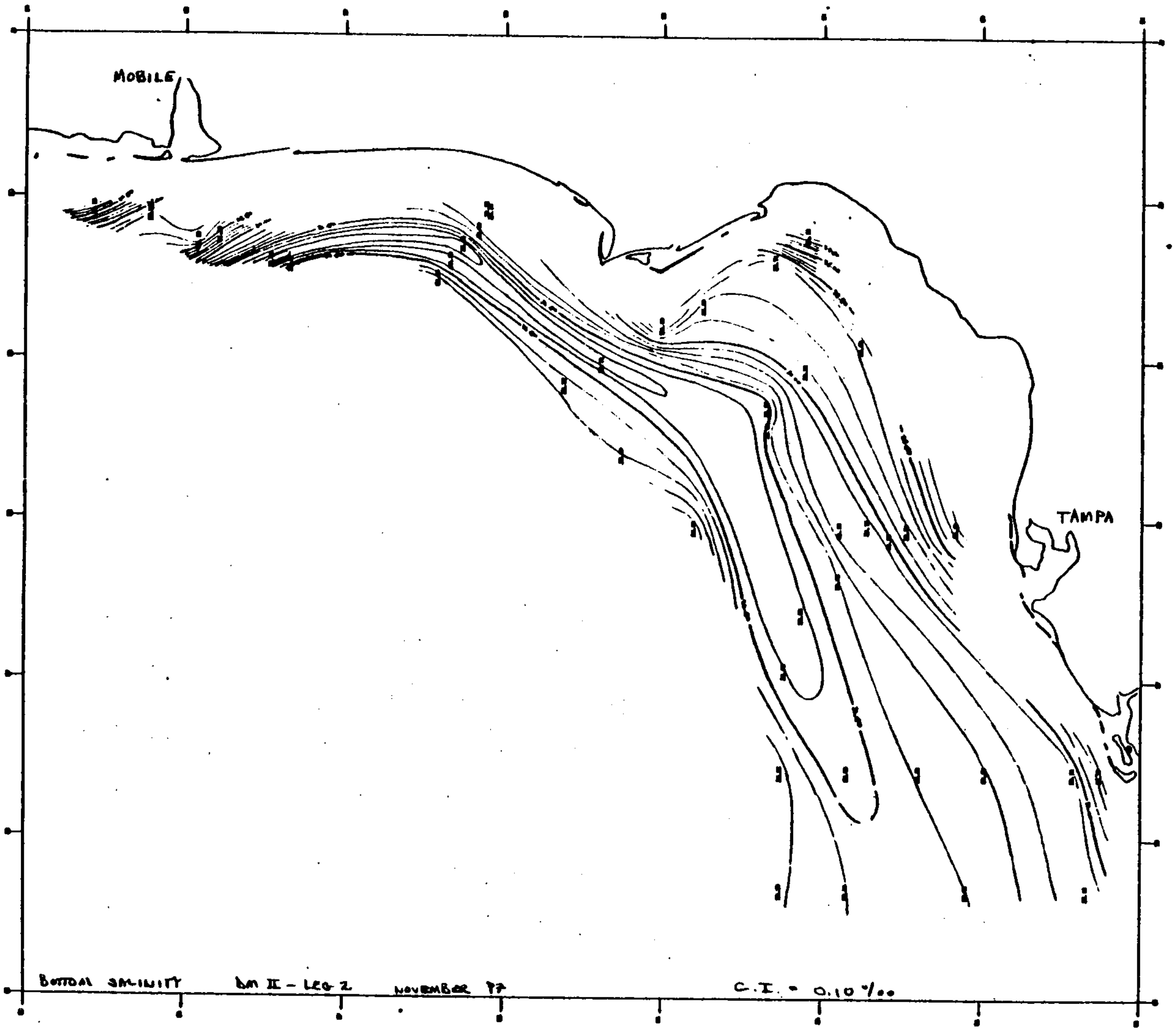


Figure 260

Refractory Cr, Cu and Pb were the only trace elements that could be related to changes in the biogenic component of the suspended particulate matter. By selecting those stations during the summer (all), the fall (2747, 2529), and winter (2747) where the mean Si/Al ratios were higher in surface waters than near-bottom waters, interesting changes in the ratios of refractory Cr, Cu, and Pb to aluminum were noted. When the refractory Cr, Cu, and Pb concentrations are normalized to refractory aluminum in surface and near-bottom waters for the aforementioned stations, one finds that most of the element-to-aluminum ratios are substantially higher in surface waters than in bottom waters. Since their ratios decrease as the Si/Al ratio decreases, this suggests that these elements are associated with the siliceous frustules of diatoms. These data agree with work previously performed in this area (Betzer and Peacock, 1976) where a similar relationship was found between high Si/Al ratios and high Pb/Al and Cr/Al ratios.

In summary, we realize the fallibility of comparing the summer time-series data of 1976 with the fall of 1977. However, the data from the summer of 1976 (BLM-4) compare favorably with the data collected during the summer of 1975 (MAFLA) for the standing crop of $CaCO_3$ and for Si/Al ratios. We feel, therefore, that the comparison is valuable in pointing out the uniqueness of the biogenic component of the suspended particulates in the fall of 1977 (DM II). This period was characterized by low surface suspended loads and low biological productivity at all stations except 2529 (Panama City) which we feel resulted from the intrusion of high salinity - low productivity offshore water.

The suspended particulate matter from the 1977 fall cruise (DM II) offered a unique opportunity to examine the effect of a Loop Current intrusion on the West Florida Shelf. During previous samplings in the northeastern Gulf of Mexico there was no evidence for such an event. Most of the effects of this intrusion have already been previously discussed in sediment-water interactions and biological productivity. However, because of the major changes which resulted, it will be briefly reiterated and expanded upon.

The intrusion of this high salinity water caused resuspension of bottom material at the Sarasota and Mobile stations as well as reducing biological productivity in all regions except Panama City. Suspended loads were also reduced to the lowest concentrations ever collected in this area. Mean silica-to-aluminum ratios were also consistently low ($\bar{x}$ = 2.4 - 8.0) in both surface and near-bottom samples from all areas except the surface samples at Panama City ($\bar{x}$ = 14.4). This suggests that the high salinity water is poor in nutrients and unable to support any diatom productivity. Instead, the majority or particulate silica is held in alumino-silicate minerals.

Incursion of the Loop Current and associated water masses during the fall of 1977 (DM II) resulted in increases of the concentrations of many trace elements in both the weak-acid soluble and refractory phases. Mean weak-acid soluble Cr, Cu, Fe, and Pb concentrations (ppm) during the fall (DM II) were significantly (at the 95% confidence level) increased in both surface and bottom waters over metal concentrations during the winter (DM III). The only exception was the iron concentrations at the Mobile (2639) station. The fall versus summer was not as clear-cut, although with the exception of lead at the Mobile station, mean WAS Cr and Pb concentrations during the fall were higher in both surface and bottom waters at all stations. WAS copper concentrations were increased in surface and bottom waters at the Sarasota (2747) station and WAS iron concentrations were higher in surface waters at the Sarasota (2747), Middle Grounds (III A), and the Mobile (2629) stations during the fall.

Where data were available (above detection limits or sufficient data points to determine a mean) the refractory fraction evidenced the same increase in concentration (ppm) during the fall for Cd, Cr, Cu and Fe over the other two sampling periods (see Tables E through G). As in the case of the weak-acid soluble elements, this trend was not evident at all depths for each station, but was present sufficiently often (>60%) to warrant a notation. This trend suggests that suspended particulates contained in the Loop Current have a unique chemical composition which is generally higher in trace element metals than normal continental shelf suspended loads. It should be noted that this does not suggest that the elemental composition per liter of seawater is greater in offshore water, but, that the metal concentration in the particles (in ppm) themselves is greater. The cause of this enrichment probably results from the offshore particulates being both very small (increased surface area) and having increased residence times which provides a longer time for diagenetic chemical processes such as adsorption, absorption and precipitation to take place. Evidence for this hypothesis is indirect, in that Maturo and Caldwell (1976) have noted very low zooplankton biomass concentrations in offshore waters suggesting the removal of suspended particulate matter by fecal pellets is also substantially reduced.

River input from the Mississippi was only observed at Station "B" during the summer cruise (BLM-4) of 1976. Surface salinities were less than 29 ^{o}/oo (see Figure 260) and large masses of fresh water hyacinths were present on the surface. Suspended loads in both surface and bottom waters were also significantly (95%) greater than those at the three other sample locations (Sarasota, Middle Grounds, Panama City). As evidenced by the high aluminum concentrations (surface $\bar{x} = 1.21 \pm 2.32\%$; bottom $\bar{x} = 4.21 \pm 2.32\%$), low Si/Al ratios (surface 2.1; bottom 3.4), and low calcium carbonate content (surface 1.9 ± 1.2%; bottom 0.9 ± .5%), alumino-silicates dominated the suspended particles collected at this station. Mean refractory iron concentrations were two to eight times greater at this station than at the three other stations. In addition, mean near-bottom refractory iron and aluminum concentrations were three times greater than surface concentrations suggesting some sediment-water interaction. Further evidence for resuspension is the ratio of WAS/Ref iron in surface (0.04) and near-bottom waters (0.07). If both near-bottom and surface waters had the same article source, then the WAS/Ref ratio should be the same. However, they are not similar which suggests that bottom suspended particulates have an additional source of WAS iron.

Other trace elements also showed interesting trends as the result of this fluvial input. Mean weak-acid soluble and refractory Pb concentrations were elevated during the summer at Station "B" compared to those at the other stations (Table 101). These data agree with Patterson et al. (1977)

who noted terrestrial runoff is one of the three major sources of lead to the oceans. Mean surface concentrations of weak-acid soluble Cu and Cd and refractory Cd during the summer were also somewhat elevated over the concentrations at the other stations. These data suggest that in addition to alumino-silicates, river input might also be an important source of Pb, Cd, and Cu.

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APPENDIX A

BLM ZOOPLANKTON

TOTAL ELEMENT ANALYSIS

Summer, 1975

CRUISE NUMBER 1

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1101	0.	509.	NA	NA	4.36	0.21	8.07	61.	1.18	0.72	NA	8.95
1102	0.	512.	NA	NA	6.93	0.67	10.72	116.	1.50	2.17	NA	13.02
1103	0.	510.	NA	NA	13.66	0.91	28.98	106.	3.80	1.94	NA	5.65
1204	0.	480.	NA	NA	7.35	0.84	11.08	151.	1.48	1.75	NA	3.95
1205	0.	533.	NA	NA	7.52	0.52	26.34	126.	1.86	3.63	NA	12.22
1206	0.	524.	NA	NA	8.33	0.38	9.40	67.	1.40	1.29	NA	7.40
1207	0.	535.	NA	NA	6.95	0.25	9.67	51.	1.78	1.24	NA	5.97
1308	0.	995.	NA	NA	5.34	0.16	14.42	67.	1.93	0.86	NA	1.01
1309	0.	1047.	NA	NA	4.96	0.06	8.09	54.	0.88	0.40	NA	2.17
1310	0.	993.	NA	NA	5.57	0.69	11.59	83.	2.23	2.58	NA	1.07
1311	0.	909.	NA	NA	11.85	1.06	15.86	161.	3.59	3.28	NA	1.26
1412	0.	1003.	NA	NA	10.96	3.23	14.83	553.	2.29	3.03	NA	4.59
1413	0.	994.	NA	NA	4.20	0.42	15.78	178.	1.94	1.28	NA	11.92
1414	0.	997.	NA	NA	2.82	0.28	9.55	86.	1.57	0.98	NA	15.32
1415	0.	1008.	NA	NA	4.26	0.75	31.95	197.	3.79	2.91	NA	7.45

***** = NOT DETECTABLE

APPENDIX B

BLM ZOOPLANKTON

TOTAL ELEMENT ANALYSIS

Fall, 1975

CRUISE NUMBER 2

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1101	0.	518.	NA	NA	2.09	0.17	9.78	55.	3.15	0.25	NA	1.69
1102	0.	567.	NA	NA	2.91	0.16	14.29	69.	3.46	0.86	NA	5.66
1103	0.	491.	NA	NA	17.95	0.37	21.66	60.	5.27	0.79	NA	0.80
1204	0.	590.	NA	NA	2.60	0.38	12.15	77.	0.91	1.26	NA	5.40
1205	0.	505.	NA	NA	10.70	0.30	17.05	97.	1.59	3.54	NA	*****
1215	0.	521.	NA	NA	2.80	1.05	21.88	192.	1.56	4.22	NA	0.37
1206	0.	543.	NA	NA	3.01	0.31	12.43	79.	2.14	2.01	NA	1.42
1207	0.	519.	NA	NA	3.19	0.17	12.19	62.	1.05	1.17	NA	0.47
1308	0.	476.	NA	NA	2.83	0.33	13.30	54.	0.98	0.69	NA	4.75
1309	0.	502.	NA	NA	10.65	0.17	12.44	60.	3.34	1.07	NA	0.19
1310	0.	526.	NA	NA	12.70	3.81	23.44	52.	9.74	1.18	NA	2.05
1311	0.	555.	NA	NA	12.17	0.70	19.77	144.	9.22	2.09	NA	0.28
1412	0.	486.	NA	NA	2.65	0.21	88.01	84.	1.23	0.66	NA	1.02
1413	0.	505.	NA	NA	3.07	0.71	16.71	49.	1.27	2.52	NA	34.32
1414	0.	506.	NA	NA	23.99	0.63	20.34	94.	5.52	3.37	NA	0.92
1415	0.	472.	NA	NA	22.19	5.46	42.40	237.	9.75	13.37	NA	1.04

***** = NOT DETECTABLE

APPENDIX C

B L M Z O O P L A N K T O N

TOTAL ELEMENT ANALYSIS

Winter, 1976
CRUISE NUMBER 3

ELEMENT CONCENTRATION IN PARTS PER MILLION

STATION NUMBER	DEPTH IN M	SAMPLE MASS (MILLIGRAMS)	AL	CA	CD	CR	CU	FE	NI	PB	SI	V
			1X	1X	1X	1X	1X	1X	1X	1X	1X	1X
1101	0.	519.	NA	NA	9.57	1.59	14.54	381.	1.68	3.26	NA	1.60
1102	0.	537.	NA	NA	7.86	0.89	14.18	113.	2.07	3.44	NA	0.99
1103	0.	522.	NA	NA	6.78	0.19	10.54	53.	3.76	0.67	NA	2.35
1204	0.	486.	NA	NA	3.12	0.54	33.26	173.	1.26	1.78	NA	1.32
1205	0.	597.	NA	NA	4.61	0.18	12.55	82.	0.90	0.16	NA	1.21
1206	0.	526.	NA	NA	5.33	0.39	12.48	118.	1.32	0.37	NA	2.88
1207	0.	540.	NA	NA	6.16	*****	17.61	60.	1.25	0.34	NA	2.17
1308	0.	500.	NA	NA	8.51	2.79	12.47	1892.	2.10	7.89	NA	4.79
1309	0.	506.	NA	NA	4.66	0.98	19.43	224.	3.23	0.94	NA	1.77
1310	0.	513.	NA	NA	6.84	0.50	13.44	244.	3.41	12.49	NA	15.22
1311	0.	453.	NA	NA	8.21	0.33	18.16	100.	5.49	0.69	NA	2.05
1412	0.	558.	NA	NA	3.97	1.98	11.89	*****	2.45	1.17	NA	25.41
1413	0.	516.	NA	NA	2.69	1.00	24.09	1542.	3.54	0.97	NA	3.66
1414	0.	490.	NA	NA	2.85	0.32	17.12	280.	1.54	0.16	NA	3.04
1415	0.	505.	NA	NA	6.12	0.59	17.70	892.	2.12	0.80	NA	6.83

***** = NOT DETECTABLE

APPENDIX D

BLM ZOOPLANKTON TOTAL ELEMENT ANALYSIS
BLM-4 SUMMER 1976

Sample ID	Date/ Time	Cd	Cr	Cu	Fe	Ni	Pb	Zn
C-2	*07/23/76 0130	1.04	0.90	42.6	89.6	3.03	3.0	80.2
C-4	0730	2.40 ±0.40	0.50 ±0.05	17.7 ±0.2	46.2 ±1.8	2.78 ±0.20	2.6 ±0.1	70.1 ±2.2
C-6	1330	2.85	0.45	24.2	55.0	2.30	4.1	70.2
C-8	1930	1.80	0.60	17.8	52.9	2.33	3.3	52.1
C-10	0130	1.30	0.60	10.1	24.8	1.85	4.8	49.2
C-12	0730	1.50	0.80	15.5	46.9	2.61	4.1	60.6
C-14	1730	2.60	0.90	24.5	68.4	2.86	7.06	70.2
C-16	1930	1.60	1.50	77.0	59.6	2.86	4.90	58.6
C-18	0130	1.70	0.80	18.2	92.0	2.15	3.90	66.6
C-20	0730	1.90	0.80	34.5	174.9	4.14	5.40	142.0
C-22	1330	1.50	0.80	24.5	173.4	2.26	5.30	118.8
C-24	2130	2.20	1.00	28.7	172.1	2.50	6.40	90.7
C-26	0130	2.10	0.80	23.4	108.8	2.36	5.10	83.2
C-28	0730	1.40	0.90	27.5	162.9	2.85	4.60	113.1
C-30	1330	2.40	0.85	15.3	120.8	2.50	4.90	69.8
C-32	1930	2.00 ±0.80	0.61 ±0.20	16.3 ±6.9	90.0 ±24.0	2.60 ±0.60	3.80 ±0.40	71.3 ±19.1
C-34	0130	2.40	1.11	21.1	107.9	2.76	6.80	69.4
C-36	0730	1.30	0.93	31.2	134.4	2.93	5.70	70.5
C-38	1330	1.70	1.20	97.6	134.3	4.80	12.10	129.7
C-40	1930	2.70	0.98	18.7	118.3	2.55	7.50	64.0

*Beginning date - days sequentially in order

APPENDIX E

BLM ZOOPLANKTON TOTAL ELEMENT ANALYSIS
DM-III WINTER 1978

Sample ID	Date/ Time	Cd	Cr	Cu	Fe	Ni	Pb	Zn
ZP#1	*02/08/78 0930	2.9	0.6	10.3	162.1	4.67	2.1	42.7
ZP#2	1600	1.9	0.3	13.8	135.1	5.69	5.2	35.0
ZP#3	2200	2.3	0.5	9.3	120.8	5.03	ND	22.3
ZP#4	1600	2.3	0.5	8.6	122.4	4.51	2.4	28.2
ZP#5	2200	2.4	0.5	11.0	154.6	4.97	1.7	46.2
ZP#6	0330	2.7	1.3	9.4	176.2	2.80	2.1	74.4
ZP#7	0930	3.2	0.7	11.9	266.1	3.00	1.0	68.3
ZP#8	1600	3.1	0.9	12.9	300.3	3.10	4.9	106.2
ZP#9	2200	2.6	1.0	13.4	248.0	3.70	3.7	62.5
ZP#10	0330	3.1	1.0	212.4	173.5	2.90	4.0	153.4
ZP#11	0930	2.5	0.9	12.5	197.8	2.80	3.5	83.6
ZP#12	1600	2.5	0.8	160.4	174.7	2.70	3.0	65.1
ZP#13	2200	1.8	0.8	11.3	211.3	3.90	1.8	52.2
ZP#14	0330	4.2	10.5	71.2	300.0	20.20	12.98	191.1
ZP#15	0930	1.7	0.8	140.2	200.1	3.80	1.90	98.4
ZP#16	1600	2.8	0.5	6.8	117.1	2.42	2.10	50.2
ZP#17	2200	1.8	0.7	9.2	175.1	3.26	1.40	38.0
ZP#18	0330	2.0	2.0	36.3	209.7	4.11	1.60	182.1

*Beginning date - days sequentially in order

APPENDIX F

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
			ppm - ELEMENT IN THE SUSPENDED LOAD											
A-1	3.0	44.5	NA	6592	24	BDL	201	591	NA	NA	BDL	37	NA	ND
A-1	29.0	63.8	NA	4083	BDL	BDL	BDL	707	NA	NA	BDL	5	NA	ND
A-2	5.0	40.2	NA	5441	23	BDL	186	611	NA	NA	BDL	35	NA	ND
A-2	30.0	58.7	NA	5736	1	BDL	84	287	NA	NA	BDL	66	NA	ND
A-3	5.0	70.6	NA	2311	BDL	BDL	30	420	NA	NA	BDL	BDL	NA	ND
A-3	30.0	58.7	NA	4394	3	BDL	55	1091	NA	NA	BDL	93	NA	ND
A-4	10.0	50.5	NA	2806	BDL	BDL	63	344	NA	NA	BDL	57	NA	ND
A-4	30.0	39.8	NA	4115	BDL	BDL	4	500	NA	NA	BDL	9	NA	ND
A-5	5.0	64.6	NA	3737	6	BDL	212	606	NA	NA	BDL	33	NA	ND
A-5	30.0	39.3	NA	3733	13	BDL	17	349	NA	NA	BDL	19	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

B L M SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE BLM-4

			ppm - ELEMENT IN THE SUSPENDED LOAD											
STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
B-1	7.0	101.1	NA	13669	46	BDL	231	BDL	NA	NA	BDL	226	NA	ND
B-1	27.0	173.4	NA	3766	1	BDL	29	3026	NA	NA	BDL	114	NA	ND
B-2	7.0	253.5	NA	3773	8	BDL	103	510	NA	NA	BDL	156	NA	ND
B-2	25.0	107.8	NA	3570	1	BDL	32	1837	NA	NA	BDL	58	NA	ND
B-3	7.0	151.2	NA	8814	2	BDL	29	71	NA	NA	BDL	71	NA	ND
B-3	25.0	45.5	NA	3502	4	BDL	76	394	NA	NA	BDL	194	NA	ND
B-4	7.0	0.0	NA	ND	ND	ND	ND	ND	NA	NA	ND	ND	NA	ND
B-4	25.0	206.1	NA	3247	14	BDL	77	819	NA	NA	BDL	77	NA	ND
B-5	7.0	261.9	NA	4137	20	BDL	240	666	NA	NA	BDL	140	NA	ND
B-5	27.0	319.9	NA	3683	5	BDL	46	2320	NA	NA	BDL	26	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
C-1	11.0	80.2	NA	6559	6	BDL	104	44	NA	NA	BDL	66	NA	ND
C-1	22.0	49.8	NA	5541	5	BDL	90	239	NA	NA	BDL	28	NA	ND
C-2	11.0	93.5	NA	1578	24	BDL	125	1700	NA	NA	BDL	123	NA	ND
C-2	22.0	40.3	NA	4846	10	BDL	115	BDL	NA	NA	BDL	96	NA	ND
C-3	12.0	77.8	NA	5800	12	BDL	116	33	NA	NA	BDL	76	NA	ND
C-3	25.0	63.4	NA	3380	25	BDL	35	BDL	NA	NA	BDL	33	NA	ND
C-4	12.0	99.0	NA	4483	60	BDL	55	39	NA	NA	BDL	37	NA	ND
C-4	24.0	70.5	NA	5610	19	BDL	95	257	NA	NA	BDL	92	NA	ND
C-5	9.0	96.0	NA	4109	BDL	BDL	20	154	NA	NA	BDL	21	NA	ND
C-5	24.0	46.2	NA	5752	7	BDL	112	212	NA	NA	BDL	42	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
C-6	10.0	74.9	NA	4621	BDL	BDL	26	BDL	NA	NA	BDL	39	NA	ND
C-6	27.0	52.2	NA	7436	11	BDL	88	380	NA	NA	BDL	64	NA	ND
C-7	5.0	53.5	NA	4547	8	BDL	62	BDL	NA	NA	BDL	28	NA	ND
C-7	25.0	63.8	NA	6499	11	BDL	139	272	NA	NA	BDL	69	NA	ND
C-8	10.0	0.0	NA	ND	ND	ND	ND	ND	NA	NA	ND	ND	NA	ND
C-8	24.0	81.1	NA	5877	8	BDL	44	485	NA	NA	BDL	59	NA	ND
C-9	12.0	76.4	NA	3395	1	BDL	49	997	NA	NA	BDL	77	NA	ND
C-9	30.0	60.2	NA	6550	10	BDL	113	180	NA	NA	BDL	110	NA	ND
C-10	5.0	46.0	NA	3371	3	BDL	73	967	NA	NA	BDL	202	NA	ND
C-10	24.0	31.7	NA	6733	BDL	BDL	35	BDL	NA	NA	BDL	68	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
			ppm - ELEMENT IN THE SUSPENDED LOAD											
C-11	10.0	49.2	NA	3571	88	BDL	55	498	NA	NA	BDL	186	NA	ND
C-11	24.0	58.1	NA	4633	1	BDL	118	BDL	NA	NA	BDL	40	NA	ND
C-12	5.0	58.4	NA	4997	1	BDL	60	116	NA	NA	BDL	80	NA	ND
C-12	22.0	82.1	NA	5618	3	BDL	63	424	NA	NA	BDL	89	NA	ND
C-13	7.0	72.3	NA	4256	11	BDL	68	1251	NA	NA	BDL	56	NA	ND
C-13	22.0	94.8	NA	3708	5	BDL	13	682	NA	NA	BDL	39	NA	ND
C-14	6.0	38.3	NA	5900	2	BDL	125	164	NA	NA	BDL	141	NA	ND
C-14	20.0	48.8	NA	6566	12	BDL	44	1746	NA	NA	BDL	75	NA	ND
C-15	10.0	72.0	NA	4031	BDL	BDL	393	BDL	NA	NA	BDL	66	NA	ND
C-15	21.0	0.0	NA	ND	ND	ND	ND	ND	NA	NA	ND	ND	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
			ppm - ELEMENT IN THE SUSPENDED LOAD											
C-16	10.0	58.1	NA	2938	BDL	BDL	13	BDL	NA	NA	BDL	82	NA	ND
C-16	24.0	59.1	NA	6746	25	BDL	56	BDL	NA	NA	BDL	89	NA	ND
C-17	10.0	75.4	NA	4633	313	BDL	562	409	NA	NA	BDL	65	NA	ND
C-17	24.0	42.1	NA	6427	1	BDL	57	247	NA	NA	BDL	125	NA	ND
C-18	10.0	63.0	NA	7338	5	BDL	97	BDL	NA	NA	BDL	52	NA	ND
C-18	21.0	71.7	NA	63	6	BDL	BDL	2941	NA	NA	BDL	302	NA	ND
C-19	7.0	83.3	NA	2907	BDL	BDL	13	2444	NA	NA	BDL	107	NA	ND
C-19	21.0	80.7	NA	4003	5	BDL	10	BDL	NA	NA	BDL	21	NA	ND
C-20	10.0	70.8	NA	5126	BDL	BDL	94	143	NA	NA	BDL	59	NA	ND
C-20	24.0	80.2	NA	1621	98	BDL	BDL	14970	NA	NA	BDL	9	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
D-1	10.0	32.5	NA	31961	2	BDL	54	BDL	NA	NA	BDL	95	NA	ND
D-1	60.0	37.0	NA	18387	7	BDL	75	BDL	NA	NA	BDL	44	NA	ND
D-2	10.0	34.6	NA	37536	13	BDL	109	147	NA	NA	BDL	88	NA	ND
D-2	65.0	65.9	NA	88888	BDL	BDL	29	205	NA	NA	BDL	11	NA	ND
D-3	10.0	119.3	NA	164825	13	BDL	66	118	NA	NA	BDL	42	NA	ND
D-3	65.0	33.8	NA	4277	BDL	BDL	60	2682	NA	NA	BDL	85	NA	ND
D-4	10.0	56.6	NA	7430	5	BDL	23	120	NA	NA	BDL	98	NA	ND
D-4	65.0	23.2	NA	5915	2	BDL	19	174	NA	NA	BDL	92	NA	ND
D-5	10.0	80.0	NA	7356	4	BDL	83	343	NA	NA	BDL	102	NA	ND
D-5	65.0	48.9	NA	80661	1	BDL	13	152	NA	NA	BDL	65	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
A-1	3.0	44.5	2600	NA	1	757	551	1020	NA	NA	BDL	75	25377	ND
A-1	29.0	63.8	1458	NA	BDL	1189	BDL	2220	NA	NA	BDL	BDL	39149	ND
A-2	5.0	40.2	1368	NA	BDL	630	BDL	106	NA	NA	BDL	BDL	28382	ND
A-2	30.0	58.7	10055	NA	BDL	989	BDL	4035	NA	NA	BDL	20	65016	ND
A-3	5.0	70.6	2906	NA	BDL	410	BDL	1597	NA	NA	BDL	BDL	36003	ND
A-3	30.0	58.7	11077	NA	BDL	BDL	7	4668	NA	NA	BDL	51	67740	ND
A-4	10.0	50.5	1684	NA	BDL	997	114	581	NA	NA	BDL	37	36909	ND
A-4	30.0	39.8	6017	NA	BDL	115	BDL	1822	NA	NA	BDL	BDL	34539	ND
A-5	5.0	64.6	2055	NA	BDL	684	BDL	1908	NA	NA	BDL	BDL	28440	ND
A-5	30.0	39.3	4693	NA	BDL	143	8	1573	NA	NA	BDL	15	24718	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CPUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
B-1	7.0	101.1	2635	NA	2	120	35	1151	NA	NA	BDL	239	40006	ND
B-1	27.0	173.4	50708	NA	BDL	107	8	27692	NA	NA	BDL	79	171853	ND
B-2	7.0	253.5	18563	NA	1	137	17	10758	NA	NA	BDL	93	71901	ND
B-2	25.0	107.8	44922	NA	1	113	33	28771	NA	NA	BDL	114	175576	ND
B-3	7.0	151.2	8970	NA	2	BDL	BDL	5438	NA	NA	BDL	35	52750	ND
B-3	25.0	45.5	11034	NA	2	BDL	43	8754	NA	NA	BDL	53	68574	ND
B-4	7.0	0.0	ND	NA	ND	ND	ND	ND	NA	NA	ND	ND	ND	ND
B-4	25.0	206.1	30563	NA	1	BDL	42	17234	NA	NA	BDL	121	109471	ND
B-5	7.0	261.9	18145	NA	1	BDL	44	11697	NA	NA	BDL	36	81659	ND
B-5	27.0	319.9	73153	NA	BDL	BDL	35	36985	NA	NA	BDL	48	188269	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
			ppm - ELEMENT IN THE SUSPENDED LOAD											
C-1	11.0	80.2	989	NA	BDL	BDL	BDL	1134	NA	NA	BDL	106	67057	ND
C-1	22.0	49.8	2046	NA	4	BDL	33	1984	NA	NA	BDL	BDL	41709	ND
C-2	11.0	93.5	4144	NA	5	BDL	BDL	1168	NA	NA	BDL	BDL	75367	ND
C-2	22.0	40.3	2701	NA	BDL	BDL	BDL	850	NA	NA	BDL	BDL	75100	ND
C-3	12.0	77.8	1173	NA	BDL	BDL	5	687	NA	NA	BDL	18	51736	ND
C-3	25.0	63.4	3499	NA	4	BDL	100	929	NA	NA	BDL	71	88821	ND
C-4	12.0	99.0	803	NA	1	BDL	38	755	NA	NA	BDL	BDL	48380	ND
C-4	24.0	70.5	4860	NA	BDL	BDL	41	1887	NA	NA	BDL	63	46934	ND
C-5	9.0	95.5	843	NA	1	BDL	225	687	NA	NA	BDL	43	54041	ND
C-5	24.0	46.2	1179	NA	BDL	120	BDL	223	NA	NA	BDL	62	70889	BDL

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER				ppm - ELEMENT IN THE SUSPENDED LOAD								
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
C-6	10.0	74.9	1249	NA	ND	BDL	59	64	NA	NA	BDL	69	75863	ND
C-6	27.0	52.2	9540	NA	9	BDL	194	3190	NA	NA	BDL	64	62774	ND
C-7	5.0	53.5	2312	NA	BDL	104	BDL	803	NA	NA	BDL	BDL	37015	ND
C-7	25.0	63.8	1762	NA	6	BDL	167	876	NA	NA	BDL	30	28735	ND
C-8	10.0	0.0	ND	NA	ND	ND	ND	ND	NA	NA	ND	ND	ND	ND
C-8	24.0	81.1	3199	NA	BDL	BDL	BDL	1536	NA	NA	BDL	8	58164	ND
C-9	12.0	76.4	554	NA	BDL	BDL	BDL	1298	NA	NA	BDL	BDL	47382	ND
C-9	30.0	60.2	1284	NA	9	BDL	60	1568	NA	NA	BDL	19	39836	ND
C-10	5.0	46.0	866	NA	BDL	BDL	BDL	1338	NA	NA	BDL	19	36705	ND
C-10	24.0	31.7	1272	NA	BDL	BDL	BDL	1180	NA	NA	BDL	BDL	36824	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER				ppm - ELEMENT IN THE SUSPENDED LOAD								
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
C-11	10.0	49.2	544	NA	BDL	BDL	BDL	832	NA	NA	BDL	BDL	31253	ND
C-11	24.0	58.1	1094	NA	1	BDL	BDL	BDL	NA	NA	BDL	BDL	36103	ND
C-12	5.0	58.4	1609	NA	4	BDL	BDL	683	NA	NA	BDL	BDL	42337	ND
C-12	22.0	82.1	9353	NA	1	27	16	4433	NA	NA	BDL	15	61403	ND
C-13	7.0	72.3	870	NA	3	BDL	BDL	17999	NA	NA	BDL	13	26109	ND
C-13	22.0	94.8	5130	NA	1	BDL	BDL	2809	NA	NA	BDL	BDL	37454	ND
C-14	6.0	38.3	1566	NA	3	BDL	58	510	NA	NA	BDL	35	45077	ND
C-14	20.0	48.8	5323	NA	1	BDL	BDL	2650	NA	NA	BDL	BDL	44639	ND
C-15	10.0	72.0	821	NA	BDL	BDL	15	358	NA	NA	BDL	BDL	29904	ND
C-15	21.0	0.0	ND	NA	ND	ND	ND	ND	NA	NA	ND	ND	ND	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
C-16	10.0	58.1	3155	NA	5	BDL	108	496	NA	NA	BDL	38	27116	ND
C-16	24.0	59.1	2251	NA	BDL	BDL	BDL	1070	NA	NA	BDL	BDL	35613	ND
C-17	10.0	75.4	1225	NA	BDL	BDL	BDL	1230	NA	NA	BDL	18	24174	ND
C-17	24.0	42.1	3979	NA	BDL	BDL	BDL	1393	NA	NA	BDL	BDL	45911	ND
C-18	10.0	63.0	135	NA	4	BDL	24	922	NA	NA	BDL	27	ND	ND
C-18	21.0	71.7	2871	NA	BDL	BDL	BDL	1849	NA	NA	BDL	BDL	34699	ND
C-19	7.0	83.3	638	NA	2	BDL	81	1629	NA	NA	BDL	BDL	13954	ND
C-19	21.0	80.7	987	NA	3	NA	BDL	550	NA	NA	BDL	BDL	47588	ND
C-20	10.0	70.8	600	NA	BDL	BDL	BDL	813	NA	NA	BDL	BDL	13625	ND
C-20	24.0	80.2	2420	NA	BDL	160	BDL	4117	NA	NA	BDL	BDL	33285	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

APPENDIX G

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE BLM-4

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
D-1	10.0	32.5	315	NA	BDL	BDL	41	549	NA	NA	BDL	BDL	18057	ND
D-1	60.0	37.0	1158	NA	BDL	BDL	BDL	961	NA	NA	BDL	BDL	26768	ND
D-2	10.0	34.6	642	NA	BDL	BDL	17	7222	NA	NA	BDL	11	15404	ND
D-2	65.0	65.9	6813	NA	1	BDL	17	3058	NA	NA	BDL	BDL	39278	ND
D-3	10.0	119.3	10435	NA	1	15	17	4276	NA	NA	BDL	11	53244	ND
D-3	65.0	33.8	1708	NA	3	84	BDL	1359	NA	NA	BDL	23	20340	ND
D-4	10.0	56.6	1032	NA	2	BDL	39	2488	NA	NA	BDL	37	80399	ND
D-4	65.0	23.2	1155	NA	BDL	BDL	13	1728	NA	NA	BDL	11	28006	ND
D-5	10.0	80.0	1310	NA	1	BDL	45	3686	NA	NA	BDL	25	57562	ND
D-5	65.0	48.9	9088	NA	1	BDL	BDL	4157	NA	NA	BDL	16	52692	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-II

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
			ppm - ELEMENT IN THE SUSPENDED LOAD											
2747-C1	2.0	15.6	NA	4061	5	148	190	1382	NA	NA	BDL	712	NA	ND
2747-C1	66.0	40.2	NA	195808	42	89	176	323	NA	NA	BDL	197	NA	ND
2747-C2	3.0	9.9	NA	4364	140	147	313	2687	NA	NA	BDL	318	NA	ND
2747-C2	66.0	21.7	NA	131811	84	109	37	327	NA	NA	BDL	79	NA	ND
2747-C3	3.0	11.9	NA	2598	BDL	72	145	574	NA	NA	BDL	146	NA	ND
2747-C3	73.0	40.8	NA	303364	262	73	20	148	NA	NA	BDL	45	NA	ND
2747-C4	3.0	15.5	NA	4497	BDL	190	199	899	NA	NA	BDL	417	NA	ND
2747-C4	68.0	57.0	NA	324864	2	63	24	213	NA	NA	BDL	99	NA	ND
2747-C5	3.0	8.5	NA	4196	BDL	209	66	875	NA	NA	BDL	218	NA	ND
2747-C5	68.0	81.7	NA	11613	BDL	21	BDL	34	NA	NA	BDL	7	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-II

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
IIIA-C1	3.0	12.0	NA	3329	2	90	55	1145	NA	NA	BDL	98	NA	ND
IIIA-C1	27.0	13.8	NA	15419	266	110	26	306	NA	NA	BDL	77	NA	ND
IIIA-C2	3.0	13.3	NA	3751	19	102	116	1582	NA	NA	BDL	123	NA	ND
IIIA-C2	27.0	10.8	NA	6278	5	181	24	724	NA	NA	BDL	68	NA	ND
IIIA-C3	3.0	8.9	NA	4679	BDL	103	40	1602	NA	NA	BDL	192	NA	ND
IIIA-C3	27.0	10.8	NA	5306	BDL	212	BDL	52	NA	NA	BDL	99	NA	ND
IIIA-C4	3.0	11.9	NA	8363	BDL	211	164	1193	NA	NA	BDL	374	NA	ND
IIIA-C4	27.0	14.5	NA	32982	BDL	218	35	476	NA	NA	BDL	140	NA	ND
IIIA-C5	3.0	25.0	NA	4239	BDL	252	117	1282	NA	NA	BDL	330	NA	ND
IIIA-C5	27.0	6.8	NA	4566	127	292	12	467	NA	NA	BDL	23	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-II

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2529-C1	3.0	17.5	NA	13624	6	183	91	391	NA	NA	BDL	225	NA	ND
2529-C1	33.0	25.4	NA	23402	101	141	40	753	NA	NA	BDL	228	NA	ND
2529-C2	3.0	27.1	NA	37547	9	164	56	347	NA	NA	BDL	314	NA	ND
2529-C2	33.0	19.1	NA	13769	BDL	170	93	1105	NA	NA	BDL	256	NA	ND
2529-C3	3.0	7.9	NA	21908	6	86	46	368	NA	NA	BDL	215	NA	ND
2529-C3	33.0	10.0	NA	5516	BDL	321	98	17422	NA	NA	BDL	324	NA	ND
2529-C4	3.0	52.2	NA	33384	4	75	70	408	NA	NA	BDL	110	NA	ND
2529-C4	33.0	78.1	NA	6989	3	24	1	182	NA	NA	BDL	10	NA	ND
2529-C5	3.0	14.6	NA	5965	5	73	149	733	NA	NA	BDL	55	NA	ND
2529-C5	33.0	15.7	NA	17968	11	60	82	1383	NA	NA	BDL	88	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-II

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2639-C1	3.0	75.3	NA	4557	BDL	48	38	1177	NA	NA	BDL	260	NA	ND
2639-C1	29.0	149.0	NA	17236	BDL	38	11	4675	NA	NA	BDL	113	NA	ND
2639-C2	3.0	72.8	NA	19116	BDL	72	28	1895	NA	NA	BDL	39	NA	ND
2639-C2	29.0	419.4	NA	1638	BDL	12	16	6489	NA	NA	BDL	161	NA	ND
2639-C3	3.0	29.6	NA	4425	2	59	55	1596	NA	NA	BDL	80	NA	ND
2639-C3	29.0	538.0	NA	24212	6	12	6	7092	NA	NA	BDL	76	NA	ND
2639-C4	3.0	34.6	NA	7326	2	49	29	1444	NA	NA	BDL	100	NA	ND
2639-C4	29.0	654.5	NA	5159	15	11	5	6938	NA	NA	BDL	64	NA	ND
2639-C5	3.0	29.2	NA	3364	2	51	8	2780	NA	NA	BDL	124	NA	ND
2639-C5	29.0	152.2	NA	7501	BDL	15	4	7794	NA	NA	BDL	56	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-II

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2747-C1	2.0	15.6	2245	NA	48	22	66	8208	NA	NA	BDL	BDL	19210	ND
2747-C1	66.0	40.2	10250	NA	1	81	32	4656	NA	NA	BDL	BDL	33033	ND
2747-C2	3.0	9.9	17940	NA	19	846	191	10319	NA	NA	BDL	BDL	10563	ND
2747-C2	66.0	21.7	21262	NA	1	60	61	5927	NA	NA	BDL	8	48039	ND
2747-C3	3.0	11.9	7310	NA	4	126	212	3127	NA	NA	BDL	90	98217	ND
2747-C3	73.0	40.8	14339	NA	5	24	34	4916	NA	NA	BDL	13	38346	ND
2747-C4	3.0	15.5	4464	NA	23	1082	580	5769	NA	NA	BDL	80	32854	ND
2747-C4	68.0	57.0	15568	NA	2	BDL	17	5154	NA	NA	BDL	BDL	41596	ND
2747-C5	3.0	8.5	19063	NA	1	BDL	470	3398	NA	NA	BDL	BDL	53240	ND
2747-C5	68.0	81.7	3261	NA	BDL	BDL	23	999	NA	NA	BDL	BDL	8025	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-II

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
			ppm - ELEMENT IN THE SUSPENDED LOAD											
IIIA-C1	3.0	12.0	ND	ND	ND	ND	ND	ND	NA	NA	ND	ND	ND	ND
IIIA-C1	27.0	13.8	ND	NA	10	BDL	42	3001	NA	NA	BDL	72	28476	ND
IIIA-C2	3.0	13.3	6289	NA	1	164	100	7982	NA	NA	BDL	126	32844	ND
IIIA-C2	27.0	10.8	4806	NA	10	BDL	502	1537	NA	NA	BDL	146	19337	ND
IIIA-C3	3.0	8.9	1355	NA	14	BDL	109	7969	NA	NA	BDL	12	16588	ND
IIIA-C3	27.0	10.8	3544	NA	29	BDL	1308	1290	NA	NA	BDL	18	29611	ND
IIIA-C4	3.0	11.9	3534	NA	BDL	BDL	203	15161	NA	NA	BDL	32	16234	ND
IIIA-C4	27.0	14.5	1270	NA	BDL	BDL	185	1064	NA	NA	BDL	120	BDL	ND
IIIA-C5	3.0	25.0	2519	NA	BDL	BDL	248	3542	NA	NA	BDL	72	4747	ND
IIIA-C5	27.0	6.8	4508	NA	BDL	BDL	21	201	NA	NA	BDL	BDL	44145	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-II

		SUSPENDED LOAD	ppm - ELEMENT IN THE SUSPENDED LOAD											
STATION	DEPTH (m)	ug/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2529-C1	3.0	17.5	1670	NA	2	BDL	108	1325	NA	NA	BDL	20	28599	ND
2529-C1	33.0	25.4	17495	NA	6	BDL	52	4421	NA	NA	BDL	BDL	71491	ND
2529-C2	3.0	27.1	2606	NA	6	56	81	1878	NA	NA	BDL	BDL	41913	ND
2529-C2	33.0	19.1	6335	NA	4	BDL	76	2772	NA	NA	BDL	BDL	57954	ND
2529-C3	3.0	7.9	812	NA	BDL	43	101	2161	NA	NA	BDL	BDL	23513	ND
2529-C3	33.0	10.0	2648	NA	1	BDL	BDL	1531	NA	NA	BDL	BDL	16405	ND
2529-C4	3.0	52.2	2917	NA	2	BDL	56	2427	NA	NA	BDL	32	46838	ND
2529-C4	33.0	78.1	1498	NA	1	13	BDL	626	NA	NA	BDL	BDL	11885	ND
2529-C5	3.0	14.6	4990	NA	5	88	BDL	2063	NA	NA	BDL	BDL	46922	ND
2529-C5	33.0	15.7	11618	NA	68	BDL	673	3012	NA	NA	BDL	27	69208	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-II

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2639-C1	3.0	75.3	33948	NA	6	251	42	12596	NA	NA	BDL	23	92958	ND
2639-C1	29.0	149.0	60023	NA	BDL	109	BDL	20523	NA	NA	BDL	27	185007	ND
2639-C2	3.0	72.8	35907	NA	9	69	106	15433	NA	NA	BDL	58	106041	ND
2639-C2	29.0	419.4	80058	NA	1	97	53	40085	NA	NA	BDL	40	212288	ND
2639-C3	3.0	29.6	55160	NA	6	214	71	17053	NA	NA	BDL	228	133736	ND
2639-C3	29.0	538.0	10233	NA	9	80	39	38773	NA	NA	BDL	24	210433	ND
2639-C4	3.0	34.6	55551	NA	24	94	81	16678	NA	NA	BDL	16	140683	ND
2639-C4	29.0	654.5	10330	NA	8	88	21	37229	NA	NA	BDL	20	208664	ND
2639-C5	3.0	29.2	65527	NA	6	99	BDL	21950	NA	NA	BDL	BDL	149992	ND
2639-C5	29.0	152.2	91100	NA	1	102	47	44482	NA	NA	BDL	14	215868	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

APPENDIX H

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2747-1	3.0	36.4	NA	1675	2	BDL	23	215	NA	NA	BDL	98	NA	ND
2747-1	74.0	46.7	NA	10484	2	BDL	20	51	NA	NA	BDL	19	NA	ND
2747-2	3.0	73.9	NA	ND	ND	ND	ND	ND	NA	NA	ND	ND	NA	ND
2747-2	78.0	27.2	NA	2984	BDL	BDL	38	40	NA	NA	BDL	87	NA	ND
2747-3	3.0	33.9	NA	2913	BDL	BDL	35	160	NA	NA	BDL	56	NA	ND
2747-3	78.0	118.3	NA	75135	2	BDL	13	86	NA	NA	BDL	35	NA	ND
2747-4	3.0	25.0	NA	2320	43	BDL	54	696	NA	NA	BDL	92	NA	ND
2747-4	73.0	28.3	NA	ND	ND	ND	ND	ND	NA	NA	ND	ND	NA	ND
2747-5	3.0	31.1	NA	7833	BDL	BDL	43	1173	NA	NA	BDL	114	NA	ND
2747-5	75.0	11.1	NA	1890	43	BDL	36	112	NA	NA	BDL	141	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

B L M   S U S P E N D E D   M A T T E R

WEAK ACID SOLUBLE FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2315-1	3.0	72.9	NA	7082	5	BDL	15	330	NA	NA	BDL	9	NA	ND
2315-1	25.0	56.1	NA	8563	5	BDL	24	638	NA	NA	BDL	20	NA	ND
2315-2	3.0	111.6	NA	8154	5	BDL	30	424	NA	NA	BDL	36	NA	ND
2315-2	25.0	168.0	NA	13358	3	BDL	13	192	NA	NA	BDL	17	NA	ND
2315-3	3.0	210.5	NA	19532	2	BDL	11	205	NA	NA	BDL	8	NA	ND
2315-3	25.0	117.0	NA	15298	2	BDL	6	52	NA	NA	BDL	9	NA	ND
2315-4	3.0	150.0	NA	47417	2	2	39	201	NA	NA	BDL	37	NA	ND
2315-4	22.0	90.6	NA	23285	3	BDL	21	205	NA	NA	BDL	40	NA	ND
2315-5	3.0	95.8	NA	26053	7	BDL	36	415	NA	NA	BDL	24	NA	ND
2315-5	24.0	42.6	NA	10633	1	BDL	22	359	NA	NA	BDL	4	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD µg/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2315-6	3.0	109.5	NA	35088	2	BDL	11	286	NA	NA	BDL	14	NA	ND
2315-6	25.0	167.1	NA	14771	3	BDL	18	329	NA	NA	BDL	12	NA	ND
2315-7	3.0	166.8	NA	49729	10	BDL	13	340	NA	NA	BDL	28	NA	ND
2315-7	25.0	50.7	NA	29900	BDL	BDL	16	581	NA	NA	BDL	31	NA	ND
2315-8	3.0	160.5	NA	88648	2	BDL	24	265	NA	NA	BDL	38	NA	ND
2315-8	25.0	133.3	NA	37949	33	BDL	15	322	NA	NA	BDL	28	NA	ND
2315-9	3.0	124.3	NA	7267	1	BDL	12	170	NA	NA	BDL	33	NA	ND
2315-9	24.0	135.3	NA	19493	3	BDL	16	258	NA	NA	BDL	23	NA	ND
2315-10	3.0	53.0	NA	8974	8	BDL	17	336	NA	NA	BDL	32	NA	ND
2315-10	24.0	57.6	NA	12661	3	BDL	13	248	NA	NA	BDL	13	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
						ppm - ELEMENT IN THE SUSPENDED LOAD								
2315-11	3.0	225.8	NA	59797	3	BDL	17	216	NA	NA	BDL	45	NA	ND
2315-11	24.0	128.6	NA	30732	2	BDL	7	217	NA	NA	BDL	6	NA	ND
2315-12	3.0	190.6	NA	24304	1	BDL	12	261	NA	NA	BDL	7	NA	ND
2315-12	25.0	175.3	NA	7973	1	BDL	7	158	NA	NA	BDL	9	NA	ND
2315-13	3.0	212.2	NA	23831	1	BDL	11	330	NA	NA	BDL	68	NA	ND
2315-13	25.0	202.7	NA	24976	4	BDL	6	146	NA	NA	BDL	8	NA	ND
2315-14	3.0	255.2	NA	29261	2	BDL	6	121	NA	NA	BDL	14	NA	ND
2315-14	25.0	244.0	NA	23729	6	BDL	7	96	NA	NA	BDL	10	NA	ND
2315-15	3.0	124.8	NA	7379	1	BDL	27	143	NA	NA	BDL	58	NA	ND
2315-15	26.0	266.8	NA	39435	2	BDL	9	77	NA	NA	BDL	7	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2315-16	3.0	191.2	NA	5256	2	BDL	7	121	NA	NA	BDL	29	NA	ND
2315-16	25.0	251.1	NA	31708	10	BDL	12	54	NA	NA	BDL	9	NA	ND
2315-17	3.0	295.8	NA	7098	2	BDL	6	82	NA	NA	BDL	20	NA	ND
2315-17	25.0	98.7	NA	15837	1	BDL	11	101	NA	NA	BDL	18	NA	ND
2315-18	3.0	356.2	NA	28026	2	9	6	96	NA	NA	BDL	21	NA	ND
2315-18	25.0	297.7	NA	29628	4	BDL	6	208	NA	NA	BDL	6	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2528-1	3.0	66.9	NA	2392	BDL	BDL	36	225	NA	NA	BDL	50	NA	ND
2528-1	33.0	283.3	NA	351	BDL	BDL	6	103	NA	NA	BDL	9	NA	ND
2528-2	3.0	27.6	NA	2589	BDL	BDL	18	233	NA	NA	BDL	25	NA	ND
2528-2	33.0	193.5	NA	2515	4	BDL	9	150	NA	NA	BDL	14	NA	ND
2528-3	3.0	261.2	NA	2314	2	BDL	12	275	NA	NA	BDL	16	NA	ND
2528-3	33.0	253.0	NA	1851	33	BDL	13	322	NA	NA	BDL	6	NA	ND
2528-4	3.0	144.9	NA	2311	1	8	13	328	NA	NA	BDL	13	NA	ND
2528-4	33.0	72.9	NA	3621	3	BDL	15	427	NA	NA	BDL	13	NA	ND
2528-5	3.0	349.4	NA	42666	1	5	5	537	NA	NA	BDL	8	NA	ND
2528-5	33.0	396.7	NA	33382	2	2	9	532	NA	NA	BDL	11	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

WEAK ACID SOLUBLE FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2639-1	3.0	561.5	NA	1694	1	BDL	10	4921	NA	NA	BDL	13	NA	ND
2639-1	27.0	803.7	NA	2230	1	BDL	4	3052	NA	NA	BDL	9	NA	ND
2639-2	3.0	468.8	NA	1646	BDL	BDL	7	3134	NA	NA	BDL	10	NA	ND
2639-2	30.0	234.5	NA	1963	1	BDL	14	1564	NA	NA	BDL	9	NA	ND
2639-3	3.0	468.0	NA	1581	BDL	BDL	17	3421	NA	NA	BDL	21	NA	ND
2639-3	29.0	1851.1	NA	2190	1	5	4	2487	NA	NA	BDL	11	NA	ND
2639-4	3.0	626.5	NA	1902	1	BDL	10	2501	NA	NA	BDL	11	NA	ND
2639-4	30.0	266.5	NA	1969	26	BDL	26	1609	NA	NA	BDL	7	NA	ND
2639-5	3.0	337.2	NA	1776	2	BDL	19	4230	NA	NA	BDL	16	NA	ND
2639-5	28.0	2203.4	NA	4631	BDL	BDL	3	2711	NA	NA	BDL	8	NA	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2747-1	3.0	36.4	NA	NA	BDL	174	17	3188	NA	NA	BDL	2	150892	ND
2747-1	74.0	46.7	7050	NA	BDL	BDL	12	1462	NA	NA	BDL	BDL	129835	ND
2747-2	3.0	73.9	4741	NA	BDL	193	39	113856	NA	NA	BDL	69	91942	ND
2747-2	78.0	27.2	6643	NA	2	BDL	18	2485	NA	NA	BDL	BDL	113119	ND
2747-3	3.0	33.9	3998	NA	BDL	233	22	3111	NA	NA	BDL	BDL	97224	ND
2747-3	78.0	118.3	7536	BDL	BDL	BDL	9	6446	NA	NA	BDL	1	132534	ND
2747-4	3.0	25.0	2257	NA	BDL	BDL	10	3433	NA	NA	BDL	BDL	81036	ND
2747-4	73.0	28.0	5192	NA	BDL	BDL	41	1742	NA	NA	BDL	BDL	82610	ND
2747-5	3.0	31.1	5059	NA	BDL	BDL	7	10326	NA	NA	BDL	BDL	78676	ND
2747-5	75.0	11.1	6106	NA	BDL	BDL	BDL	1201	NA	NA	BDL	BDL	102428	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD µg/LITER	Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
			ppm - ELEMENT IN THE SUSPENDED LOAD											
2315-1	3.0	72.9	15544	NA	BDL	BDL	7	5668	NA	NA	BDL	BDL	137384	ND
2315-1	25.0	56.1	22092	NA	BDL	BDL	6	8429	NA	NA	BDL	32	136610	ND
2315-2	3.0	111.6	16114	NA	BDL	BDL	6	7394	NA	NA	BDL	BDL	157494	ND
2315-2	25.0	168.0	13439	NA	BDL	7	11	5325	NA	NA	BDL	1	163487	ND
2315-3	3.0	210.5	12594	NA	BDL	32	16	5257	NA	NA	BDL	1	180988	ND
2315-3	25.0	117.0	7559	NA	BDL	BDL	5	3162	NA	NA	BDL	BDL	148049	ND
2315-4	3.0	150.0	15841	NA	BDL	133	12	6030	NA	NA	BDL	BDL	146909	ND
2315-4	22.0	90.6	24203	NA	BDL	BDL	9	7697	NA	NA	BDL	BDL	150853	ND
2315-5	3.0	95.8	20726	NA	BDL	82	25	8562	NA	NA	BDL	13	120152	ND
2315-5	24.0	42.6	18796	NA	BDL	208	8	7511	NA	NA	BDL	BDL	116320	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2315-6	3.0	109.5	20958	NA	BDL	23	7	6167	NA	NA	BDL	1	141298	ND
2315-6	25.0	167.1	20609	NA	BDL	165	151	7944	NA	NA	BDL	6	168400	ND
2315-7	3.0	166.8	28717	NA	BDL	35	7	8650	NA	NA	BDL	2	92586	ND
2315-7	25.0	50.7	36130	NA	BDL	BDL	12	9943	NA	NA	BDL	BDL	151615	ND
2315-8	3.0	160.5	24606	NA	BDL	BDL	12	9217	NA	NA	BDL	6	150862	ND
2315-8	25.0	133.3	22825	NA	BDL	BDL	15	8885	NA	NA	BDL	8	149318	ND
2315-9	3.0	124.3	18908	NA	BDL	BDL	20	7023	NA	NA	BDL	4	156930	ND
2315-9	24.0	135.3	23925	NA	BDL	BDL	4	4170	NA	NA	BDL	BDL	177021	ND
2315-10	3.0	53.0	21895	NA	BDL	BDL	36	7613	NA	NA	BDL	BDL	130402	ND
2315-10	24.0	57.6	22920	NA	BDL	BDL	BDL	8068	NA	NA	BDL	BDL	147655	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

B L M SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2315-11	3.0	225.8	14656	NA	BDL	98	11	5307	NA	NA	BDL	4	170273	ND
2315-11	24.0	128.6	16599	NA	7	BDL	39	6260	NA	NA	BDL	8	176855	ND
2315-12	3.0	190.6	12951	NA	BDL	BDL	12	1699	NA	NA	BDL	12	191935	ND
2315-12	25.0	175.3	13581	NA	BDL	BDL	39	4548	NA	NA	BDL	BDL	186046	ND
2315-13	3.0	212.2	13381	NA	1	BDL	34	ND	NA	NA	BDL	47	175520	ND
2315-13	25.0	202.7	14329	NA	BDL	BDL	3	4303	NA	NA	BDL	BDL	178166	ND
2315-14	3.0	255.2	9821	NA	BDL	BDL	9	4056	NA	NA	BDL	6	176097	ND
2315-14	25.0	244.0	9677	NA	BDL	BDL	13	3785	NA	NA	BDL	6	193768	ND
2315-15	3.0	124.8	12314	NA	1	BDL	24	5232	NA	NA	BDL	24	162807	ND
2315-15	26.0	266.8	9306	NA	BDL	BDL	8	3252	NA	NA	BDL	3	182983	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2315-16	3.0	191.2	7422	NA	BDL	94	36	4506	NA	NA	BDL	13	184511	ND
2315-16	25.0	251.1	8737	NA	1	7	26	3441	NA	NA	BDL	4	177719	ND
2315-17	3.0	295.8	6673	NA	1	BDL	2	2724	NA	NA	BDL	2	178499	ND
2315-17	25.0	99.0	7587	NA	BDL	128	4	3537	NA	NA	BDL	3	184884	ND
2315-18	3.0	356.2	5512	NA	BDL	56	6	2890	NA	NA	BDL	9	184655	ND
2315-18	25.0	297.7	8653	NA	BDL	38	5	2792	NA	NA	BDL	BDL	182251	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD µg/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2528-1	3.0	66.9	10658	NA	BDL	136	3	4748	NA	NA	BDL	BDL	139670	ND
2528-1	33.0	283.3	11600	NA	1	62	3	5076	NA	NA	BDL	BDL	182116	ND
2528-2	3.0	27.6	9572	NA	BDL	174	12	4323	NA	NA	BDL	BDL	115100	ND
2528-2	33.0	193.5	8248	NA	BDL	200	247	5124	NA	NA	BDL	17	159728	ND
2528-3	3.0	261.2	10390	NA	1	28	12	4486	NA	NA	BDL	BDL	156324	ND
2528-3	33.0	253.0	10543	NA	1	37	40	5073	NA	NA	BDL	22	161391	ND
2528-4	3.0	144.9	12146	NA	BDL	118	BDL	5832	NA	NA	BDL	BDL	139285	ND
2528-4	33.0	72.9	15787	NA	BDL	86	4	6054	NA	NA	BDL	BDL	133461	ND
2528-5	3.0	349.4	19464	NA	ND	BDL	20	9859	NA	NA	BDL	10	177519	ND
2528-5	33.0	396.7	23411	NA	BDL	12	9	11534	BDL	NA	BDL	3	179841	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

BLM SUSPENDED MATTER

REFRACTORY FRACTION

CRUISE DM-III

STATION	DEPTH (m)	SUSPENDED LOAD ug/LITER	ppm - ELEMENT IN THE SUSPENDED LOAD											
			Al	Ca	Cd	Cr	Cu	Fe	Mg	Mn	Ni	Pb	Si	Zn
2639-1	3.0	561.5	65925	NA	BDL	129	13	34385	NA	NA	BDL	22	178984	ND
2639-1	27.0	803.7	63782	NA	BDL	158	34	38006	NA	NA	BDL	13	234876	ND
2639-2	3.0	468.8	45193	NA	BDL	109	19	24503	NA	NA	BDL	BDL	186387	ND
2639-2	30.0	234.5	35660	NA	BDL	165	11	20283	NA	NA	BDL	13	185167	ND
2639-3	3.0	468.0	50858	NA	BDL	90	19	25850	NA	NA	BDL	10	187899	ND
2639-3	29.0	1851.1	63392	NA	BDL	151	23	37436	NA	NA	873	1	217688	ND
2639-4	3.0	626.5	55976	NA	BDL	202	12	34633	NA	NA	386	47	219947	ND
2639-4	30.0	266.5	39073	NA	1	154	145	22989	NA	NA	BDL	BDL	169940	ND
2639-5	33.0	337.2	58967	NA	BDL	113	32	33247	NA	NA	BDL	11	219648	ND
2639-5	28.0	2203.4	266973	NA	BDL	131	18	39278	NA	NA	747	57	201864	ND

ND=No Data
NA=Not Applicable
BDL=Below Detection Limits

VOLUME II

CHAPTER 23

WATER COLUMN BARIUM AND VANADIUM

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SAI
CONTRACT NO. AA550-CT7-34

BARIUM AND VANADIUM IN SEAWATER SUSPENDED PARTICULATES AND ZOOPLANKTON

MAFLA BENCHMARK SURVEY, 1977-1978

FINAL REPORT

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ABSTRACT

Concentrations of barium and vanadium were determined in plankton and refractory suspended material collected from the MAFLA lease area during 1976-1978. Seasonal trends exist with respect to the barium concentration in plankton. These trends may be controlled to a large extent by species composition.

Suspended particulates were collected from the same general area as the plankton. Although sampled as a time-series with depth, no depth or diurnal variations were seen. However, both seasonal and geographical trends were observed with respect to the levels of barium and vanadium.

INTRODUCTION

As a part of the characterization of water suspended particulates with respect to their trace metal composition (see Chapter 22), barium and vanadium were determined by neutron activation techniques. Neutron activation is substantially more sensitive for these two elements than is atomic absorption spectrophotometry. Prior to the 1977-1978 MAFLA study, barium had not been determined in eastern Gulf of Mexico particulates and vanadium had been with only poor reliability because of the limitations of the more convenient atomic absorption techniques.

Suspended particulates support the major flux of several metals through the marine environment. Metals enter the marine system either as dissolved ionic species or already associated with particles and, at the ionic strength of seawater, most metals partition effectively to the particulate phase. Marine particulates consist primarily of a combination of land-derived detritus and planktonic materials (both living and dead). For the most part, metals associated with these kinds of particles are either adsorbed onto their surfaces, bound into their mineralogical phases, or incorporated into biogenic particles.

It is difficult to generalize concerning normal or expected metal contents for suspended particulates, except to say that, depending on their sources (i.e., land runoff or productivity), their ambient metal concentrations should reflect crustal abundance levels for the appropriate source minerals being weathered and the supplying drainage basin. Also, since suspended particulates are themselves the immediate precursors to bottom sediments, there should be some resemblance between those two types of materials in terms of chemical composition. What must be recognized, however, is that the trace metal burdens of suspended particulates and the partitioning of metals between the solid and dissolved phases in the water column are dependent on local fluctuations in salinity, particulate and dissolved organic carbon, dissolved silica, and level of productivity.

In BLM's environmental baseline studies, the measurement of barium and vanadium in the various marine phases (including suspended particulates) has been predicated on the potential of these two elements to act as indicators of impacts from oil and gas development being dispersed through portions of the environment. Barium in the form of barium sulfate is a major component of drilling muds; vanadium (along with nickel) is known to substitute into the porphyrin ring system of chlorophyll, and having done so in ancient living material, it can now be found in characteristic quantities and proportions in today's crude petroleum. Vanadium is also a significant component of stainless steel and some other alloys.

Data from the 1976/1977 southern California OCS baseline survey indicate that enough barium has been released into the marine environment since around 1950 to elevate its sedimentary contents two- to three-fold (Patterson, unpublished BLM data). Although several other metals show similar trends, barium is the only one that cannot be related to terrigenous supply from urban areas and is presumably related to heavy oil production in the Santa Barbara Channel in the last 25 to 30 years.

Barium and vanadium data presented in this report comprise the first such set of values determined in the MAFLA lease area and provide initial estimates of their anticipated ambient concentration ranges in plankton and suspended particulates. Data for other metals are found in Chapter 22. Because of the extremely small amounts of barium and vanadium leached from the particulates by the 25% v/v acetic acid technique, only the refractory phases were analyzed.

METHODS AND MATERIALS

The neutron activation analysis techniques utilized in this study are detailed in Shokes and Reed, third quarterly MAFLA report, January 15-May 15, 1978 (Dames & Moore, 1978e).

RESULTS AND DISCUSSION

PLANKTON

Plankton samples were collected on cruises BLM-4 and DM-III at the Florida Middle Grounds site only. As in the case of the suspended particulates, time-series collections were made such that four samples a day were collected for a five-day period on each cruise. Table 105 lists barium and vanadium values from both sampling periods. The mean barium values in the plankton samples from the summer 1976 cruise (BLM-4) are significantly higher than those from the winter 1978 cruise (DM-III), 69 ppm vs 5.4 ppm, respectively. The probable explanation is that the plankton samples from the summer consisted mostly of zooplankton, while those collected in the winter were dominated by phytoplankton (Betzer, personal communication).

Interestingly, the mean particulate Si/Al ratio (see Table 107) was determined to be substantially higher in the summer 1976 Florida Middle Grounds sample (Station C) than n the winter 1978 sample (Station 2315), indicating a greater siliceous (phytoplanktonic) contribution to the composition of the former (summer: 39.5/21.2 (surface/deep) vs. winter: 31:0/ 12.5; Chapter 22 of this report). However, examination of the corresponding particulate iron and TSM concentration data (Table 107) suggests that the low winter Si/Al values may be due to higher Al contribution from resuspension of bottom sediments caused by winter storms.

The biomass of zooplankton is relatively high in the summer and at a minimum in the winter, whereas phytoplankton is most abundant in middle to late winter. Zooplankton, which are primarily calcareous organisms, have been shown to concentration barium to elevated levels (Martin and Knauer, 1973). The elevated barium levels in the plankton from BLM-4 are therefore most likely related to the difference in species composition between summer and winter.

Vanadium levels in plankton remained similar through both sampling periods, with all values being relatively low (0.32-2.9 ppm). The time of day in which plankton samples were collected is apparently not responsible for any trends in either barium or vanadium concentrations. Table 106 arranges the barium and vanadium data by time of day and by date, and a few trends are noteworthy. First, variation in barium during the summer is

TABLE 105

BARIUM AND VANADIUM CONCENTRATIONS IN PLANKTON

Summer 1976 (June-July)
BLM-4, Station C

Sample #	Day	Time (EST)	Ba ppm	V ppm
C-2	7/23	0130	240	2.7
C-4	7/23	0730	69	1.9
C-6	7/23	1330	210	1.5
C-8	7/23	1930	330	1.9
C-10	7/24	0130	8.8	0.32
C-12	7/24	0730	12	0.86
C-14	7/24	1730	74	1.7
C-16	7/24	1930	26	1.2
C-18	7/25	0130	21	0.85
C-20	7/25	0730	16	0.91
C-22	7/25	1330	20	1.1
C-24	7/25	2130	92	1.8
C-26	7/26	0130	18	0.88
C-28	7/26	0730	20	0.78
C-30	7/26	1330	15	0.83
C-32	7/26	1930	110	2.7
C-34	7/27	0130	15	0.82
C-36	7/27	0730	47	1.9
C-38	7/27	1330	18	0.55
C-40	7/27	1930	16	0.70
Mean ± 1σ			69 ± 87	1.3 ± 0.7
% Analytical Precision			6	12

TABLE 105 (CONTINUED)

Winter 1978 (February)
DM-III, Station 2315

Sample #	Date	Time (EST)	Ba ppm	V ppm
1	2/8	0930	7.1	2.2
2	2/8	1600	2.3	2.2
3	2/8	2200	2.2	2.3
4	2/9	1600	4.0	2.6
5	2/9	2200	3.1	2.2
6	2/10	0330	4.6	2.5
7	2/10	0930	4.0	1.5
8	2/10	1600	9.2	1.1
9	2/10	2200	5.2	1.5
10	2/11	0330	9.9	1.4
11	2/11	0930	8.3	1.3
12	2/11	1600	6.9	1.5
13	2/11	2200	3.1	2.3
14	2/12	0330	5.9	1.4
15	2/12	0930	4.8	2.3
16	2/12	1600	4.2	1.8
17	2/12	2200	4.9	2.2
18	2/13	0330	8.1	2.9
Mean ± 1 σ			5.4 ± 2.3	2.0 ± 0.5
% Analytical Precision			6	12

Note: % precision is based on the mean value obtained from the sum of the individual sample counting statistics and analytical errors.

TABLE 106

BARIUM AND VANADIUM CONCENTRATIONS IN PLANKTON ARRANGED BY TIME OF DAY AND BY CONSECUTIVE DATES

TIME, EST	Ba (ppm)	V (ppm)	DATE	Ba (mean ppm +1	V (mean ppm +1
Summer 1976 - Middle Grounds					
0730	69	1.9	7/23	212 ± 108	2.0 ± 0.5
	12	0.9			
	16	0.9			
	20	0.8	7/24	30 ± 30	1.0 ± 0.6
	47	1.9			
Mean ± 1 σ	24 ± 16 (33 ± 24)	1.3 ± 0.6			
1330	210	1.5	7/25	37 ± 37	1.2 ± 0.4
	20	1.1			
	15	0.8			
	18	0.6	7/26	41 ± 46	1.3 ± 0.9
Mean ± 1 σ	18 ± 3 (66 ± 96)	1.0 ± 0.4			
1930	330	1.9			
	26	1.2	7/27		
	110	2.7			

TABLE 106 (CONTINUED)

TIME, EST	Ba (ppm)	V (ppm)	DATE	Ba (mean ppm +1	V (mean ppm +1
	16	0.7			
Mean ± 1 σ	51 ± 52 (121 ± 146)	1.6 ± 0.9			
2130	92	1.8			
0130	240	2.7			
	9	0.3			
	21	0.9			
	18	0.9			
	15	0.8			
Mean ± 1 σ	16 ± 5 (61 ± 100)	1.1 ± 0.9			
February 1978 - Middle Grounds					
0930	7.1	2.2	2/8	3.9 ± 2.8	2.2 ± 0.1
	4.0	1.5			
	8.3	1.3			
	4.8	2.3	2/9	3.6 ± 0.6	2.4 ± 0.2
Mean ± 1 σ	6.1 ± 2.0	1.8 ± 0.5			
	2.3	2.2			

TABLE 106 (CONTINUED)

TIME, EST	Ba (ppm)	V (ppm)	DATE	Ba (mean ppm +1	V (mean ppm +1
February 1978 - Middle Grounds					
	4.0	2.6	2/10	5.8 ± 2.4	1.7 ± 0.6
	9.2	1.1			
	6.9	1.5			
	4.2	1.8	2/11	7.1 ± 2.9	1.6 ± 0.5
Mean ± 1 σ	5.3 ± 2.7	1.8 ± 0.6			
2200	2.2	2.3	2/12	5.0 ± 0.7	1.9 ± 0.4
	3.1	2.2			
	5.2	1.5			
	3.1	2.3	2/13	8.1 -	2.9 -
	4.9	2.2			
Mean ± 1 σ	3.7 ± 1.3	2.1 ± 0.3			
0330	4.6	2.5			
	9.9	1.4			
	5.9	1.4			
	8.1	2.9			
	7.1 ± 2.4	2.1 ± 0.8			

TABLE 107

SUMMARY OF SUSPENDED PARTICULATE BARIUM AND VANADIUM CONCENTRATIONS (REFRACTORY PHASE, μg/g DRY WEIGHT) AND RELATED PARAMETERS

Key: S = summer; F = fall; W = winter;
-76 = 1976; -2 = 1977; -3 = 1978

Station	Max Depth (m)	S Ba-76	F Ba-2	W Ba-3	S V-76	F V-2	W V-3	S TSM-76	F TSM-3	W TSM-3	S Si/Al-76	F Si/Al-2	W Si/Al-3	S Fe-76	F Fe-2	W Fe-3
Panama City	33															
Surface		[b]N.D.	[a]1220	148	N.D.	[a]250	31	54.1	23.9	170	15.7	17.5	12.1	1277	1970	5850
Bottom		N.D.	N.D.	107	[a]72	120	28	52.1	29.7	240	5.9	6.7	13.3	2864	2472	6572
Mobile	30															
Surface		N.D.	573	232	61	76	90	192	48.3	492	22.0	2.6	3.6	7261	16742	29558
Bottom		183	365	286	93	116	92	162	38.2	1072	3.9	2.7	4.2	23887	36218	31600
Middle Grounds	33															
Surface		N.D.	1165	344	72	N.D.	26	70.3	14.8	172	39.5	6.0	13.0	856	8664	5765
Bottom		N.D.	[a]3000	84	78	[a]200	31	60.9	10.7	142	21.1	7.4	12.5	1800	1419	5725
Sarasota	78															
Surface		N.D.	803	1524	37	230	46	64.6	12.3	40.1	41.3	6.6	28.9	2192	6168	6289
Bottom		N.D.	425	99	24	40	31	41.8	48.3	46.3	14.2	2.7	14.1	2252	4330	2667
			± 40%			± 47%										

[a] In obtaining this mean value only one sample was usable; all others were ND.

[b] ND = Non detectable.

greater than during the winter, and the concentrations are generally higher. No trends at all exist with time of day, but even though the variation (1σ) estimates are large, apparently the first summer collection date (7/23) provided samples of substantially higher barium relative to the other consecutive days of sampling. Vanadium, on the other hand, is remarkably consistent for all days and at all times of the day. The unusually high barium found on 7/23 is not able to be explained at this time.

Although previous studies have measured barium and vanadium concentrations in plankton, few such efforts exist with which to compare the present values, since most prior analytical methods have been relatively insensitive (Nicholls, et al., 1959; Vinogradov, 1953). However, Betzer and Peacock (1976) determined a mean vanadium concentration in plankton at the Florida Middle Grounds of 1.9 ppm (by atomic absorption spectrophotometry) compared to 1.6 ppm determined in this survey.

SUSPENDED PARTICULATES

Particulate samples were collected on three cruises during summer 1976, fall 1977, and winter 1978. the stations encompassed four general locations (Figure 261 and Table 105) which are geographically referred to as the Sarasota (Stations 2747 and D), the Middle Grounds (Stations 2315, C, and III-A), the Panama City (Stations 2529, 2528, and A) and the Mobile (Stations 2639 and B) stations.

The suspended particulate sampling design was intended to yield data which might indicate any seasonal, geographical, depth and short-term temporal varitions that could exist. time-series sampling was performed in detail on the scale of hours at the Middle Grounds station (winter 1978) and on the order of days at other stations (see Chapter 22). Table 107 summarizes the barium and vanadium data obtained during this study and although there are several trends worth commenting on, the first point to make is that many of the data were obtained at very near the elemental detection limits of neutron activation. A convenient example is the summer 1976 column for barium showing undetectable amounts because of the miniscule sample size able to be obtained from the atomic absorption laboratory.

Shown in Table 107 along with barium and vanadium (refractory phase only) are total suspended concentration (TSM), silicon-to-aluminum ratio (Si/Al) and refractory iron (Fe). Interesting trends are:

(1) Fall 1977 TSMs are lower than for the other two seasons

(2) Mobile area TSM values are higher at all seasons relative to the other three stations due to the particulate supply from land runoff

(3) All station TSMs appear to be higher at the surface than at depth during summer 1976 and fall 1977, but during winter, bottom resuspension reverses this trend

(4) Si/Al and Fe indicate a dominance of planktonic contribution during the summer bloom and an apparent winter "mini-bloom" and

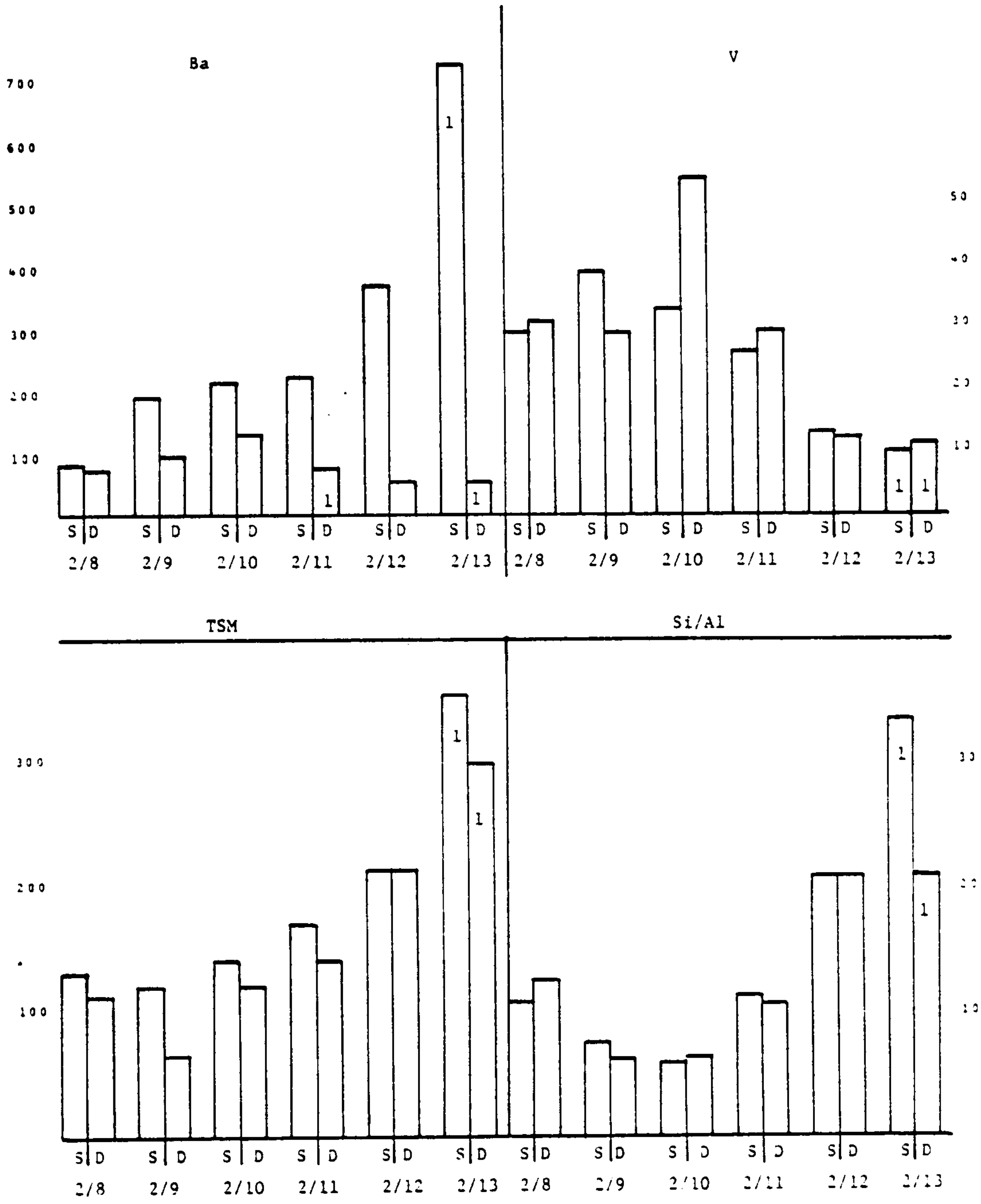

Figure 261 Histographic time series analysis of barium, vanadium, TSM and Si/Al variations in suspended particulates, Middle Grounds stations, Winter, 1978.

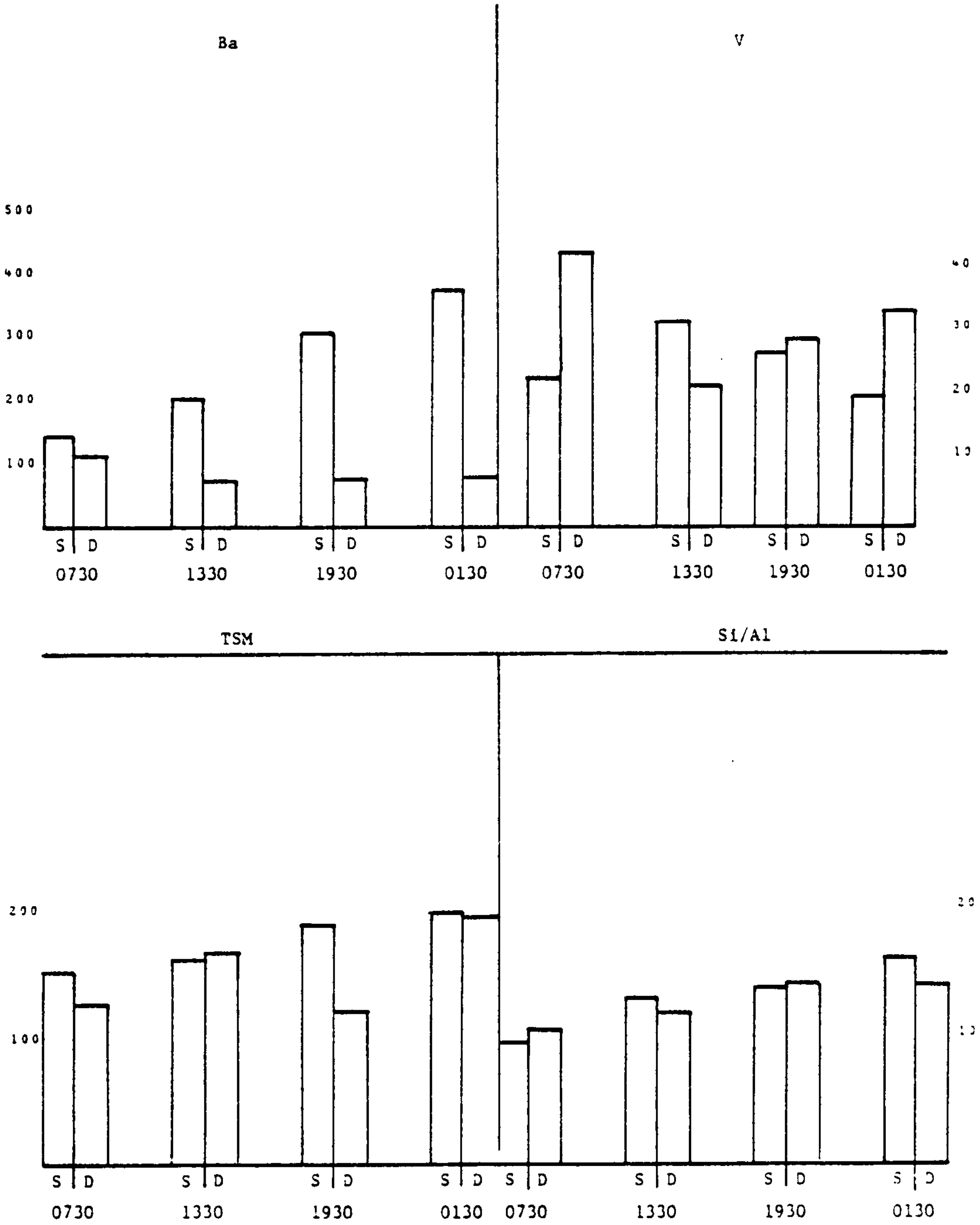

Figure 261 (continued). Histographic time series analysis of barium, vanadium, TSM and Si/Al variations in suspended particulates, Middle Grounds stations, Winter, 1978.

a dominance of non-biogenic material (higher Fe, lower Si/Al) during the low TSM fall

(5) The Mobile station only shows predominantly non-biogenic particulates (high Fe, low Si/Al) all three seasons with the only exception being the surface sample from the height of the summer bloom (Si/Al = 22, Fe = 7261 ppm).

(6) Mobile station particulates, which are primarily terrigenous materials, have barium and vanadium concentrations consistent with those found in the sediments in that area (see Chapter 3) and with average crustal abundances (Riley and Chester, 1971).

Table 108 and Figure 261 summarize the detailed time-series done at the Middle Grounds station during the winter of 1978. Because of the high degree of variability among individual samples and the relatively high analytical errors attached to the measurements, there are no significant correlations that can be made. From the histographic summary (Figure 261), however, there are a few data "trends" that are worth pointing out.

First, as might be expected, there are no systemmatic changes in either metal's concentrations with time of day. Although barium appears to trend upward from 0730 to 0130, the large uncertainty (1) bars attached to the higher values (1930h and 0130h) raises the question of how real this trend is; especially since the other parameters show no similar trends.

In inspecting the daily mean histograms, however, some trends do become apparent and internally consistent as variations between conditions on consecutive days seem to exist. As Figure 261 shows, even if the one sample at each depth from day 2/13 is discarded, barium still trends upward as TSM and Si/Al do the same. This indicates that during the five-day sampling period, a localized planktonic bloom occurred in the vicinity of the sampling and barium increased coherently with the increase in biogenic character of the particulates sampled. Interestingly, vanadium behaved in the opposite manner, tending to decrease with increasing biogenic contribution.

CONCLUSIONS

Vanadium levels in plankton sampled from the Florida Middle Grounds are generally low and do not vary. However, barium concentrations in plankton from the summer 1976 sampling period are much higher than the plankton from the winter 1978 cruise. This may partially be due to the greater contribution by calcareous zooplankton in the summer. Although sampled in a time-series, no correlation is observed between time sampled and content of barium and vanadium.

Suspended particulates show no trends with depth. However, daily variations, as well as geographical and seasonal trends, are observed. The particulates sampled off Mobile (near the Mississippi River Delta) are not only generally elevated in barium and vanadium, but are also somewhat stable and do not vary as much as the samples from other stations. This homogeneity is most likely the result of the dominating terrigenous input into the area.

TABLE 108

TIME SERIES ANALYSIS OF BARIUM, VANADIUM, TSM AND Si/Al VARIATIONS IN SUSPENDED PARTICULATES, MIDDLE GROUNDS STATIONS WINTER 1978

(February 8-13, 1978)

TIME (EST)	Ba (ppm)		V (ppm)		TSM (μg/ℓ)		Si/Al	
	SURFACE	DEEP	SURFACE	DEEP	SURFACE	DEEP	SURFACE	DEEP
0730	141 ±122 (384±495)	113 ±80	23 ±14	43 ±23	148 ±65	126 ±101	9.2 ±4.4	10.2 ±6.9
1330	198 ±65	73 ±6	32 ±10	22 ±5	161 ±33	164 ±60	13.0 ±7.4	11.8 ±5.8
1930	303 ±200 (443±356)	74 ±46	27 ±13	29 ±20	188 ±80	119 ±58	13.7 ±8.1	14.0 ±7.9
0130	369 ±333	78 ±36	20 ±12	34 ±31	194 ±138	192 ±104	16.0 ±12.9	13.9 ±7.7

	DATE					
	2/8(3)	2/9(2)	2/10(4)	2/11(4)	2/12(4)	2/13(1)
Ba-surface	87±41	185±21	211±162	220±85	367±148 (553±391)	720
V -surface	29±16	39±5	33±10	26±4	13±6	10
TSM-surface	132±71	123±38	141± 28	171±80	217±75	356
Si/Al-surface	11.0±3.0	7.6±2.5	6.1±2.1	11.4±3.8	20.7±6.3	33.5
Ba-deep	76±46	94±37	126±61	77	54±22	55
V -deep	31±24	29±1	54±25	29±13	12±6	11
TSM-deep	114±56	67±34	122±50	141±63	215±78	298
Si/Al-deep	12.7±6.7	6.2	6.6±1.7	10.8±3.2	21.1±2.2	21.1

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VOLUME II

CHAPTER 24

ZOOPLANKTON HYDROCARBON ANALYSES

DR. GEORGE GOULD
DR. BUD MOBERG
ANALYTICAL RESEARCH LABS, INC.
CONTRACT NO. AA550-CT7-34

ANALYSIS OF MARINE SAMPLES FROM THE OUTER CONTINENTAL SHELF OF MISSISSIPPI, ALABAMA, AND FLORIDA (MAFLA) FOR HIGH MOLECULAR WEIGHT HYDROCARBONS IN ZOOPLANKTON

INTRODUCTION

Analytical Research Laboratories, Inc. (ARLI) has completed work on its subcontract with Dames & Moore to perform high molecular weight hydrocarbon (HMWHC) analyses on zooplankton samples collected on the Water Column Cruise (DM III) conducted during the winter of 1978. Also included in this subcontract is a similar group of samples collected during the summer of 1976 and stored in freezers since that time. This work is performed for Dames & Moore on its Bureau of Land Management 1977/78 MAFLA Benchmark Survey (BLM Contract Number AA550-CT7-34). This final report includes a list of all zooplankton samples received, a brief description of the analytical methods used and a summary of results. The responsibility for a detailed interpretation of the results has been assigned to the Hydrocarbon Committee and that topic is not included in this report.

METHODS

The methods used in this investigation are designed to meet the requirements prescribed in Bureau of Land Management Solicitation Number AA550-RP7-10, as modified June 30, 1977. The Third Quarterly Report submitted to Dames & Moore by ARLI in June, 1978 (Dames & Moore, 1978e) should be consulted for a detailed description of the analytical methods and quality control practices used in processing these samples. Only a brief description of them is included in this report.

ANALYTICAL METHODS

Sample Preparation

The sample is allowed to thaw sufficiently to permit examination under a low-power magnifying glass for tar balls or other nonplanktonic materials. These are removed with clean forceps. Most of the sample is transferred to a tared flask and weighed to determine the wet weight of the plankton sample. The remainder of the sample is transferred to a small tared beaker, weighed, freeze-dried, and weighed again to permit calculation of the dry-weight of the plankton.

Digestion-Saponification

From this point on, the treatment of the zooplankton samples is exactly like that described for demersal fish in Chapter 8 of this report.

INTERNAL QUALITY CONTROL

The topics of sample accountability, instrument calibration, and materials used have been presented in the Benthic Hydrocarbon Report which makes up Chapter 8 of this Final Report.

Procedural Blanks

The zooplankton procedural blank is run in a manner almost identical with that described in the Benthic Hydrocarbon Report for demersal fish

(Chapter 8). The principal difference lies in the omission of the dissecting instruments and the use of a small petri dish instead of a large dissecting tray.

The two zooplankton blanks completed show total hydrocarbon levels of less than 1.0 ug · g^{-1}, a value comparable to that seen in the demersal fish and macroepifaunal blanks.

Recovery Studies

The Chromatography Recovery Tests reported in the Benthic Hydrocarbon Report (Chapter 8 of the Final Report) are pertinent here. A discussion of the results will not be repeated, except to recall that recoveries of aliphatic and aromatic hydrocarbon standards averaged well above the 70% level expected by BLM for the combined liquid chromatography-gas chromatography systems.

Sample Spiking Program

The zooplankton samples are processed exactly like the demersal fish and macroepifaunal samples, except for the initial sample preparation step. The results of the spiking program for those samples should be applicable to the zooplankton samples. Since those results were discussed in the Benthic Hydrocarbon Report (Chapter 8 of this Final Report), the discussion will not be repeated here.

A total of 8 zooplankton samples were spiked with n-tetracosane and chrysene. Recoveries averaged about 70% for the n-tetracosane and 40% for the chrysene. These recoveries are somewhat lower than those seen in the benthic tissue samples where recoveries averaged 87 and 60% for the aliphatic and aromatic spikes, respectively. The explanation for the lower recoveries with the zooplankton samples is not clear. It may be at least partially a statistical effect resulting from the fact that only 8 zooplankton samples were spiked compared to 71 spiked benthic tissue samples.

RESULTS

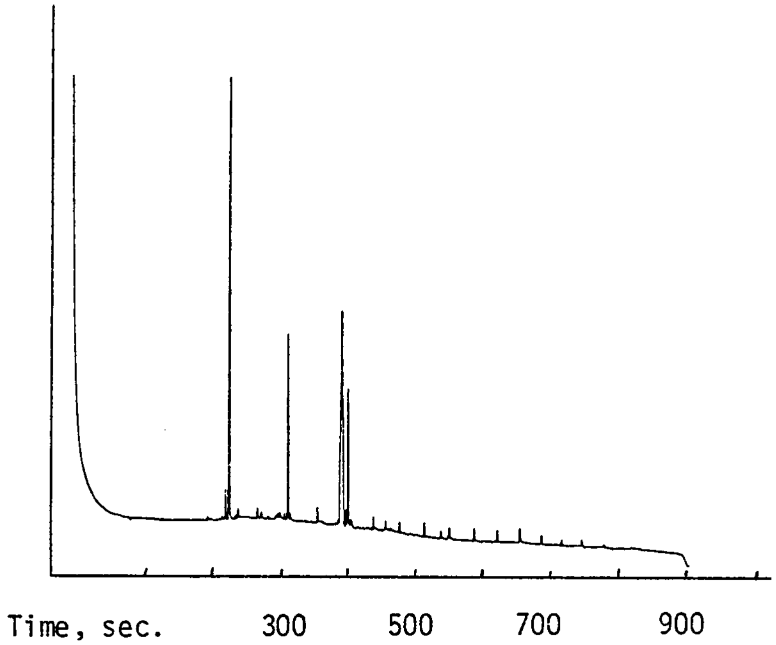
Figure 262 illustrates the gas chromatographic traces for the hexane and benzene fractions of a typical zooplankton sample. These traces along with computer print-outs of results and a cover sheet giving sample identification information compose the report submitted for each sample. A detailed explanation of the report format was given in the Benthic Hydrocarbon Report (Chapter 8). The GC traces shown in Figure 262 have been considerably reduced in size for reproduction here. The computer print-outs accompanying these traces are included in Appendix A.

A total of 38 zooplankton samples were analyzed by GC at ARLI for high molecular weight hydrocarbons. Eighteen of these samples were collected during the winter, 1978 water column cruise and the other 20 were archived from the summer of 1976. A complete list of these samples is given in Appendix B.

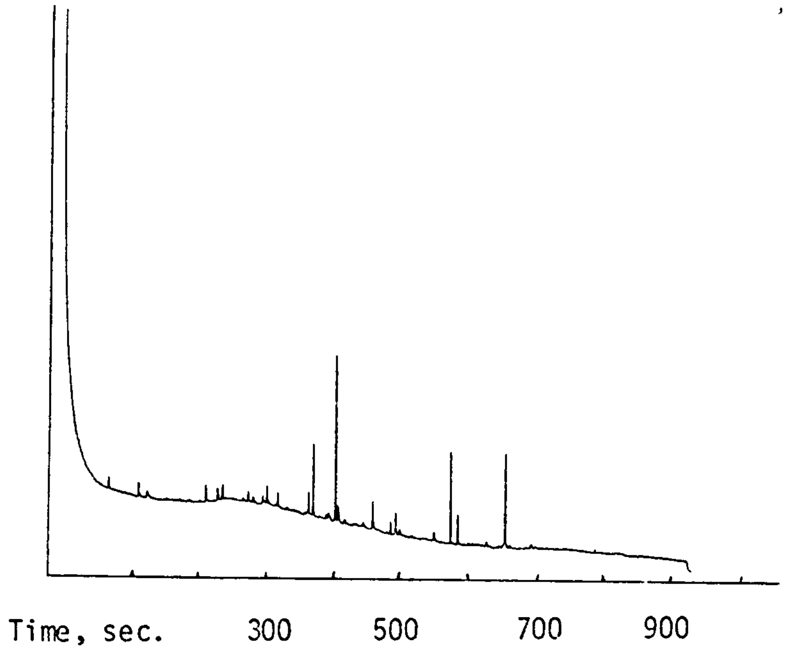
FIGURE 262

GC TRACES FOR ZOOPLANKTON SAMPLE 28074-17

Hexane Fraction



Benzene Fraction



Two LC fractions from zooplankton samples were analyzed by GC/MS. Reports have been submitted to Dames & Moore.

DISCUSSION

Since the generation of analytical data is the primary responsibility of ARLI in this project, it is appropriate to consider the quality of these data and to give some general impressions regarding the results.

DATA QUALITY

The discussion of data quality presented in the Benthic Hydrocarbon Report (Chapter 8 of this Final Report) is applicable here. These replicate analyses were performed at ARLI on each of two samples of demersal fish tissue. Results of one set of analyses showed a standard deviation of 15% while the standard deviation in the other set was 57%. The actual repeatability of the analytical method is probably somewhere between these two figures. The nonhomogeneous character of fish tissue makes it difficult to prepare equivalent subsamples for replicate analysis. Thus, variations in results are due partially to the sample material itself and partially to the limitations of the methods, but there is no way short of analyzing a very large number of samples to distinguish the two effects.

REVIEW OF RESULTS

Most of the samples in this relatively small group of 38 samples show a prominent pristane peak and a smaller normal heptadecane peak. The heptadecane seems to be less common in the DM III winter water-column cruise samples compared to the archived (summer, 1976) samples. The complex of peaks occurring in the 2080 Kovat's Index region of the gas chromatograms of many of the sediments is also found in many of the zooplankton chromatograms. The chromatograms of several samples show prominent peaks at the upper end of the molecular weight range (Kovat's Index of 2800 and higher). These may be due to the presence of suspended droplets of petroleum or tar balls in the plankton. However, no such material was seen in any of the samples when they were examined uner a 10-power microscope prior to analysis.

Results of earlier MAFLA studies of hydrocarbons in zooplankton were not available for comparison. However, the hydrocarbon levels in the zooplankton analyzed here are somewhat higher than those seen in the demersal fish samples, but lower than those seen in many of the macroepifaunal samples. Detailed analysis and interpretation of these results are the responsibility of the Hydrocarbon Committee (see Chapter 9 of this report).

CONCLUSION

A total of 38 zooplankton samples collected during the summer, 1976 and winter, 1978, were analyzed at ARLI for high molecular weight hydrocarbons. GC/MS analyses were performed on two fractions from these samples. The analysis of the samples was performed using methods and procedures approved by the BLM.

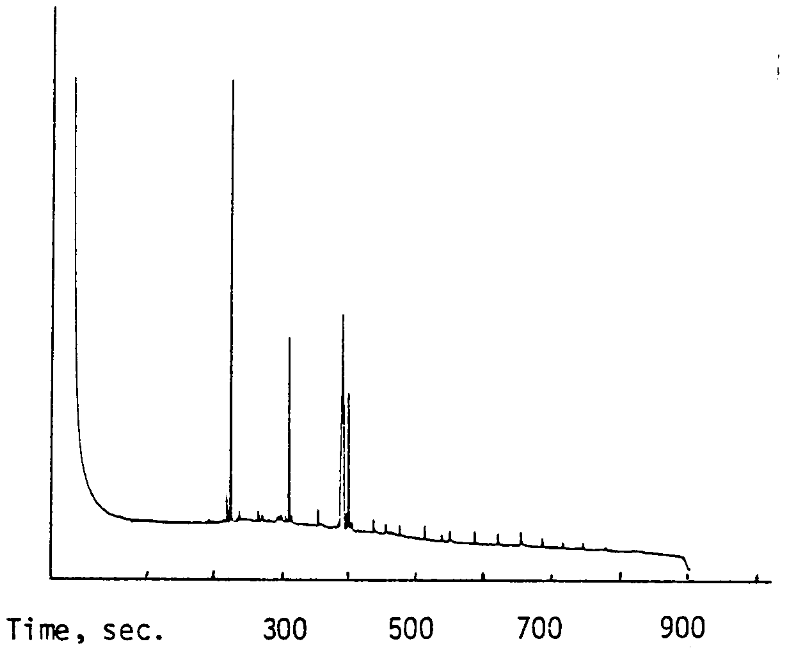
Assignment of a numerical value for the precision of the methods is difficult because the nonhomogeneous nature of the sample material makes the preparation of analytically equivalent subsamples difficult. Replicate studies on fish tissue gave standard deviations between 15 and 60%.

APPENDIX A

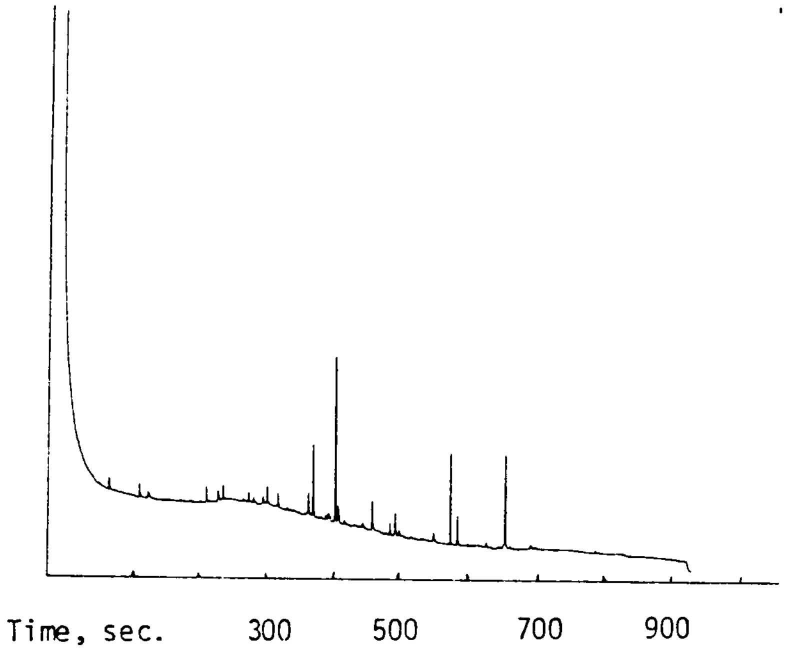
EXAMPLE OF DATA PACKAGE
PRODUCED FROM A ZOOPLANKTON SAMPLE

FIGURE A-1

GC TRACES FOR ZOOPLANKTON SAMPLE 28074-17



Hexane Fraction



Benzene Fraction

ANALYTICAL RESEARCH LABORATORIES, INC.

GAS CHROMATOGRAPHIC RESULTS

ARLI ID= 28074-17 HEXANE FRACTION
DESCRIPTION= 2315882580212
DATE= 2/12/78

TIME (SECONDS)	KOVATS ID	UG/G-TISSUE	WT% GC ELUATE	ASSIGNMENT
237.	1700.	0.068	0.79	N-C17
242.	1711.	1.1	13.	PRISTANE
255.	1739.	0.029	0.34	C18
283.	1800.	0.030	0.35	N-C18
289.	1813.	0.032	0.38	PHYTANE
324.	1839.	0.027	0.31	C19
329.	1900.	0.54	6.3	N-C19
333.	1999.	0.041	0.48	C20
373.	2000.	0.059	0.69	N-C20
404.	2055.	0.041	0.49	C21
409.	2076.	2.3	27.	C21
416.	2093.	0.062	0.73	C21
419.	2100.	0.47	5.5	N-C21
423.	2110.	0.050	0.58	C22
456.	2200.	0.072	0.85	N-C22
475.	2248.	0.060	0.70	C23
496.	2300.	0.050	0.59	N-C23
533.	2400.	0.072	0.84	N-C24
558.	2457.	0.060	0.70	C25
570.	2500.	0.087	1.0	N-C25
605.	2600.	0.075	0.88	N-C26
639.	2700.	0.073	0.86	N-C27
672.	2800.	0.15	1.7	N-C28
704.	2900.	0.076	0.89	N-C29
734.	3000.	0.049	0.57	N-C30
764.	3100.	0.050	0.59	N-C31
798.	3200.	0.055	0.65	N-C32
838.	3300.	0.042	0.49	N-C33

RESOLVED HEXANE ELUATE = 5.9 UG/G-TISSUE
UNRESOLVED HEXANE ELUATE = 2.6 UG/G-TISSUE

TOTAL "SATURATES" RECOVERED = 8.5 UG/G-TISSUE

20-A-2

ANALYTICAL RESEARCH LABORATORIES, INC.

GAS CHROMATOGRAPHIC RESULTS

ARLI ID= 28874-17 HEXANE FRACTION
DESCRIPTION= 2315882580212
DATE= 2/12/78

COMPOUND	UG/G-TISS	WT% OF GC ELUATE	COMPOUND	UG/G-TISS	WT% OF GC ELUATE
ISO-C14	0.0	0.0	ISO-C25	0.060	0.70
N-C14	0.0	0.0	N-C25	0.087	1.0
ISO-C15	0.0	0.0	ISO-C26	0.0	0.0
N-C15	0.0	0.0	N-C26	0.075	0.89
ISO-C16	0.0	0.0	ISO-C27	0.0	0.0
N-C16	0.0	0.0	N-C27	0.073	0.86
ISO-C17	0.0	0.0	ISO-C28	0.0	0.0
N-C17	0.058	0.79	N-C28	0.15	1.7
PRISTANE	1.1	13.			
ISO-C18	0.029	0.34	ISO-C29	0.0	0.0
N-C18	0.030	0.35	N-C29	0.076	0.89
PHYTANE	0.032	0.38			
ISO-C19	0.027	0.31	ISO-C30	0.0	0.0
N-C19	0.54	6.3	N-C30	0.049	0.57
ISO-C20	0.041	0.48	ISO-C31	0.0	0.0
N-C20	0.059	0.69	N-C31	0.050	0.59
ISO-C21	2.4	29.	ISO-C32	0.0	0.0
N-C21	0.47	5.5	N-C32	0.056	0.65
ISO-C22	0.050	0.58	ISO-C33	0.0	0.0
N-C22	0.072	0.85	N-C33	0.042	0.49
ISO-C23	0.060	0.70	ISO-C34	0.0	0.0
N-C23	0.050	0.59	N-C34	0.0	0.0
ISO-C24	0.0	0.0	ISO-C35	0.0	0.0
N-C24	0.072	0.84	N-C35	0.0	0.0

SUMMARY

8.5 UG/G-TISSUE TOTAL ALKANES
2.6 NORMAL ALKANE ODD/EVEN RATIO 0.91 = B&E CPI
0.59 ISOPRENOID-ALKANE/N-ALKANE RATIO
35. PRISTANE/PHYTANE RATIO
17. PRISTANE/N-C17 RATIO. 1.1 PHYTANE/N-C18 RATIO
0.74 NORMAL/BRANCHED ALKANE RATIO
24. PERCENT N-ALKANES
14. PERCENT ISOPRENOID ALKANES

NOTE: ISO- DENOTES SUM OF BRANCHED ISOMERS FOR EACH CARBON NO.
0.0 DENOTES LESS THAN 0.0005

~~20-A-39~~

ANALYTICAL RESEARCH LABORATORIES, INC.

GAS CHROMATOGRAPHIC RESULTS

ARLI ID= 28074-17 BENZENE FRACTION
DESCRIPTION= 2315682590212
DATE= 2/12/78

TIME (SECONDS)	KOVATS ID	UG/G-TISSUE	WT% GC ELUATE	ASSIGNMENT
79.	1350.	0.018	0.28	UNIDENTIFIED
123.	1456.	0.031	0.50	2,3-DIMETHYLNAPHTHALENE
136.	1485.	0.026	0.41	UNIDENTIFIED
225.	1674.	0.033	0.53	UNIDENTIFIED
242.	1711.	0.037	0.59	PHENANTHRENE
250.	1729.	0.039	0.60	ANTHRACENE
289.	1813.	0.024	0.37	UNIDENTIFIED
310.	1856.	0.032	0.50	UNIDENTIFIED
316.	1871.	0.048	0.76	UNIDENTIFIED
332.	1937.	0.033	0.53	UNIDENTIFIED
378.	2011.	0.057	0.90	UNIDENTIFIED
385.	2027.	0.16	2.5	UNIDENTIFIED
404.	2065.	0.019	0.30	UNIDENTIFIED
409.	2074.	0.052	0.83	UNIDENTIFIED
418.	2099.	0.38	6.1	UNIDENTIFIED
423.	2110.	0.11	1.7	METHYL STEARATE
432.	2133.	0.023	0.37	UNIDENTIFIED
462.	2210.	0.023	0.36	UNIDENTIFIED
474.	2245.	0.096	1.5	UNIDENTIFIED
501.	2313.	0.044	0.69	METHYL ARACHIDATE
509.	2334.	0.082	1.3	UNIDENTIFIED
515.	2351.	0.024	0.38	UNIDENTIFIED
558.	2494.	0.051	0.80	UNIDENTIFIED
593.	2565.	0.28	4.5	UNIDENTIFIED
604.	2597.	0.11	1.7	UNIDENTIFIED
672.	2800.	0.44	6.9	UNIDENTIFIED
710.	2919.	0.016	0.25	METHYL CEROTATE
945.	3492.	0.092	1.5	UNIDENTIFIED

RESOLVED BENZENE ELUATE = 2.4 UG/G-TISSUE
UNRESOLVED BENZENE ELUATE = 3.9 UG/G-TISSUE

TOTAL "AROMATICS" RECOVERED = 6.3 UG/G-TISSUE
TOTAL OILS RECOVERED = 15. UG/G-TISSUE

APPENDIX B

INVENTORY AND STATUS OF MAFLA ZOOPLANKTON SAMPLES FOR HMWHC ANALYSIS

Collection Date	Number of Samples	Page
Summer, 1976 (Archive)	20	
Winter, 1978 (DM III)	19	

INVENTORY OF MAFLA ZOOPLANKTON SAMPLES
FROM WINTER CRUISE, 1978 (DM III) FOR HMWHC

ARLI ID# 28074-N	SAMPLE ID#	STATUS
- 1	2315 8525 80208	All Analyses Completed
- 2	2315 8625 80208	
- 3	2315 8725 80208	
- 4	2315 8525 80209	
- 5	2315 8625 80209	
- 6	2315 8525 80210	
- 7	2315 8625 80210	
- 8	2315 8725 80210	
- 9	2315 8825 80210	
-10	2315 8525 80211	
-11	2315 8625 80211	
-12	2315 8725 80211	
-13	2315 8825 80211	
-14	2315 8525 80212	
-15	2315 8625 80212	
-16	2315 8725 80212	
-17	2315 8825 80212	
-18	2315 8525 80213	

INVENTORY OF MAFLA ZOOPLANKTON SAMPLES FROM SUMMER, 1976 (ARCHIVE) FOR HMWHC

ARLI ID# 77067-N	MAFLA ID#	STATUS
- 1	6003 17 2560723	All Analyses Completed
- 2	6003 30 2560723	
- 3	6003 31 2560723	
- 4	6003 32 2560723	
- 5	6003 17 2560724	
- 6	6003 30 2560724	
- 7	6003 31 2560724	
- 8	6003 32 2560724	
- 9	6003 17 2560725	
-10	6003 30 2560725	
-11	6003 31 2560725	
-12	6003 17 2560726	
-13	6003 30 2560726	
-14	6003 31 2560726	
-15	6003 32 2560726	
-16	6003 33 2560726	
-17	6003 17 2560727	
-18	6003 30 2560727	
-19	6003 31 2560727	
-20	6003 32 2560727	

VOLUME II

CHAPTER 25

WATER COLUMN DISSOLVED AND PARTICULATE HYDROCARBONS

DR. LELA M. JEFFREY
TEXAS A&M UNIVERSITY
CONTRACT NO. AA550-CT7-34

FINAL REPORT

BUREAU OF LAND MANAGEMENT 1977/78 MAFLA BENCHMARK SURVEY

Contract Number AA550-CT7-34

WATER COLUMN PARTICULATE AND DISSOLVED HEAVY HYDROCARBONS

To

Dames & Moore

From

Lela M. Jeffrey
Texas A&M University
Department of Oceanography

January 31, 1979

TABLE OF CONTENTS

ABSTRACT

Water samples from four stations in the MAFLA survey area were collected during fall, 1977, and winter, 1978 for hydrocarbon analysis of the suspended material and the filtered water. Forty water samples of approximately 90ℓ each were collected in the fall, and 66 in the winter season. Hydrocarbon concentrations were determined by capillary gas chromatography. Confirmation of compound identification was attained by gas chromatography-mass spectrometry of some randomly selected samples, and also, in some cases, by comparison with standard mixtures of hydrocarbons. No aromatic hydrocarbons were detectable in the samples, but a series of n-alkanes from C-15 to C-32 and branched chain hydrocarbons pristane and phytane were found. Overall average aliphatic hydrocarbons for all stations and depths found dissolved in the water was 0.05 microgram per litre and for the particulate phase the overall average was 0.09 microgram per litre. Seasonal variations were most noticeable in the particulate hydrocarbons. Aliphatic particulate concentrations were higher in the winter than in the fall in the water column, presumably because of higher primary productivity during the winter than in the fall in this area. The average dissolved aliphatic hydrocarbon concentrations were higher at two stations in the winter than in the fall, but at one station they were slightly lower and at another approximately the same. The particulate hydrocarbons were in nearly equal concentrations to the dissolved ones in the fall, but exceeded the soluble concentrations in the winter. Resolved envelopes, indicative to some of pollution by oil, was present only in the particulate hydrocarbon chromatograms, particulary at the two northernmost stations.

On the basis of the low total hydrocarbon concentrations at all the stations in the MAFLA area in both particulate and dissolved phases, it is concluded that the water column at the times sampled and at the four stations sampled was not polluted with petroleum. This conclusion is strengthened by the fact that no aromatic hydrocarbons were detectable by gas chromatography-mass spectrometry analyses.

INTRODUCTION

PURPOSE

The purpose of this portion of the Bureau of Land Management 1977/78 MAFLA Benchmark Survey, Contract Number AA550-CT7-34, is to determine the concentrations of particulate and soluble heavy hydrocarbons, both by gravimetric and gas chromatography-mass spectrometry methods, in the water column and to determine if these hydrocarbons are of natural and/or anthropogenic origin.

PREVIOUS WORK

The spectrum of hydrocarbons and their concentrations found dissolved and suspended in marine coastal or offshore waters can reflect petroleum contamination, particularly if it is severe, but in marginally contaminated waters it is sometimes difficult to separate the hydrocarbons of natural origin from those of anthropogenic origin. The best way is to determine whether or not aromatic hydrocarbons are present. So far as we know, marine organisms do not produce aromatic hydrocarbons. However, it is customary to examine the saturated hydrocarbon distribution and concentrations and the aromatic hydrocarbon compounds and concentrations.

The primary sources of soluble hydrocarbons in ocean water are: decomposition products of marine organisms, riverine sources containing both natural decomposition products and anthropogenic hydrocarbons, solution of hydrocarbons from suspended matter, diffusion of hydrocarbons from sediments, oil spills, floating tar balls, and in some areas, oil seeps. The sources of particulate hydrocarbons are somewhat comparable to those in solution. The hydrocarbons present in particulate matter filtered from solution can have the following sources: biogenic, riverine, particles from air, resuspended sediment in some shallow areas, or from oil spills or natural seeps. Most of the particles that are remnants of an oil spill or oil seeps will be found on or very near the surface.

Fortunately, both natural and biogenic hydrocarbons are continuously removed from the water column at unknown rates, some of which are rapid and others very slow. Pathways of removal of hydrocarbons from solution in the ocean include bacterial decomposition and ingestion by some organisms, adsorption of hydrocarbons to particles, and near-surface evaporation of some of the light hydrocarbons (up to hexadecane or higher). For particulate hydrocarbons, evaporation near the surface, bacterial decomposition, solution, and settling to the bottom appear to be the primary removal processes. The ultimate sinks of both dissolved and particulate hydrocarbons of both natural and anthropogenic origin appear to be carbon dioxide and burial within the sediment. It appears from available data that, except in continuously polluted areas, there is no exorbitant concentration of hydrocarbons in the water column in open ocean areas and in many coastal areas.

Heavy hydrocarbon concentrations in ocean water reportedly vary from less than 1 to 1,130 $\mu g \cdot \ell^{-1}$. A variety of methods have been used in the past, including gravimetry, infrared absorption, fluorescence, gas chromatography, and, more recently, a combination of gas chromatography and mass spectrometry. Comparison of some of the reported concentrations of hydrocarbons is obviously difficult because the methods used are measuring different components of oil. However, we will attempt to summarize the available published information. Barbier et al. (1973) used a gravimetric method, after extraction and column fractionation, and found soluble heavy hydrocarbon concentrations in the range of 10 to 137 $\mu g \cdot \ell^{-1}$ in the Atlantic off the coast of Africa. The latter high concentration was in contaminated waters. Wade and Quinn (1975), using a similar method, reported soluble hydrocarbon concentrations in subsurface (20 to 30 cm) Sargasso Sea water samples in the range of 13 to 239 $\mu g \cdot \ell^{-1}$. They attributed the higher concentrations to solution of nearby tar balls. For the Eastern Gulf of Mexico, Iliffe and Calder (1975) reported soluble hydrocarbon concentrations in the range of 12 to 47 $\mu g \cdot \ell^{-1}$, based on weights of the so-called saturates and aromatic fractions. Levy (1971), using a combination of UV and fluorescent methods on the extracts, found values for total hydrocarbons of 2 to 13 $\mu g \cdot \ell^{-1}$ in the Atlantic off the coast of Halifax, Nova Scotia. Brown et al. (1975) used an infrared method of measuring hydrocarbons in a solvent extract and reported hydrocarbon concentrations in the open Atlantic and Pacific were mostly near 1 $\mu g \cdot \ell^{-1}$ near the surface, but in the Mediterranean the concentrations ranged from 3 to 6 $\mu g \cdot \ell^{-1}$ and near Bermuda were 2 to 8 $\mu g \cdot \ell^{-1}$.

It appears that when gas chromatography is used for quantitation of soluble and particulate heavy hydrocarbons, the concentration levels are lower than when gravimetric values are used. Parker et al. (1972) used gas chromatography for quantitation and found saturated hydrocarbon concentrations in the water off the South Texas coast to be in the range of 0.1 to 0.6 $\mu g \cdot \ell^{-1}$. In a BLM supported study of offshore California water, concentrations of as low as 0.06 $\mu g \cdot \ell^{-1}$ for ocean water were reported, but near shore the range was higher from 0.15 to 11 $\mu g \cdot \ell^{-1}$. Recently, Shaw and Baker (1978), also using gas chromatography for quantitation, reported total hydrocarbon concentrations for unfilterred water to be in the range of 0.02 to 2.5 for the water column near Port Valdez, Alaska. Most of their samples were in the concentration range of 0.02 to 0.2 $\mu g \cdot \ell^{-1}$.

Calder (1976), in his report on hydrocarbon levels in the water column of the MAFLA lease area in the years 1975-76, used gas chromatography as an anlaytical method. However, at that time mass spectrometry was not used to identify compounds in gas chromatography peaks. He reported an overall average concentration of 0.4 $\mu g \cdot \ell^{-1}$ for dissolved hydrocarbons and 0.3 $\mu g \cdot \ell^{-1}$ for the particulate hydrocarbons. Calder included in his averages both the hexane (saturates) and the benzene (unsaturates and aromatics) fractions in his calculations. He did not include quantitation of hydrocarbons in unresolved envelopes, when present. This is a tentative method anyway, because it is difficult to apply a response factor. The concentration ranges for the MAFLA area, as reported by Calder (1976), were 0.1 to 1.3 $\mu g \cdot \ell^{-1}$ for total dissolved hydrocarbons (using the above criteria), with the highest values occuring in the summer and the lowest in the autumn. His particulate hydrocarbon ranges were 0.01 to 1.0 $\mu g \cdot \ell^{-1}$. The particulate hydrocarbon concentrations were highest in the winter and lowest in the fall.

This work on the heavy hydrocarbons in the MAFLA area differs in two respects, but basically the approach and general methodology is the same. Capillary gas chromatography was used for separation of the hydrocarbons as well as their quantitation. A number of representative and randomly selected samples were analyzed by a combination of capillary gas chromatography and mass spectrometry. Particular emphasis was placed on searching for aromatic hydrocarbons. The tool of mass spectrometry enabled us to delete nonhydrocarbon compounds and to detect sample contamination. In addition, mass spectrometry enabled us to omit the benzene fraction (includes unsaturates and aromatics) from our total hydrocarbon concentrations when no aromatics were present, and they were not present.

In this work, time-series studies at four locations were made for late autumn, November 1977 and for winter, February 1978. Dissolved and particulate organic carbon concentrations were also determined on the same water samples used for hydrocarbon analysis. Forty dissolved and particulate samples were collected in the fall of 1977 and 66 dissolved and particulate samples in the winter of 1978. See Figure 263 for locations.

The hydrocarbon fractions as well as the total lipid extracts were weighed and the gravimetric and gas chromatographic concentrations were compared. In general, the latter concentrations were lower than those determined by weight, and this discrepancy will be discussed in following sections.

METHODS AND MATERIALS

SAMPLING AND SHIPBOARD PROCEDURES

For each soluble and particulate hydrocarbon sample, approximately 90ℓ of seawater were collected in a 90ℓ PVC sampler cleaned daily with hexane, after an initial cleaning with Micro solution and several rinses with distilled water. The samples were obtained from near-surface (3 to 5 m below the surface) to near-bottom of the water column. After collection, the water in the sampler was filtered through a 293 mm diameter Gelman Type A/E precombusted fiberglass filter housed in a hydrocarbon-free Millipore stainless steel filter holder. All tubing used for connecting the sampler to the filter to the 18ℓ glass jugs was teflon. The particulates were retained on the fiberglass filter and the soluble hydrocarbons were in the filtered water which were stored in the clean 18ℓ jugs. After completion of filtration of the 90ℓ samples, the filter was stored in specially cleaned glass jars with teflon lined tops and stored frozen until analysis in the laboratory.

The filtered water samples contained in five 18ℓ glass jugs were acidified to pH 2.0, and 500 mℓ Burdick and Jackson nanograde chloroform were added to each jug and stirred. To every tenth sample, 250 μg each of tetracosane and chrysene were added as internal standards for determining procedural efficiencies. All the jugs were sealed with teflon lined stopper to avoid contamination. The water samples were stored in a cool place on the ship, transported to College Station in a refrigerated van, and stored in a cool area until they were extracted.

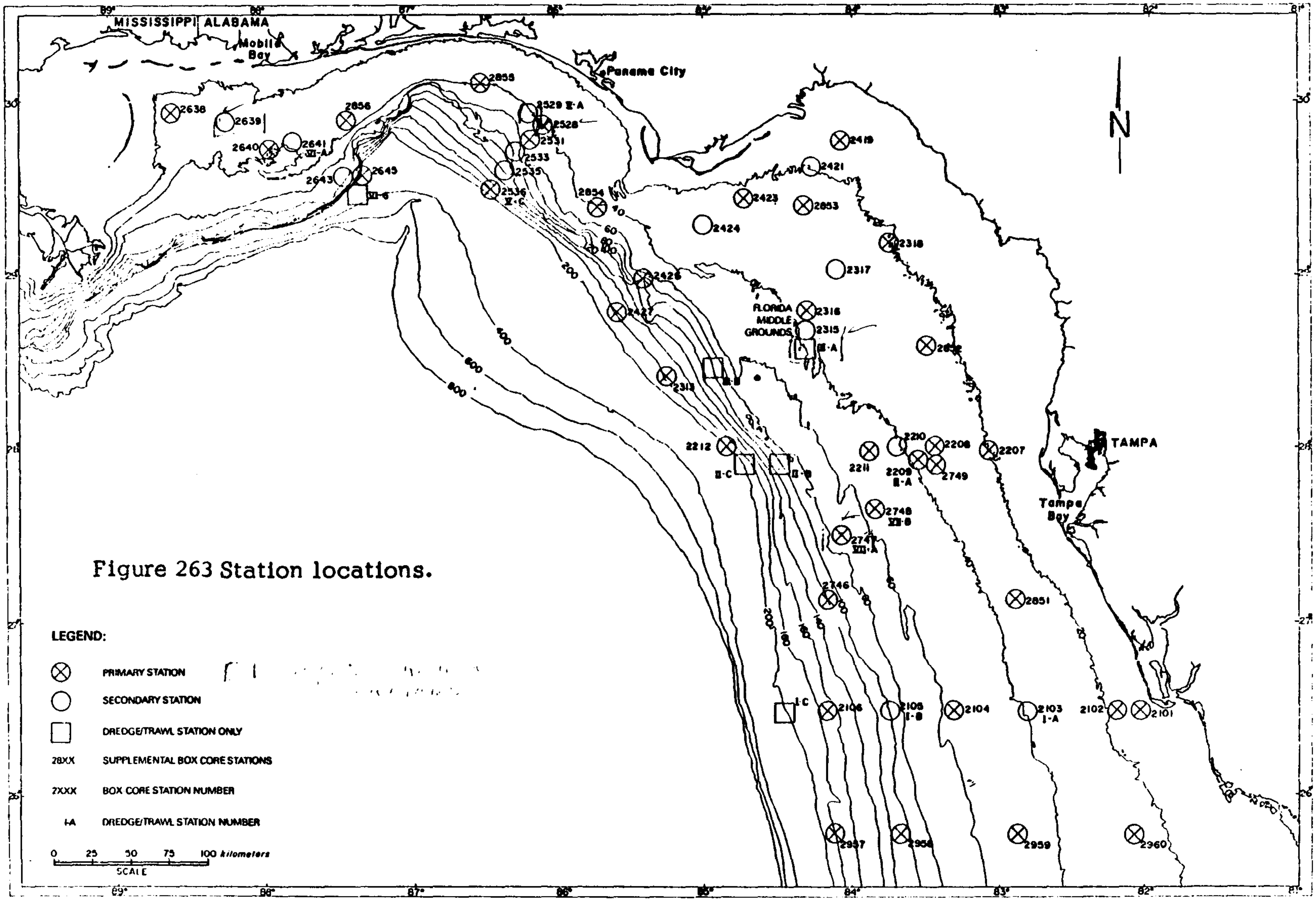


Figure 263 Station locations.

BLM 77/78 MAFLA SURVEY STATION LOCATIONS

EXTRACTION OF PARTICULATE HEAVY HYDROCARBONS

In the laboratory, the particulate samples were dried thoroughly with a freeze drier. After drying, they were transferred to especially cleaned soxhlet extraction apparatus. No thimbles were used, because of possible contamination. Hexane (250 mℓ), Burdick and Jackson nanograde was used for the first four-hour extraction. The filters were reextracted with nanograde Burdick and Jackson chloroform for four hours. Spikes of tetracosane and chrysene were added to blank combusted filters and these were extracted periodically. Blank combusted filters were extracted with each batch of seven particulate samples and treated the same way as the samples throughout the analysis procedure. Each of the solvent extracts of the filters were reduced in volume to 3 or 4 mℓ and then transferred to small specially cleaned dry vials and reduced to dryness under vacuum in a dessicator. The extracts were then weighed on a six place balance and later rechecked on a Cahn Electrobalance, using aliquots of a 500μℓ solution of the particulate extract. We have found that we obtain more consistent weights by placing an aliquot of dissolved sample on a small filter paper, which is preweighed on the Cahn Electrobalance, drying and reweighing. However, prior to weighing, the solution must be filtered. A syringe fitted with a combusted fiberglass filter in a filter holder is used for this operation which removes small particles of filter paper and salt.

EXTRACTION OF SOLUBLE HEAVY HYDROCARBONS

The 90ℓ water samples were extracted three times with 500 mℓ chloroform in the glass jugs in which the samples were filtered. Stainless steel stirrers that can be inserted into the narrow necks of the jugs were constructed. They are powered by small 1,750 rpm motors that fit in a teflon stopper above the jugs. The stirrers were cleaned with Micro solution, acetone, methanol and chloroform, then heated overnight at 500°C and then rewashed with acetone, methanol and chloroform. The last washing of chloroform was evaporated to dryness, weighed and gas chromatogrammed, and no contamination was noted. An additional blank of a preextracted seawater was performed, and no hydrocarbons of any detectable weight was found.

For each extraction of the water samples, the seawater and chloroform was stirred for three minutes, during which time a cloudy emulsion was formed. The samples were allowed to clear for six minutes, and then the chloroform phase on the bottom was siphoned off through glass and teflon tubing under vacuum. The glass and teflon connections were precleaned and were rinsed extensively between samples, as were the stirrers. Recovery of the spikes of tetracosane were above 90%, and chrysene was above 80%. Subsequently, we found that some of the chrysene was lost in the evaporation procedure. If we use extra care in evaporation, we do not lose so much chrysene. In order to determine if three extractions are sufficient, we have extracted some samples four times, but the fourth extraction showed no detectable weight or hydrocarbons. Table 109 summarizes the percentage recovery of the spikes.

After extraction of the water, the chloroform extract was evaporated to near dryness in rotary evaporators under vacuum, transferred to small vials that had been cleaned by the standard cleaning procedures. The

TABLE 109. Extraction and procedural efficiencies for spike additions of tetracosane (n-C24) and chrysene to water samples collected in the fall and winter in the MAFLA area.

Station	Cast	% Recovery n-C24	% Recovery Chrysene
		Fall, 1977	
2639	9	101	99
	10	99	95
2747	9	100	97
	10	101	96
2529	9	102	93
	10	101	96
IIIA	9	99	95
	10	98	94
		Winter, 1978	
2639	9	94	93
	10	96	95
2747	9	101	98
2528	9	97	95
	10	101	99
2315	9	95	94
	10	92	90
	19	101	98
	20	98	96
	29	103	100
	30	95	94
	35	100	98
	36	101	99

extracts were dried overnight in a vacuum dessicator, and then an aliquot of the extracts was weighed on the Cahn Electrobalance. A few of the samples had some salt in them. These were redissolved in chloroform, filtered with the syringe filter, redried and weighed. All the extracts were redissolved in chloroform and stored in a refrigerator until further analysis.

SILICA GEL COLUMN CHROMATOGRAPHY

The extracts of both the particulate and water samples were then separated into saturates, aromatics (and other compounds of similar polarity), and polar lipids on silica gel columns. The silica gel was Davison Grade 12 (100 to 200 mesh), and was purified by heating in a furnace at 230°C for 15 to 16 h. Prior to packing in a 30 cm column, the silica gel was thoroughly washed with nanograde Burdick and Jackson hexane. A 12 to 15 cm bed in the columns with glass stopcocks was packed with a hexane slurry of silica gel. The packed column was rinsed with 50 mℓ of hexane before the sample was applied. The sample, dissolved in 0.5 mℓ chloroform, was applied evenly to the top of the silica gel bed and allowed to enter the bed before adding the first solvent. The saturated hydrocarbons were then eluted with 50 mℓ of hexane, the unsaturates and aromatics with 50 mℓ nanograde benzene, and the polar lipids with methanol. The fractions eluted from the column were reduced in volume in a rotary evaporator and carefully transferred to clean vials. The solvent in the vials was then evaporated in a vacuum dessicator just until they were dry. Then 200 μℓ of benzene were added to each vial and a 20 μℓ aliquot was removed and air dried on a small fiberglass filter and weighed on a Cahn Electrobalance. The sample weight was thus the difference between the weight of the filter and the weight of filter plus dried sample aliquot. The samples were then redried for gas chromatography.

The above technique was checked for completion of separation and recovery with standards containing a mixture of saturated and aromatic hydrocarbons with each separate batch of silica gel. Blanks were also run, because we found that some grades of silica gel contained some organic compounds in all cases, separation was complete and recovery of the standard hydrocarbons was greater than 95%.

GAS CHROMATOGRAPHY ANALYSIS OF HEAVY HYDROCARBONS

Heavy hydrocarbon analyses of samples and blanks were made on three Hewlett-Packard Model 5830A gas chromatographs fitted with flame ionization detectors. The data were recorded and digitized with Hewlett-Packard Model 1 50A terminals. The columns were glass capillary ones coated with Supelco 2100 (OV-101). They were 30 m long and 0.25 mm inside diameter. A splitless injection system was used. Initially we made our own glass injection port, but for the second set of samples we obtained a glass lined injection system from SGE, Ltd., which eliminated any possible septum bleed. In this latter system, the injection septum was held above the heated injection port. Capillary flame jets also had to be installed on the chromatographs. Nitrogen gas was added to the low (1 mℓ · min^{-1}) flow of helium carrier gas between the capillary column and the flame detector to optimize the detector response. The injection port temperature was 300°C and the detector temperature was 350°C initially, but those were changed to 280 and 350°C for the last set of samples, because we found no difference in detector response and the lower temperature of the injection port reduced septum bleed. For the samples from the first cruise, the column temperature was programmed at a rate of 1.6°C • min^{-1} from 120° to 260° and held at the final temperature of 260° for 30 m or until C-32 was eluted. For the samples from the second cruise, the column was temperature programmed from 0 to 260°C at the rate of 2.5°C • min^{-1} with a 30 m hold. This procedure worked better for our samples and it allowed volatile components to be detected. It also saved time without loss of resolution or sensitivity.

QUANTITATIVE STANDARDIZATION OF HEAVY HYDROCARBONS

Gas chromatographic separation of the compounds in the hexane and benzene fractions of the samples were evaluated and quantified with standard hydrocarbon solutions. Initially, a nine component alkane standard prepared by ARLI was used, but later we prepared our own 20 component standard, including pristane and phytane. This latter standard was cross-checked with the former, so that quantitation was comparable between the two. This latter, more complete, standard reduced the number of calculations. These standards were used to tentatively identify saturated hydrocarbons by comparing retention times of standards and sample peaks, for checking resolution of C-17 and pristane and C-18 from phytane, and for calculating response factors for the flame detector. Daily, a carefully measured volume of the standard (0.2 or 0.5 $\mu\ell$) was injected and run precisely the same as the samples. Response factors (μg per integration unit or the reciprocal) were calculated for each component in the standard. Response factors for the alkanes not in the standard (C-29, C-30 and C-31) were extrapolated from a plot of response factor vs. carbon number of alkanes. It should be noted here that the sensitivity of the detector was well above the required sensitivity of 5×10^{-11} gm • sec^{-1} for n-decane at a signal to noise ratio of 5:1. Resolution of pristane from C-17 and phytane from C-18 was unity.

After the daily response factors for a series of hydrocarbons are determined, the concentration of each hydrocarbon compound in the samples can be determined after tentative identification. Unidentified peaks were assigned a Kovat's retention index extrapolated from a plot of Kovat's retention index versus the log of retention time in seconds. Kovat's Indices were calculated on a computer for both the benzene and hexane fraction peaks. The Hewlett-Packard gas chromatographs print out the area of each peak and quantitate each peak that is in the standard, and if programmed correctly, will print out the micrograms or nanograms per liter of each component in the standard. They also print out the area of every peak and its retention time in minutes to the nearest 0.01 minute. Both response factors and retention times vary slightly from day to day and also from machine to machine; consequently, standards and blanks had to be run daily. Figures 264 to 266 show a typical chromatogram of a standard, a plot of response factors for a series of alkanes, and a plot of Kovat's Index as a function of retention time.

The dried hexane and benzene fractions of the water samples were diluted to either 20 or 50 $\mu\ell$ with benzene and 1% of that solution was injected into the standard calibrated gas chromatograph. Occasionally,

Figure 264

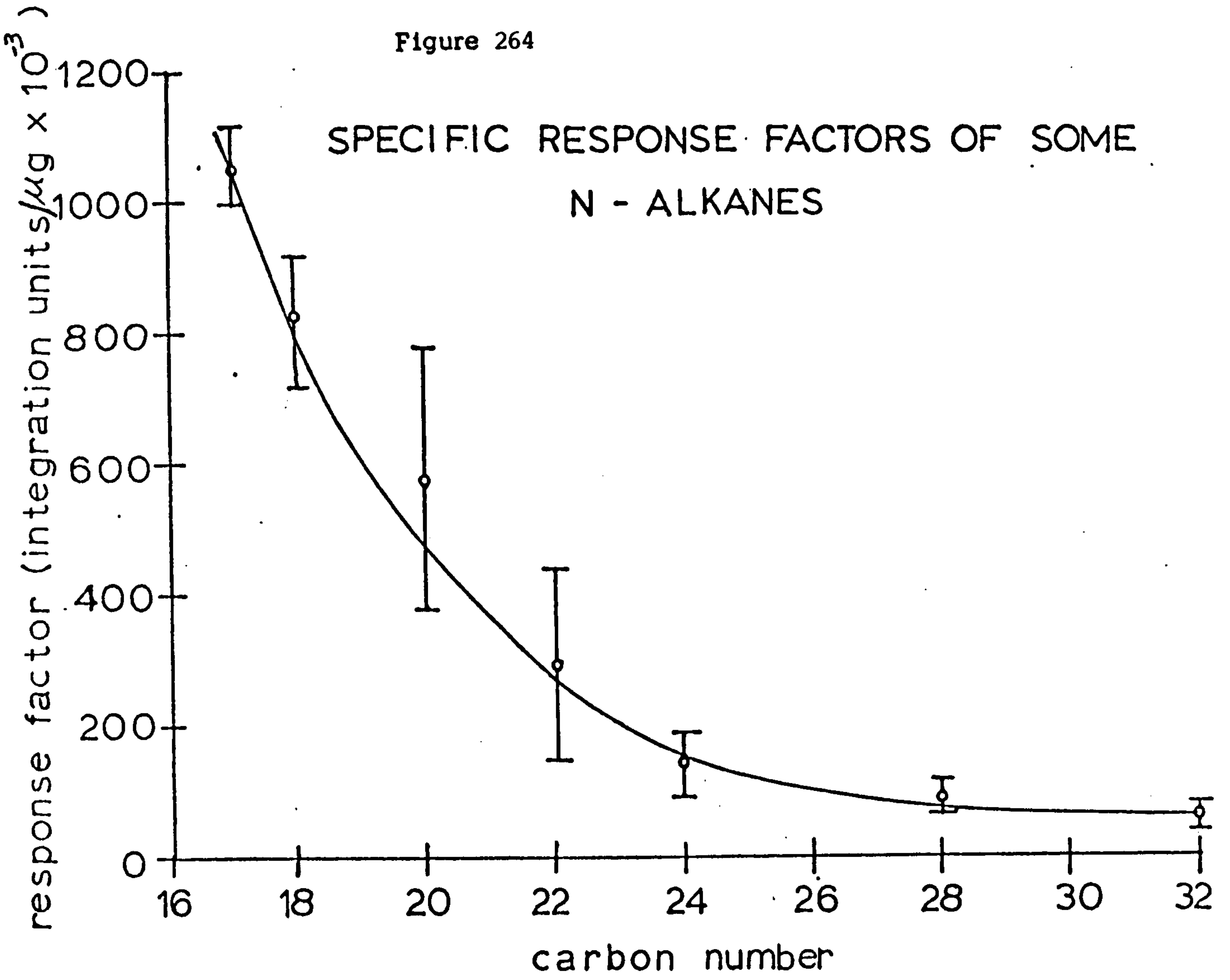
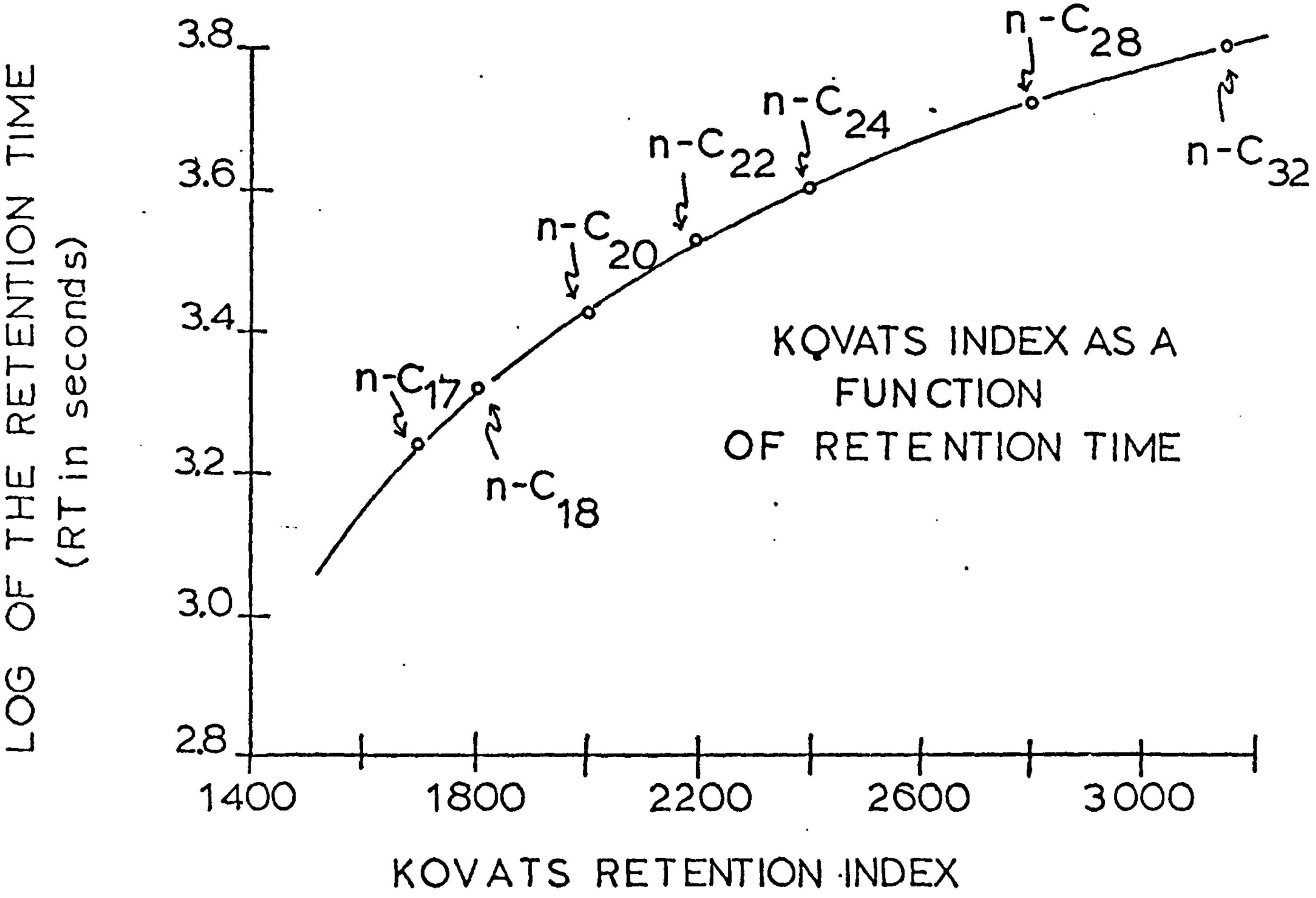
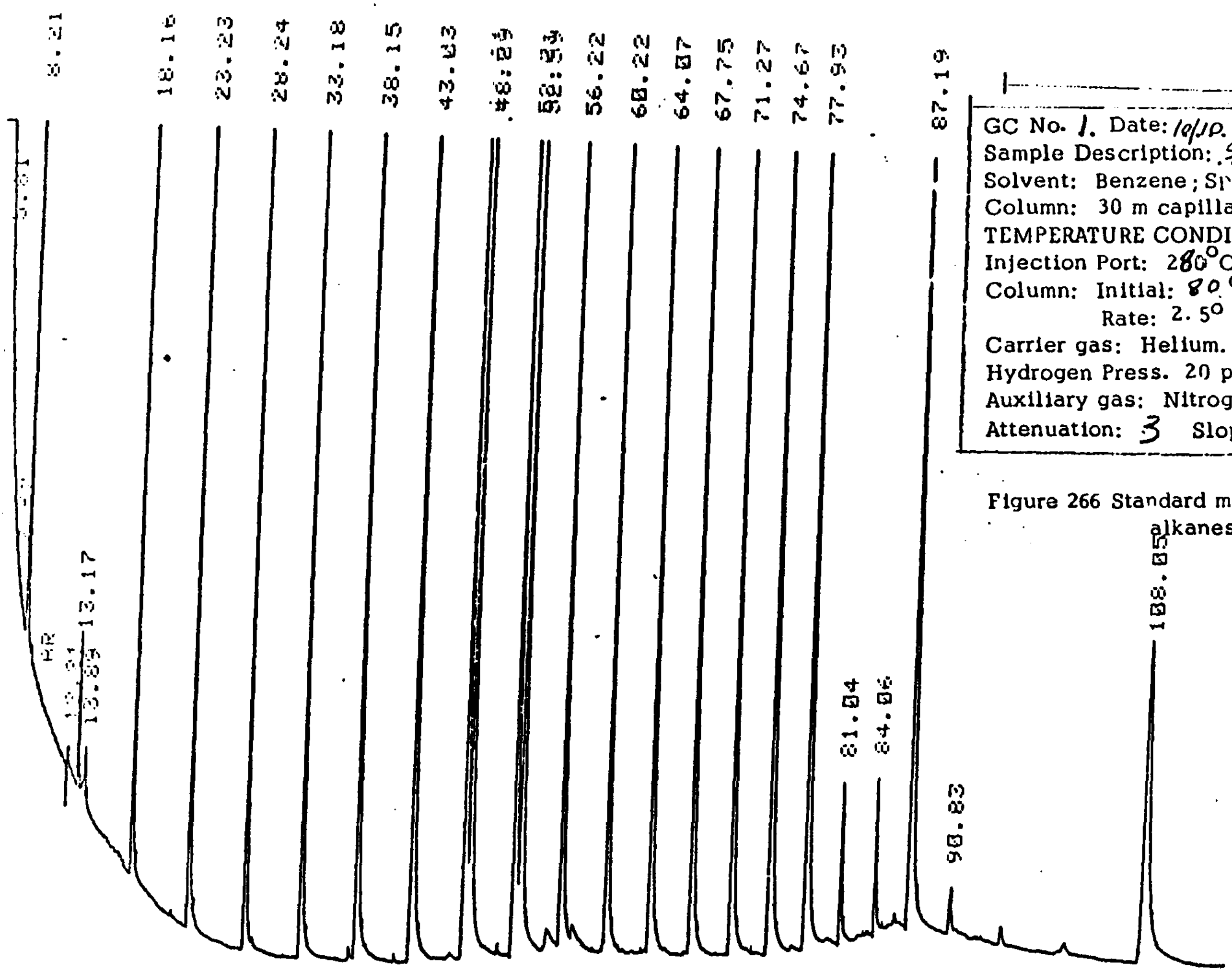

SPECIFIC RESPONSE FACTORS OF SOME
N - ALKANES
response factor (integration units/μg x 10⁻³)
1200
1000
800
600
400
200
0
16
18
20
22
24
26
28
30
32
carbon number

Figure 265



LOG OF THE RETENTION TIME
(RT in seconds)
3.8
3.6
3.4
3.2
3.0
2.8
1400
1800
2200
2600
3000
KOVATS RETENTION INDEX
n-C17
n-C18
n-C20
n-C22
n-C24
n-C28
n-C32
KOVATS INDEX AS A FUNCTION OF RETENTION TIME



GC No. 1. Date: 10/10. Operator: MK
Sample Description: STD.
Solvent: Benzene; Spl. diln: 0.5 µl
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 280°C FID: 300°C
Column: Initial: 80°C Final: 260°C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: 1 ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 3 Slope Sens. 0.02

Figure 266 Standard mixture of alkanes.

dilutions greater than 100 were used to keep the chromatograms on scale. Quite often, samples had to be run more than once, but there was always plenty of sample for reruns.

MASS SPECTROMETRY

Mass spectra of selected water column hydrocarbon samples (both hexane and benzene fractions) were obtained in order to confirm our identifications by gas chromatographic retention times, and also to identify as many as possible compounds that had retention times different from those in the standard. Although every chromatographic peak cannot be identified positively beyond a shadow of a doubt, mass spectrometry was extremely useful in interpreting the sample chromatograms. First of all, phthalate ester contamination was easily determined, and those peaks could be deleted from our calculations of total alkanes or unsaturates/aromatics. Our identification of normal and branched alkanes were confirmed. The mass spectrometer was able to detect two components in a single peak, if present. This happened occasionally with phthalates having the same retention time as some of the long chain alkanes. Aromatic compounds were particularly searched for in the mass spectometer analyses, since the compounds are a very good indicator of petroleum pollution of the water column.

The mass spectral data were obtained with a Hewlett-Packard 5980 GC-MS system coupled with a Hewlett-Packard HP5933 MS data system, by subcontract with the Trace Characterization Center of Texas A&M University. The practical detection limits of this GC-MS instrument was estimated to be 0.05 ng for most compounds. The operating conditions for the mass spectrometer are listed in Table 110.

Each of the sample fractions was chromatographed on a glass wall coated-open-tubular (WCOT) SP-2100 (same as OV 101) capillary column 30 m long. The oven temperature was programmed from 80° to 270°C at a rate of $4°C \cdot min^{-1}$. Helium carrier flow rate was approximately $2\ m\ell \cdot min^{-1}$ through the column. The splitless injection technique was used with an injector flush occurring 50 s after injection. Three microliters of sample was injected in every case. No splitter or carrier gas separator was used. The total column effluent was routed directly into the ion source of the mass spectrometer. Standards were run daily.

The mass spectrometer was repetitively scanned from m/e 50 to m/e 500 every 2.1 s. Ionization was accomplished using 70 eV electrons. The ion source temperature was 175° ± 10°C. Ion chromatograms were generated to identify various groups of compounds. The following m/e scans were made: 71 for saturated and branched aliphatic hydrocarbons and alkenes, 91 for aromatic hydrocarbons, 101 for fatty acid esters, and 149 for phthalates and dioctyladipate. All substantial peaks were analyzed. Printouts were made of all mass spectra and were also stored on discs. Spectral interpretations were aided by computer library searches, the 8 peak index, reference texts and periodical literature. Mass spectra were recorded for a number of compounds for which no complete structure could be proven.

QUALITY CONTROL

The most critical factor in determining hydrocarbon concentrations in environmental samples is quality control, or prevention of any type of contamination of the samples from the air and containers, because in unpolluted water samples the hydrocarbon concentrations are of the order of ng $\cdot$ ℓ^{-1}. Consequently, frequent procedural blanks were determined both gravimetrically and gas chromatographically.

Twenty-two filter blanks were determined by extracting precombusted fiberglass filters from the same batch of filters used for filtering the field water samples. After extraction, the residue was weighed, fractionated on silica gel column, evaporated, and weighed again. The fractions were then gas chromatogrammed, even when there was no detectable weight in the fractions. Most of the time, no gas chromatography peaks were noted, but occasionally a phthalate peak was noted, so whenever those peaks occurred in the sample, they were subtracted or omitted. Table 111 shows the gravimetric results of the filter blank determinations and Figures A-2 and A-3 in the Appendix show an example of the gas chromatograms of the hexane and benzene fractions of a blank filter extract.

The dissolved hydrocarbon blanks consisted of evaporating to near-dryness, four liters of the nanograde chloroform used for extraction of hydrocarbons from the water samples, and then fractionating the residue on the silica gel columns, weighing the dried fractions and then analyzing by gas chromatography the dried fractions. Ten such blanks were analyzed and no hydrocarbons were found on the gas chromatograms, even through there was some measurable weight on the Cahn Electrobalance at times. See Table 112 for the gravimetric results of the dissolved hydrocarbon blanks.

Another procedural blank was run on every batch of silica gel. Some batches had to be discarded, because they could not be purified completely by heating to 230°C overnight. Initially, our glassware cleaning procedures were checked in much the same way as the filters and solvents were and were found to be acceptable.

Initially, one of the unexpected contamination problems was septum bleed on the gas chromatographs. A large number of commercially available septa had to be tried before we found an acceptable one, and then the second batch of these septa were also very unsatisfactory. Septum bleed shows numerous peaks, not just one or two. We finally purchased an accessory which held the septa far enough above the heated injection port so that it would not bleed volatile components onto the capillary column. Daily baseline runs were made and an example is shown in Figure A-1 in the Appendix.

The procedural blanks outlined above were devoid of hydrocarbons, but occasionally exhibited some phthalates, which had characteristic Kovat's Indices. Phthalates were quite evident in many of our samples and were observed and proven in the mass spectrometric procedures. The origin of these phthalates is not definitely known, but they may have entered the samples during evaporation and some may have been in the original water samples, for phthalates are common pollutants. In any case, whatever

TABLE 111. Particulate procedural blanks. Weights are in mg.

Blank Number	Total Extract Weight	Hexane fraction	Benzene fraction
1	0.029	0.000	0.000
2	0.000	0.000	0.000
3	0.005	0.000	0.000
4	0.000	0.000	0.000
5	0.100	0.000	0.000
6	0.005	0.000	0.000
7	0.004	0.000	0.000
8	0.010	0.000	0.000
9	0.079	0.000	0.000
10	0.000	0.000	0.000
11	0.045	0.000	0.000
12	0.020	0.000	0.000
13	0.010	0.000	0.000
14	0.005	0.000	0.000
15	0.010	0.000	0.000
16	0.004	0.000	0.000
17	0.050	0.000	0.000
18	0.010	0.000	0.000
19	0.021	0.000	0.000
20	0.014	0.000	0.000
21	0.015	0.000	0.000
22	0.015	0.000	0.000

TABLE 112. Solvent procedural blanks. Weights are in mg.

Blank Number	Extract	Hexane	Benzene
1	0.000	0.000	0.000
2	0.000	0.000	0.005
3	0.000	0.000	0.005
4	0.000	0.000	0.002
5	0.000	0.002	0.005
6	0.000	0.000	0.005
7	0.000	0.005	0.000
8	0.000	0.005	0.000
9	0.000	0.005	0.000
10	0.000	0.005	0.000

their origin, the phthalates were omitted from our final calculations of hydrocarbon concentrations.

RESULTS

DISSOLVED HYDROCARBONS

The gas chromatographically derived average concentrations of the aliphatic hydrocarbons (hexane fraction) and the unsaturated/aromatic fraction (benzene fraction) are listed in Table 113. The resolvable dissolved aliphatic hydrocarbons in the four stations studied in the MAFLA survey area were in very low concentration with an overall range of 0.03 to 0.12 $\mu g \cdot \ell^{-1}$. The overall range of concentration of the unsaturated aromatic fraction was 0.04 to 0.60 $\mu g \cdot \ell^{-1}$, but essentially no aromatic hydrocarbons were detected by mass spectrometry, so essentially the only hydrocarbons in solution are the aliphatic hydrocarbons, and the overall average for all stations for both seasons is 0.05 $\mu g \cdot \ell^{-1}$. Calder (1976) in a study of 15 stations for three seasons in the MAFLA area reported an overall range of aliphatic hydrocarbons dissolved in water of 0.06 to 0.38 $\mu g \cdot \ell^{-1}$ and an overall average of 0.19 $\mu g \cdot \ell^{-1}$. Calder's aliphatic hydrocarbon concentrations are higher than those found in this work, probably because he had a number of stations much nearer shore than our four stations and possibly also because he did not have the advantage of having mass spectrometry confirmation of compound identification. Shaw and Baker (1978) found a range of 0.01 to 1.7 $\mu g \cdot \ell^{-1}$ of aliphatic hydrocarbons with most in the range of 0.01 to 0.19 $\mu g \cdot \ell^{-1}$ in water at Port Valdez, Alaska. They felt that this area was typical of unpolluted nearshore marine environments. If that is the case, then certainly the MAFLA study area has to be unpolluted also.

As Calder (1976) found, the soluble hydrocarbon concentrations may vary seasonally at a given station, even if they are all of natural origin. In this study of winter and fall concentrations, it was found that the aliphatic hydrocarbon (hexane fraction) were higher in the winter than in the fall at all stations except for Station 2315. In general, the benzene fractions were also in higher concentrations in the winter than the fall (see Table 113). We expected that Stations 2639 and 2529, the two stations nearest shore, to have the highest hydrocarbon concentrations, but in the winter the highest hydrocarbon concentrations were found at Station 2747 and in the fall the highest were at IIIA. However, the samples taken in November were reasonably homogeneous with a station-to-station average concentration ranging from 0.03 to 0.06 $\mu g \cdot \ell^{-1}$ for the aliphatic fraction and 0.04 to 0.08 $\mu g \cdot \ell^{-1}$ for the benzene fraction. The winter range of average station concentrations of the aliphatic fraction was from 0.03 to 0.12 $\mu g \cdot \ell^{-1}$ and for the benzene fraction from 0.06 to 0.57 $\mu g \cdot \ell^{-1}$. One possible reason for the seasonal differences observed was that phytoplankton concentrations were visibly more numerous in the winter than in the autumn sampling. This was particularly apparent at Station 2747, where the highest soluble aliphatic hydrocarbon concentrations and particulate hydrocarbon concentrations were observed also (see Table 114).

Although, for the most part, the hydrocarbon concentrations dissolved in the water column are low enough to be open ocean values, it is still

TABLE 113. Summary of average concentrations and ranges of aliphatic (hexane) and unsaturated/ aromatic (benzene) fractions of dissolved hydrocarbons for November, 1977 and February, 1978 at four stations in the MAFLA survey area. (Concentrations are in micrograms per litre. Figures in parentheses are concentration ranges).

Station	Depth	November, 1977		February, 1978	
		Hexane	Benzene	Hexane	Benzene
2639	Surface	.033 (.025-.042)	.039 (.013-.081)	.055 (.037-.071)	.134 (.038-.157)
	Bottom	.037 (.024-.052)	.062 (.005-.156)	.047 (.028-.065)	.082 (.005-.260)
2528	Surface	.049 (.038-.064)	.087 (.007-.110)	.051 (.041-.059)	.062 (.005-.114)
	Bottom	.028 (.014-.044)	.079 (.025-.122)	.040 (.005-.114)	.059 (.029-.061)
2747	Surface	.042 (.021-.068)	.064 (.017-.064)	.117 (.055-.174)	.109 (.003-.197)
	Bottom	.035 (.016-.073)	.049 (.018-.104)	.048 (.027-.099)	.042 (.033-.052)
2315 (JTTA in Nov.)	Surface	.056 (.020-.120)	.050 (.024-.074)	.029 (.015-.094)	.315 (.005-.653)
	Bottom	.087 (.040-.187)	.049 (.019-.122)	.033 (.012-.122)	.567 (.017-1.94)

TABLE 114. Summary of average concentrations and ranges of aliphatic (hexane) and unsaturated/ aromatic (benzene) fractions of particulate hydrocarbons for November, 1977 and February, 1978 at four stations in the MAFLA survey area. (Concentrations are in micrograms per litre. Figures in parentheses are concentration ranges).

Station	Depth	November, 1977		February, 1978	
		Hexane	Benzene	Hexane	Benzene
2639	Surface	.019 (0.0-.040)	.062 (.011-.169)	.109 (.064-.235)	.479 (.140-.872)
	Bottom	.093 (.027-.217)	.088 (.026-.138)	.087 (.033-.180)	.423 (.089-.773)
2528	Surface	.052 (.002-.213)	.069 (.026-.145)	.104 (.041-.259)	.293 (.036-.804)
	Bottom	.023 (.002-.056)	.040 (0.0-.117)	.150 (.027-.236)	.328 (.074-.681)
2747	Surface	.032 (.004-.107)	.029 (.004-.069)	.250 (.090-.801)	.080 (.017-.248)
	Bottom	.019 (.007-.037)	.042 (.004-.063)	.144 (.017-.297)	.094 (.00-.233)
2315 (IIIA in Nov.)	Surface	.032 (.022-.047)	.056 (.017-.091)	.091 (.015-.337)	.196 (.003-.753)
	Bottom	.051 (.020-.061)	.049 (.005-.090)	.127 (.011-.489)	.215 (.002-1.10)

worthwhile to discuss the compound types found. In the aliphatic or hexane fraction GC-MS analysis indicated the presence of a series of n-alkanes from C-15 to C-33, as well as pristane and phytane. Often, one or more phthalates were also found in the hexane fractions. When present, they were the predominant compound or compounds present. Dioctyl adipate was also detected in some samples. This is also a contaminant, and like the phthalates, was omitted from our calculations. Occasionally, a few alkenes were detected in this fraction. See Figure A-22 in Appendix A for an example of compounds found in an aliphatic soluble hydrocarbon fraction. Figure A-23, in the same appendix, shows typical compounds found in the benzene fraction of the water samples. A series of fatty acid derivatives and ethyl esters of fatty acids were found along with one or more phthalates and dioctyl adipate. The latter two compounds were omitted from our calculation of concentrations. No aromatic hydrocarbons were detectable in the benzene fractions of the extracts. They were specifically searched for.

The only possible indication of petroleum contamination of the water column is the presence of C-21 to C-33 normal alkanes with an odd to even ratio of near 1. It may be possible that these components are residues of petroleum contamination, but these compounds exist in such low concentrations (0.05 to 5 ng $\cdot \ell^{-1}$) that they probably are not toxic, or even have chronic effects on organisms. Calder (1976) observed unresolved humps in the chromatograms of the soluble hydrocarbons, but, for the most part, we did not. One or two chromatograms exhibited slight humping, but for the most part we did not observe it. Unresolved envelopes in chromatograms may result if the temperature programming rate is too fast or the amount of injected sample is too high. Unresolved humps or envelopes are considered by many to be a result of petroleum contamination. In any case, for our samples, the unresolved envelopes were either minor or nonexistent for the soluble hydrocarbon samples.

Examples of gas chromatograms for the hexane and benzene fractions of the water extracts for Stations 2639 and 2747 for fall and winter are contained in Appendix A, Figures A-6 to A-9 and A-14 to A-17, respectively.

PARTICULATE HYDROCARBONS

The gas chromatographically derived hydrocarbon average concentrations of particulate aliphatic fractions and aromatic/unsaturated benzene fractions for near-surface and bottom of each of the four stations for both winter and fall are listed in Table 114. Particulate aliphatic hydrocarbon concentrations were higher at all stations in the winter than in the fall. This was also true of the particulate organic carbon concentrations. The concentration range for particulate aliphatic hydrocarbons in the fall in the MAFLA survey area was 0.02 to 0.09 $\mu g \cdot \ell^{-1}$, and the winter range was 0.09 to 0.25 $\mu g \cdot \ell^{-1}$. Calder (1976) reported similarly that the average fall particulate concentrations of aliphatic hydrocarbons were lower in the fall than in the winter. Calder's average fall aliphatic hydrocarbon concentration for 15 stations was 0.055 and the average winter concentration was 0.49 $\mu g \cdot \ell^{-1}$. The averages from this work were 0.040 $\mu g \cdot \ell^{-1}$ for the fall and 0.132 $\mu g \cdot \ell^{-1}$ for the winter aliphatic hydrocarbons. The benzene fraction concentrations showed a similar trend with the highest concentrations occurring in the winter. This probably is a function of higher phytoplankton concentrations in the winter than in the fall.

The low concentrations of hydrocarbons, well under one microgram per litre, do not indicate much, if any, petroleum contamination. No aromatic hydrocarbons were detectable in the benzene fractions of the extracts of the particulates. Figures A-24 to A-26 show compound identifications of chromatographic peaks for typical hexane and benzene fractions of the extracts of the particulates. The aliphatic or hexane fractions contained a series of n-alkanes from C-15 to C-32, traces of olefins at times, two or three phthalates and dioctyl adipate, and the branched chain hydrocarbons, pristane and phytane. Again the phythaltes and dioctyl adipate were omitted from our calculations of total concentration. The GC-MS analyses indicated in the benzene fractions of the particulates the following compounds: ethyl esters of fatty acids, methyl esters of fatty acids, phthalates, dioctyl adipate, and, in a few samples, 2, 5 di-t-amyl quinones, 2, 4 bis-l-methyl butyl phenol, and 1, 3, 5 tri-t-butyl benzene. The latter two compounds were tentative identifications.

Unlike the dissolved hydrocarbon chromatograms, unresolved envelopes were observed in the particulate hydrocarbon chromatograms. Unresolved envelopes were most evident at Stations 2639 and 2528 in the fall, and they were even more evident and severe in the winter samples. Stations 2747 and IIIA in the fall exhibited practically no unresolved humping or envelopes and minor envelopes in the winter. Most of the unresolved envelopes occurred in the aliphatic fractions of 2639 and 2528, the two northernmost stations nearest shore. No bimodal distributions of aliphatics were observed in the particulates. Calder (1976), however, did note that the southern areas of the MAFLA region exhibited bimodal unresolved envelopes, but his station locations were somewhat different from ours. Unresolved envelopes were less evident in the benzene fractions. When present, they were minor. Examples of gas chromatograms of particualte hydrocarbon hexane and benzene fractions for fall and winter are shown in Appendix A in Figures A-10 to A-13 and A-18 to A-21.

Like the soluble hydrocarbons, the aliphatic fraction (hexane fraction) of the particulates contained n-alkanes in the range of C-21 to C-32 often, and the odd to even ratio was near unity more often than not. By some, this is considered to be a criteria of petroleum contamination. If this is true, the level of contamination is still quite low.

In comparing the average aliphatic hydrocarbon concentration for a given station for particulates and solubles, it was interesting to note that, from our data, the particulate hydrocarbons were almost as high in concentration as the dissolved ones in the fall, but in the winter the particulate hydrocarbons were considerably higher in concentration than the dissolved hydrocarbons. Note that only the hexane fractions are considered, since the benzene fractions had no detectable hydrocarbons. Calder's (1976) data on the average exhibit the same situation. Since the POC of the water is considerably lower than the DOC, this means that the percentage of hydrocarbons in particulates with respect to total organic carbon is higher than that dissolved in the water. A rough estimate of percentages of aliphatic (and other) hydrocarbons in the particulate and soluble phase of the water column is 0.005% hydrocarbons in the dissolved phase and 0.10% for the particulates, both with respect to the total organic carbon in that phase.

TIME-SERIES STUDIES OF WATER COLUMN HYDROCARBONS

Up to this point, the discussion has been centered on averages of concentrations of particulate and soluble hydrocarbons. For each station, there were five near-surface samples and five near-bottom samples taken over a 12 h period, except at Station 2315, where 18 surface and bottom samples were taken. Considerable variation in concentrations of aliphatics between casts at the same station and same depth were observed for both particulate and dissolved hydrocarbon concentrations. This was expected for the particulates, because of their noted inhomogeneity in the water column. However, we were somewhat surprised at the range of concentrations for the soluble hydrocarbons in a 12 h period, with no apparent trend. There are two possible explanations for the broader than expected range. One is that hydrocarbons are not in true solution and some may adhere to the sides of the water sampler or onto the filter in a random fashion or may simply be inhomogeneous in the water column itself. Another reason which has to be considered is possible contamination which has crept in despite all our precautions, or losses in sample handling. However, all our procedural blanks and recoveries of spikes to the water refute this latter explanation. In any case, it is always advisable to take multiple water samples at a given location in order to obtain meaningful data. We have examined all the data points carefully and noted no periodicity in hydrocarbon concentrations. Quite often, there appears to be more hydrocarbons near the surface than at the bottom, but this is not always so. Statistically speaking, there is no significant difference between near-surface and near-bottom at the stations studied.

GRAVIMETRIC HYDROCARBON CONCENTRATIONS

As mentioned earlier, extract weights, and hexane and benzene fraction weights were obtained on a Cahn Electrobalance. Gravimetric concentrations of the extracts and fractions were determined simply by dividing the weights by the volume of water. It was observed early in the study that the gravimetrically derived hydrocarbon concentrations were one or two orders of magnitude higher than the gas chromatographically derived ones. Calculations and procedures were checked and double checked, but the fact remained that the weight concentrations were higher than those obtained for gas chromatography. For example, the range of gas chromatographically derived hydrocarbon concentrations in the soluble phase was from 0.028 to .117 $\mu g \cdot \ell^{-1}$ for the hexane fraction (aliphatics), and the gravimetric concentrations were in the range of 1.7 to 3.5 $\mu g \cdot \ell^{-1}$ for the same hexane fractions. In addition, the ratio of the gravimetric concentrations to the GC-derived concentrations was not constant. It is believed that the primary reason for this lack of agreement is salt occlusion and solution. We made every effort to minimize this, but never could accomplish complete removal of salt. Another reason for lack of agreement between the two methods was the presence of phthalates in varying amounts in the extracts and fractions. Concentrations of the phthalates were not included in the calculations of the GC-derived concentrations. It is our conclusion that gravimetric concentrations of hydrocarbons in marine samples is not as accurate as GC-derived concentrations. The former is always much higher than the latter.

CONCLUSIONS

The evidence that has accumulated in this work and Calder's (1976) earlier work on soluble and particulate hydrocarbons in the MAFLA survey area supports the conclusion that the water column at the stations and times studied were not contaminated with petroleum to any detectable degree. The concentrations of aliphatic hydrocarbons in both the soluble and particulate form are equivalent to, or less than, open-ocean values reported, using GC-derived concentrations. In this work, no aromatic hydrocarbons were detectable, i.e., aromatic compound concentration levels were below the 0.01 $\mathrm{ng} \cdot \ell^{-1}$ level.

Hydrocarbon concentrations in the water column do vary seasonally in the MAFLA area, with higher concentrations in the winter than in the fall. This was particularly true for the particulate hydrocarbons, and, to a lesser extent, for the soluble hydrocarbons, apparently because of heavy phytoplankton blooms in the winter in this area.

The sources of the hydrocarbons in the MAFLA area appear to be a combination of marine and terrestrial biogenic processes. There may be some aliphatics present which are indicative of petroleum, i.e., K.I. range of 2,200 to 2,650, but these components are also found in open-ocean water in about the same concentrations.

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APPENDIX A

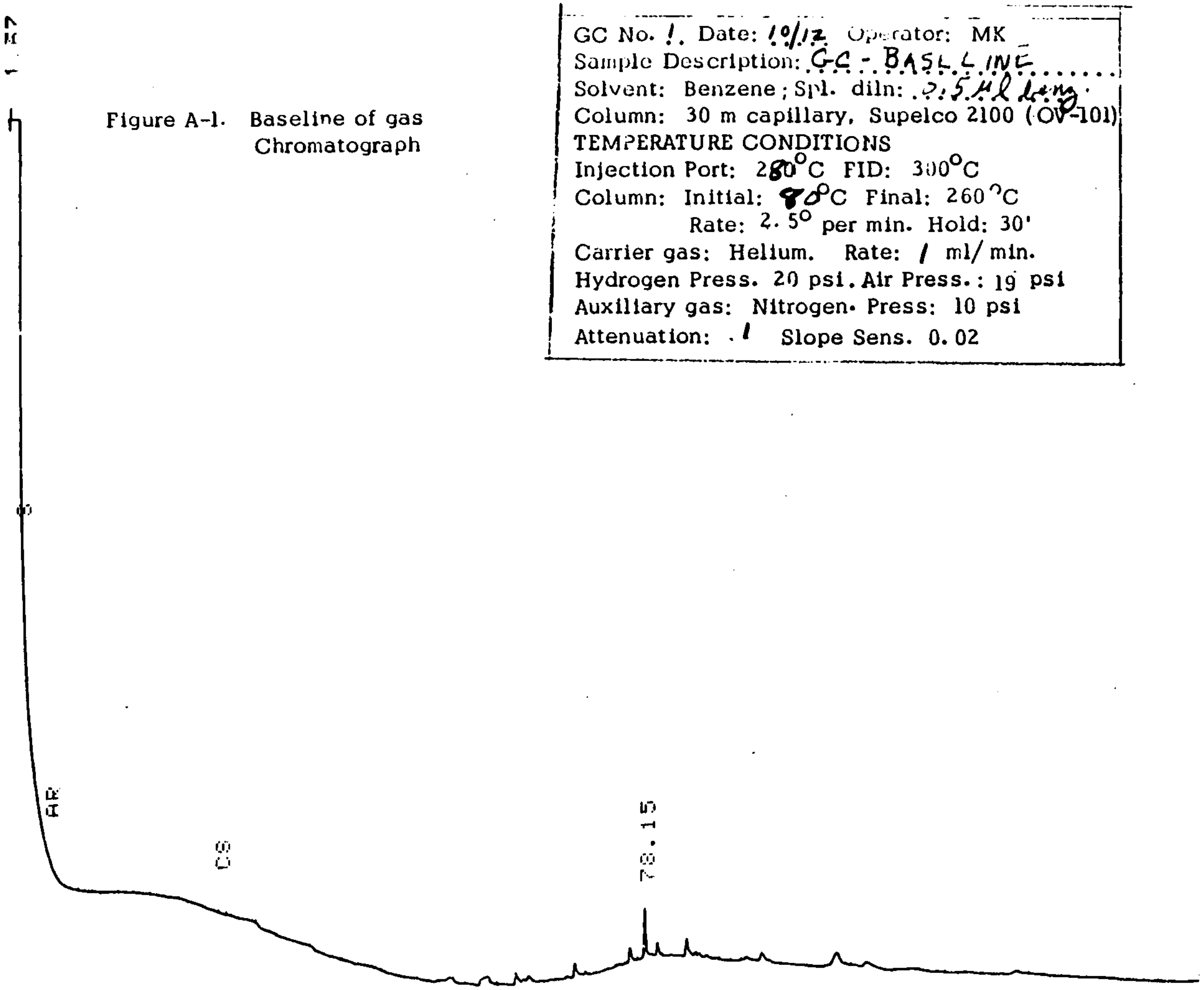
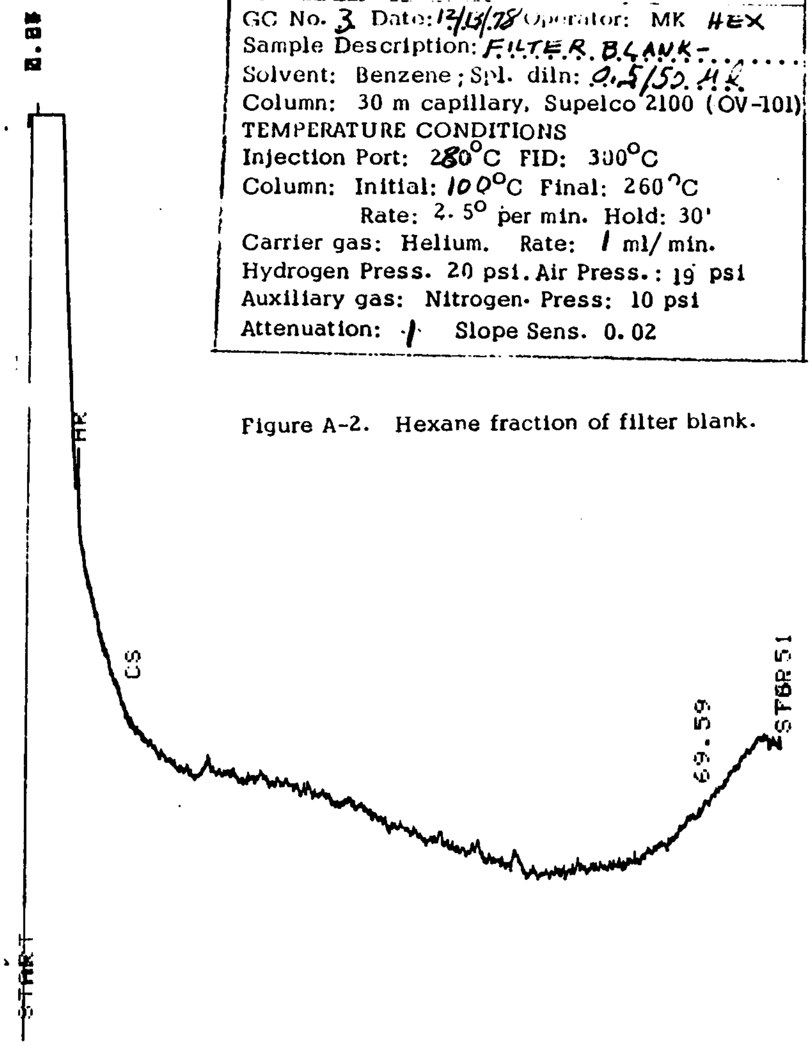


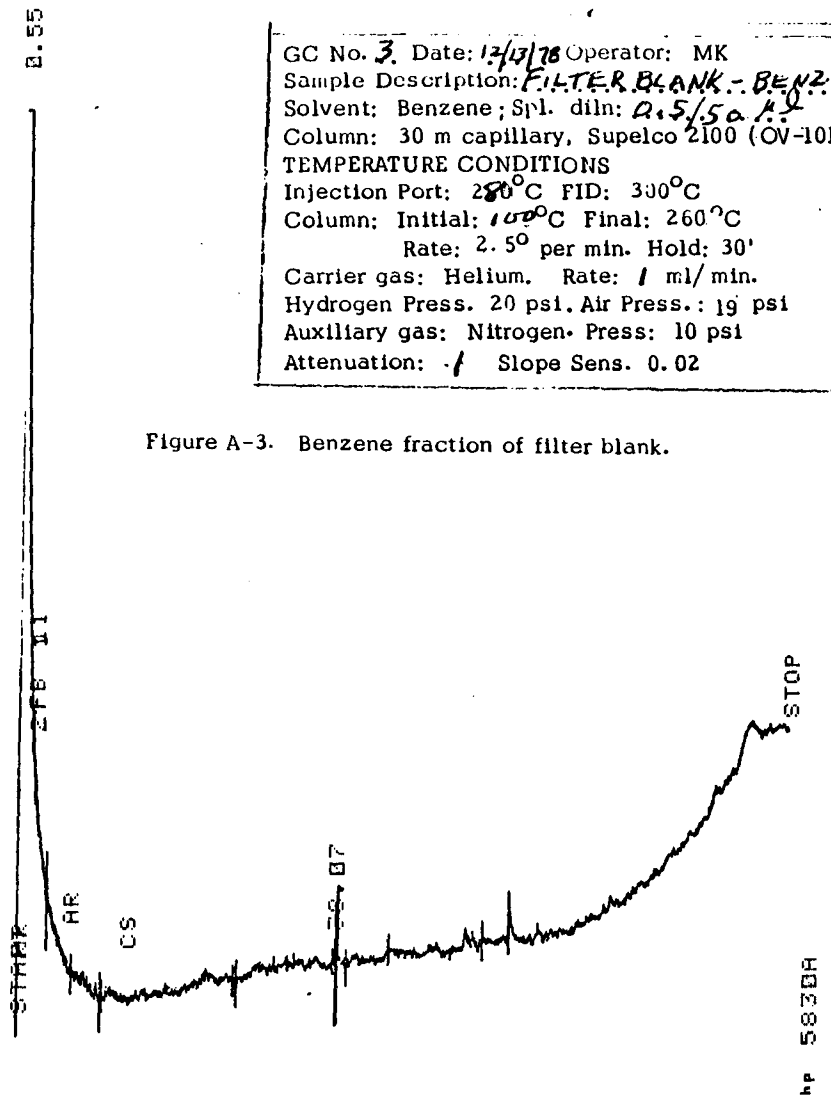
Figure A-1. Baseline of gas Chromatograph

GC No. 1. Date: 10/12 Operator: MK
Sample Description: GC - BASELINE
Solvent: Benzene; Spl. diln: 0.5 µl benz.
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 280°C FID: 300°C
Column: Initial: 80°C Final: 260°C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: 1 ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: .1 Slope Sens. 0.02



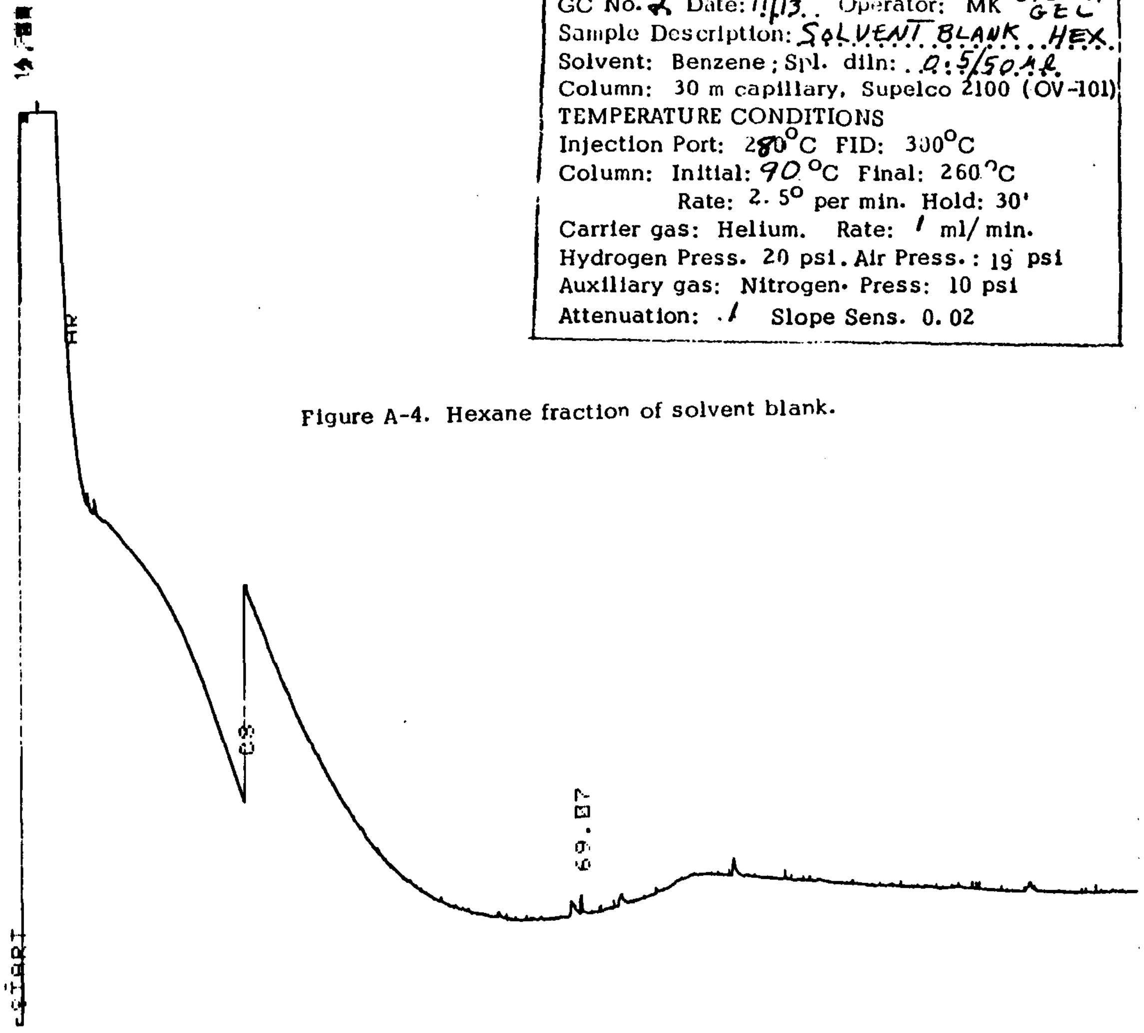
GC No. 3 Date: 12/13/78 Operator: MK HEX
Sample Description: FILTER BLANK-
Solvent: Benzene ; Spl. diln: 0.5/50 HL
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 280°C FID: 300°C
Column: Initial: 100°C Final: 260°C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: 1 ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 1 Slope Sens. 0.02

Figure A-2. Hexane fraction of filter blank.



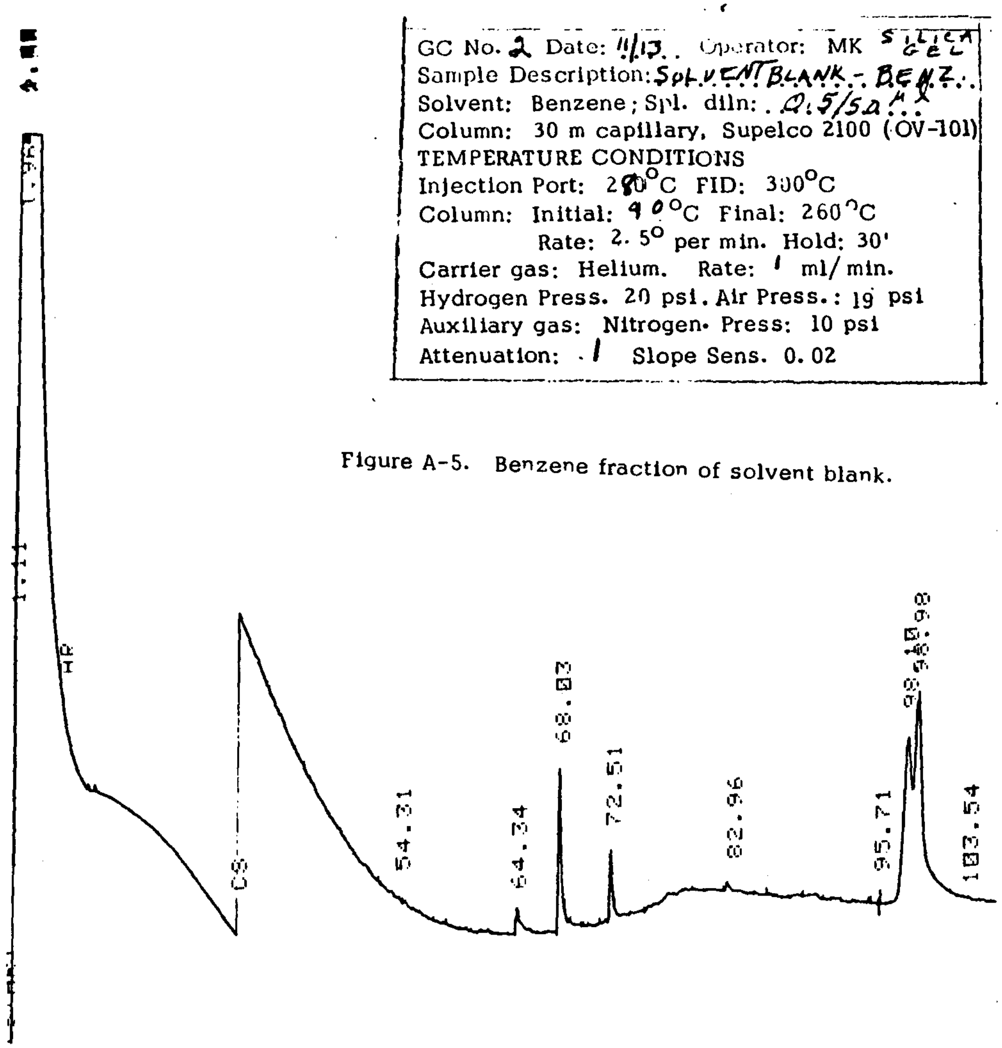
GC No. 3. Date: 12/13/78 Operator: MK
Sample Description: FILTER BLANK - BENZ.
Solvent: Benzene; Spl. diln: 0.5/50 µl
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 280°C FID: 300°C
Column: Initial: 100°C Final: 260°C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: 1 ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: ·1 Slope Sens. 0.02

Figure A-3. Benzene fraction of filter blank.



GC No. 2 Date: 11/13. Operator: MK SILICA GEL
Sample Description: SOLVENT BLANK HEX.
Solvent: Benzene; Spl. diln: 0.5/50 ml.
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 280°C FID: 300°C
Column: Initial: 90 °C Final: 260 °C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: 1 ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: .1 Slope Sens. 0.02

Figure A-4. Hexane fraction of solvent blank.



GC No. 2 Date: 11/13 Operator: MK SILICA GEL
Sample Description: SOLVENT BLANK - BENZ.
Solvent: Benzene; Spl. diln: 0.5/50 μl
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 280°C FID: 300°C
Column: Initial: 90°C Final: 260°C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: 1 ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 1 Slope Sens. 0.02

Figure A-5. Benzene fraction of solvent blank.

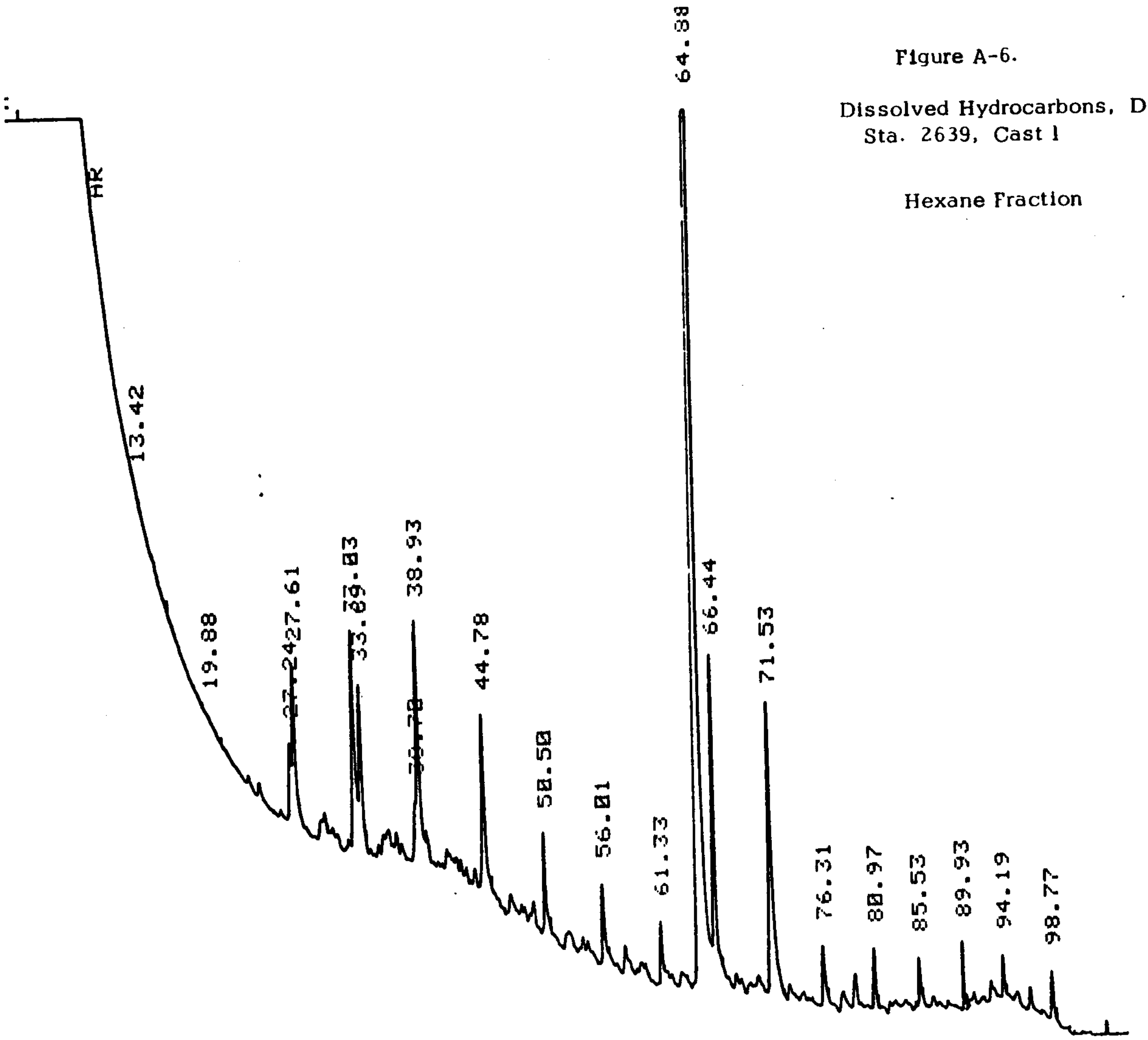


Figure A-6.

Dissolved Hydrocarbons, D & M 2,
Sta. 2639, Cast 1

Hexane Fraction

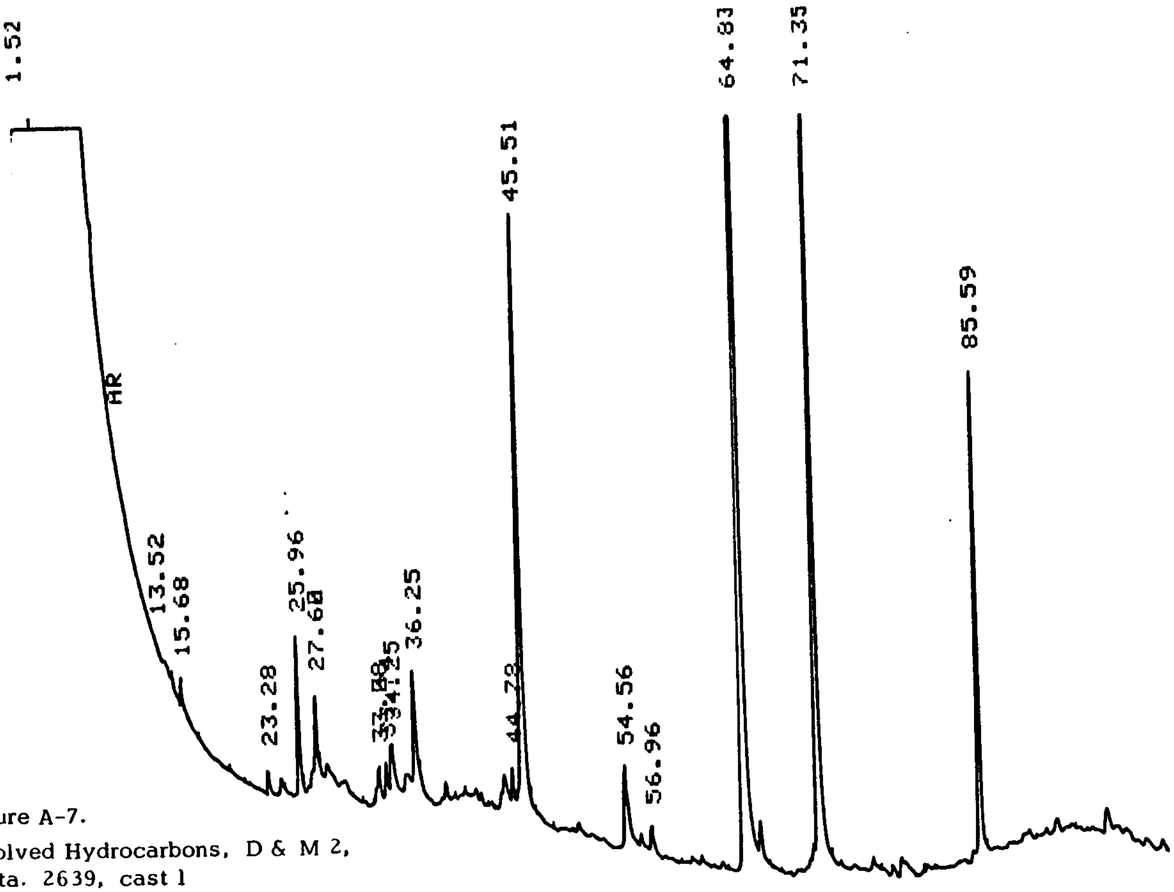


Figure A-7.
Dissolved Hydrocarbons, D & M 2,
Sta. 2639, cast 1

Benzene fraction

Figure A-8.

Dissolved Hydrocarbons, D & M 2, Sta. 2747, Cast 1

Hexane Fraction

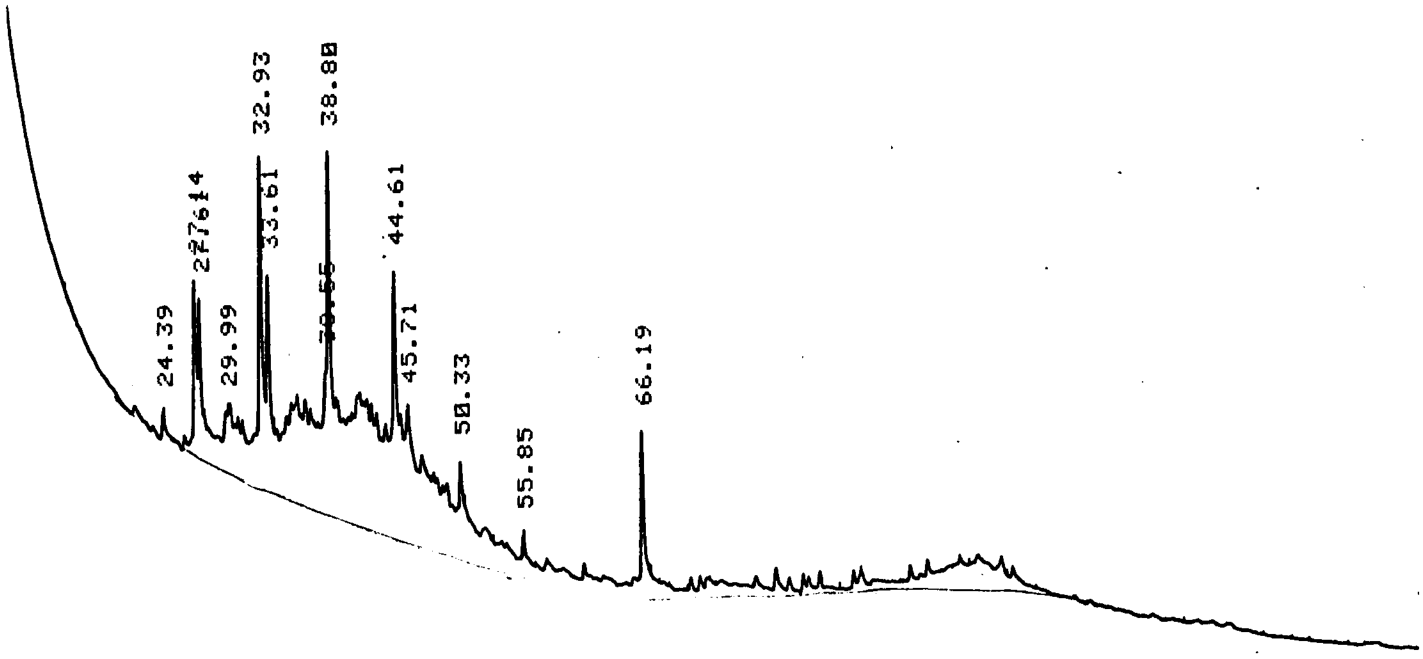
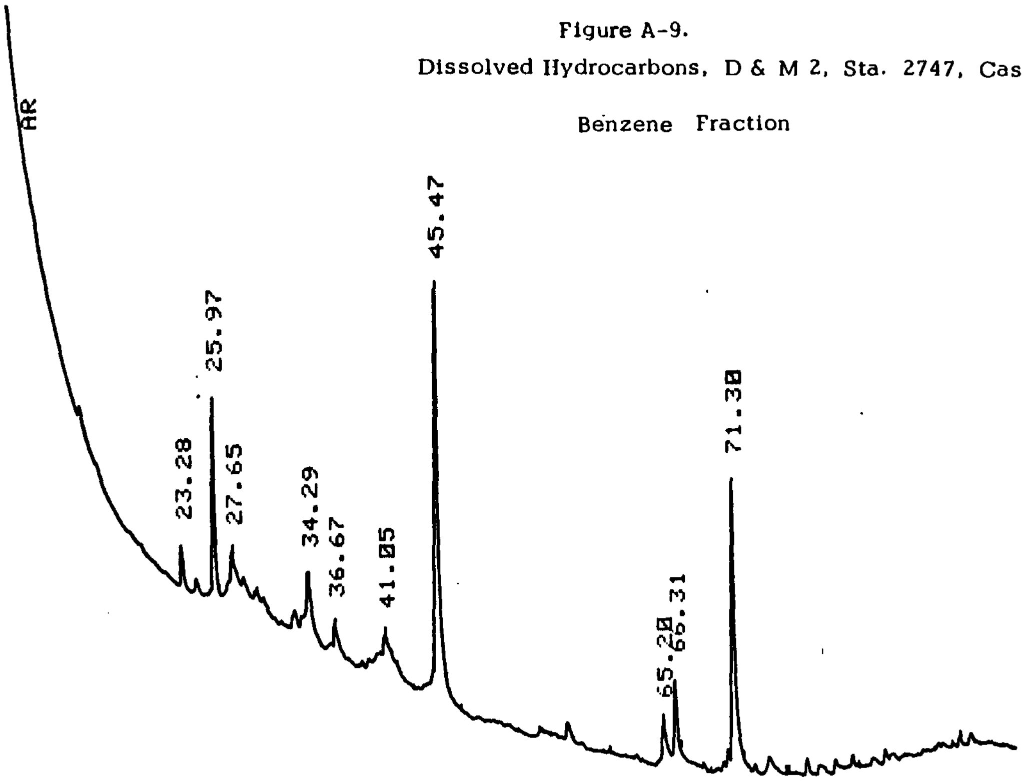


Figure A-9.

Dissolved Hydrocarbons, D & M 2, Sta. 2747, Cast 1

Benzene Fraction



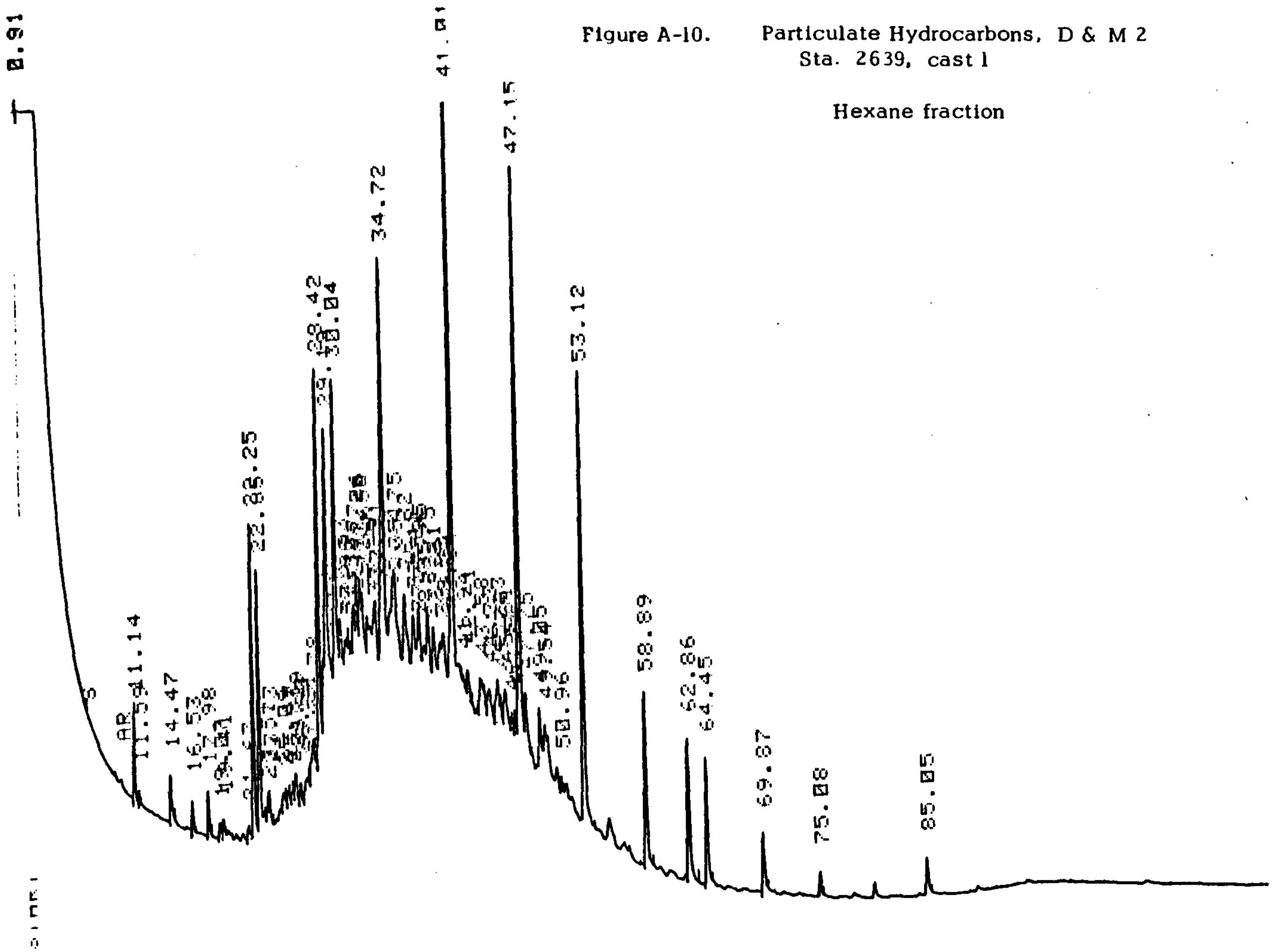


Figure A-10. Particulate Hydrocarbons, D & M 2
Sta. 2639, cast 1

Hexane fraction

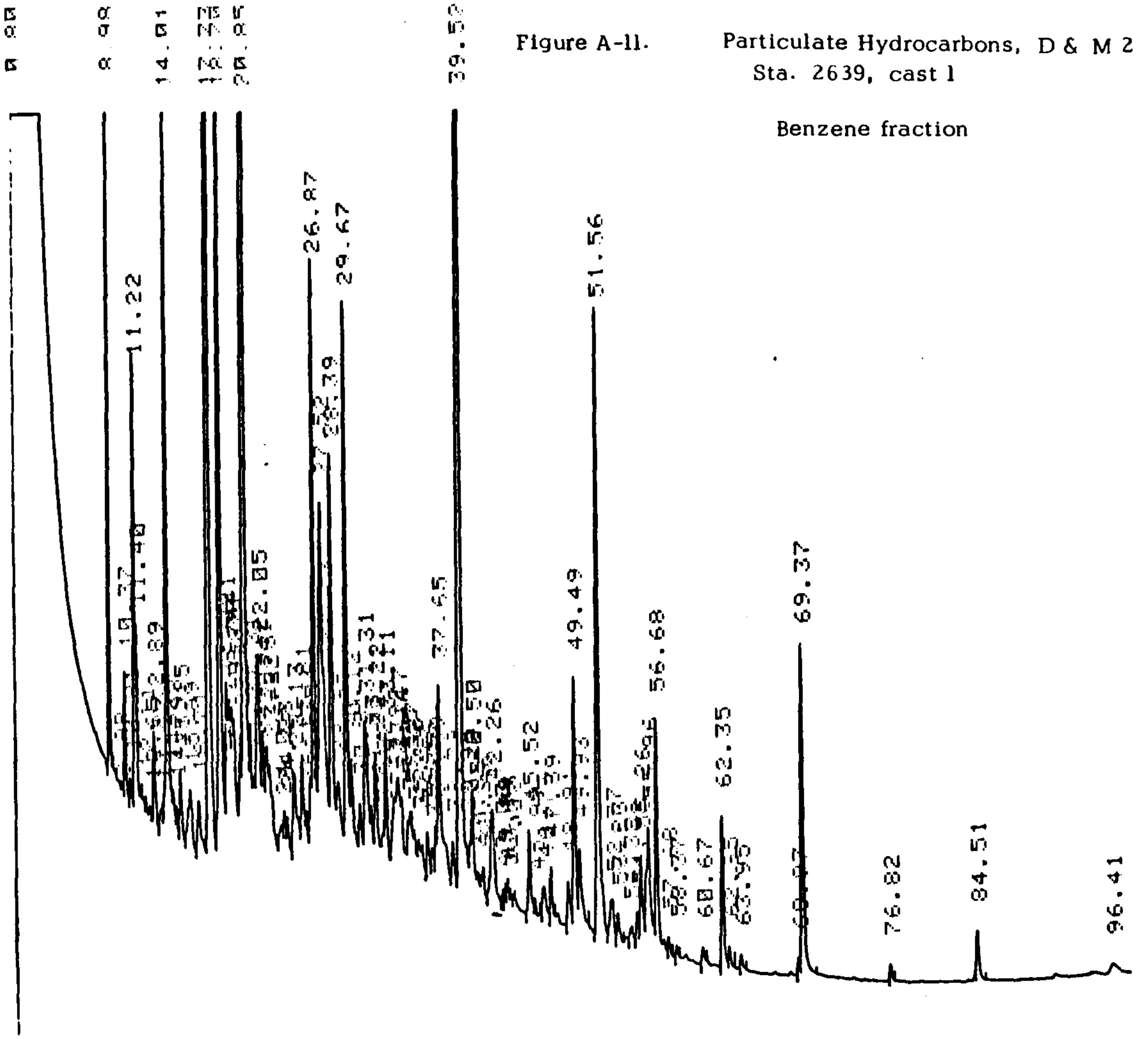
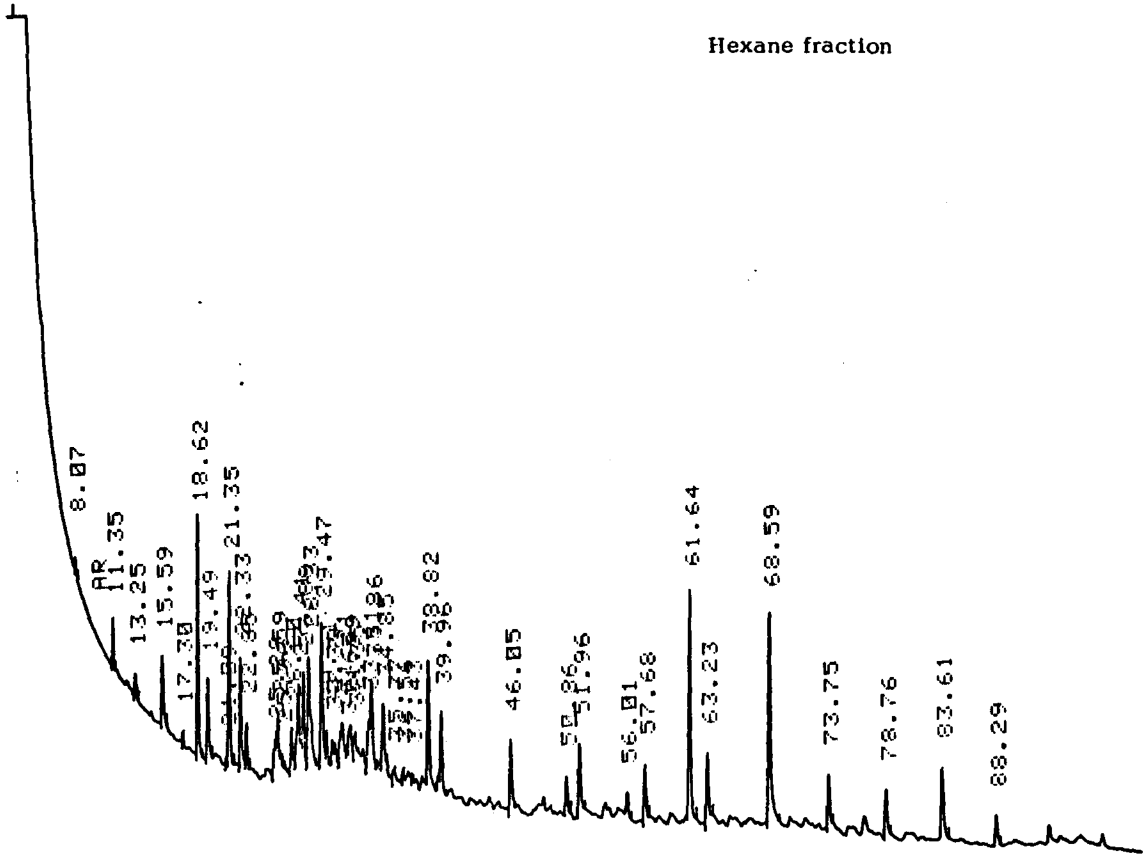


Figure A-11. Particulate Hydrocarbons, D & M 2
Sta. 2639, cast 1

Benzene fraction

Figure A-12. Particulate Hydrocarbons, D & M 2
Sta. 2747, cast 1

Hexane fraction



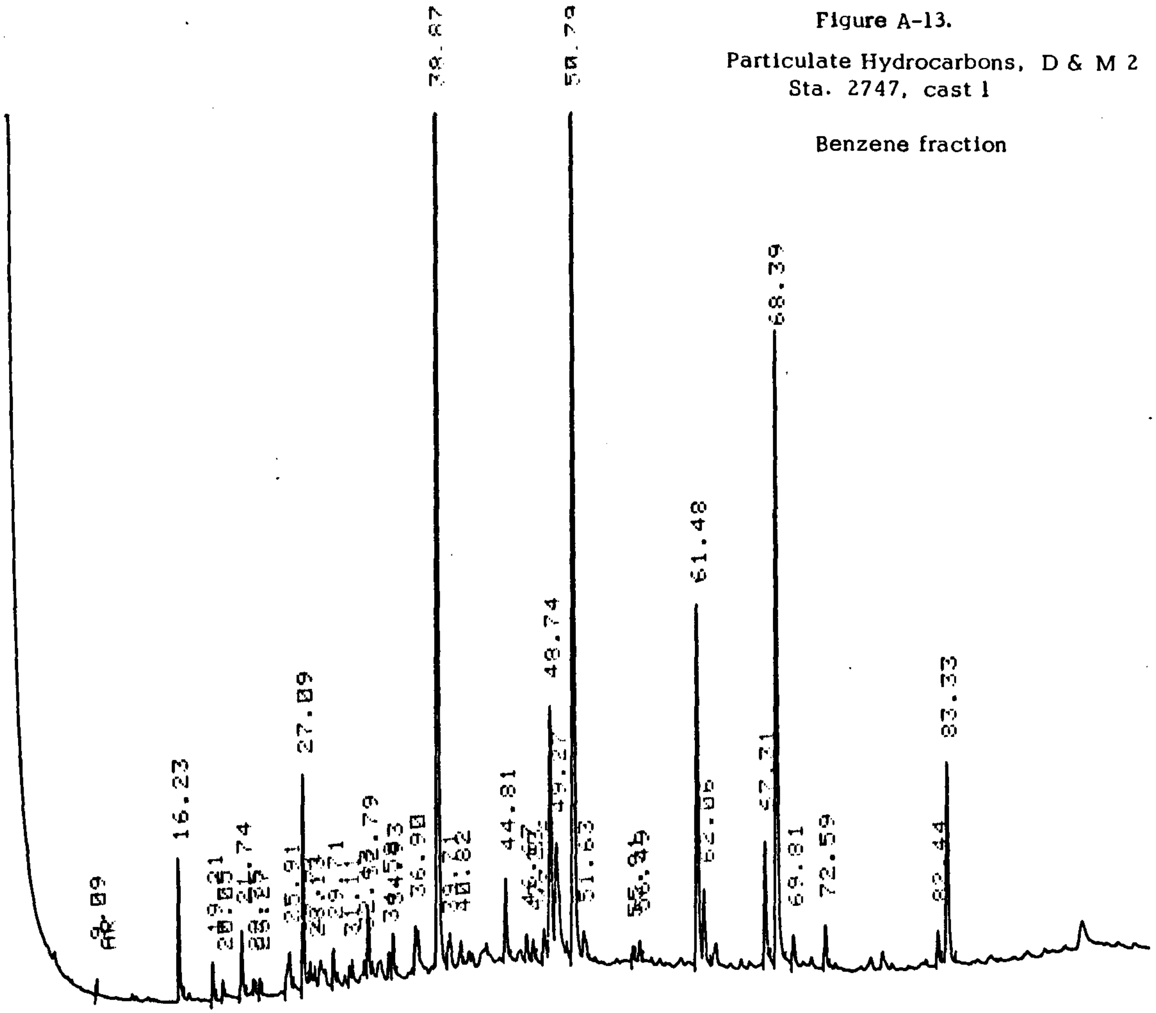


Figure A-13.

Particulate Hydrocarbons, D & M 2
Sta. 2747, cast 1

Benzene fraction

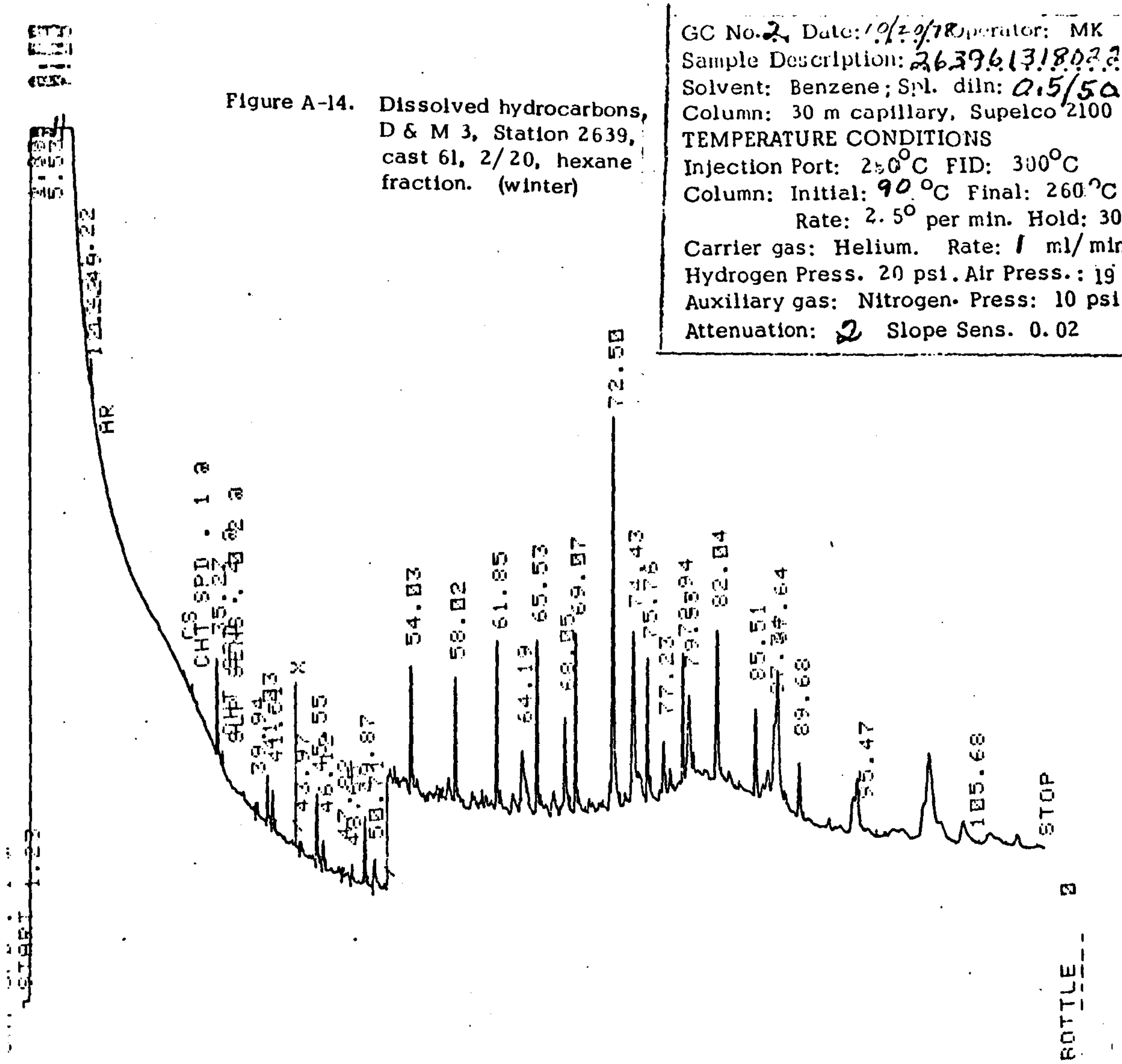
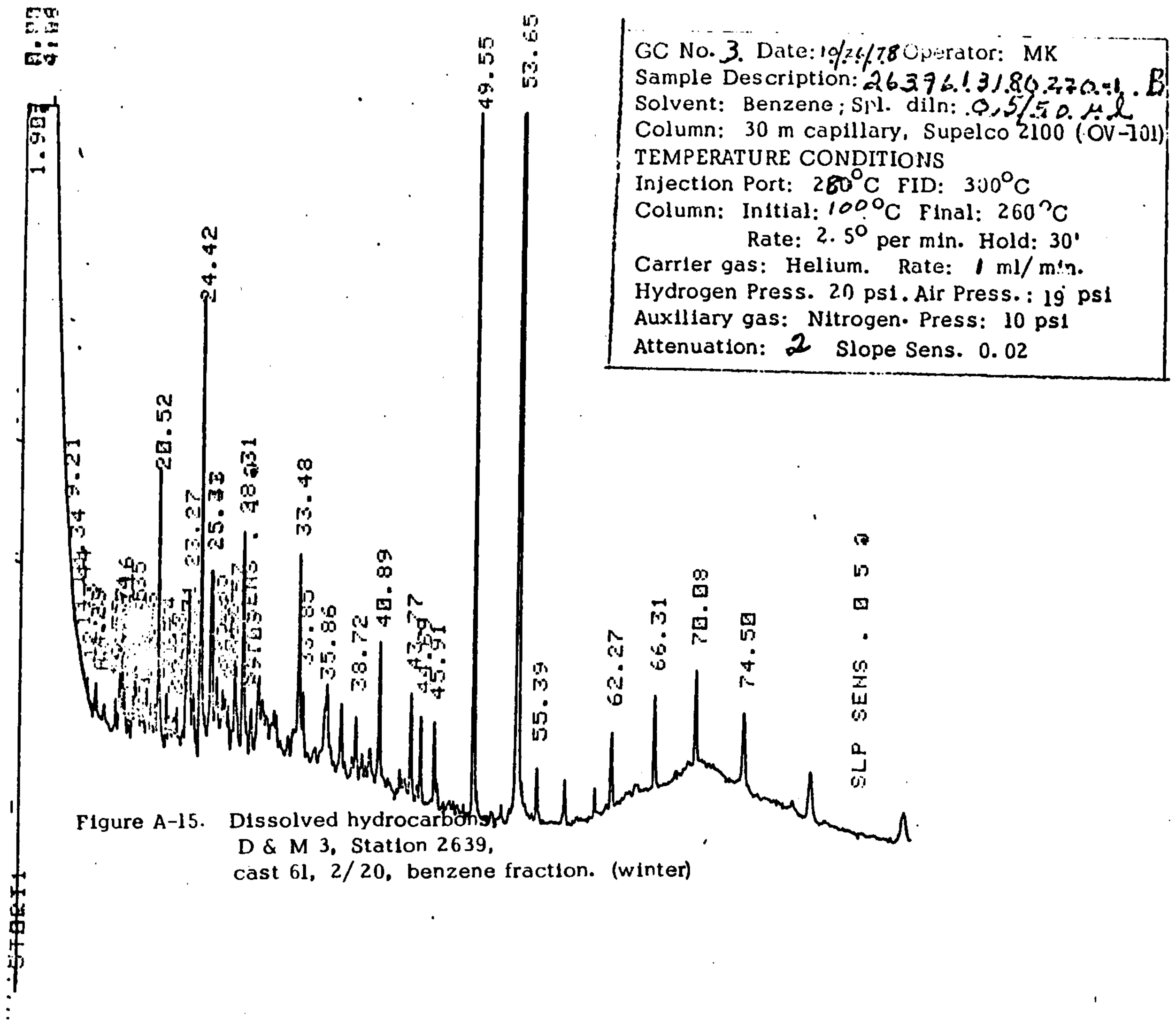


Figure A-14. Dissolved hydrocarbons, D & M 3, Station 2639, cast 61, 2/20, hexane fraction. (winter)

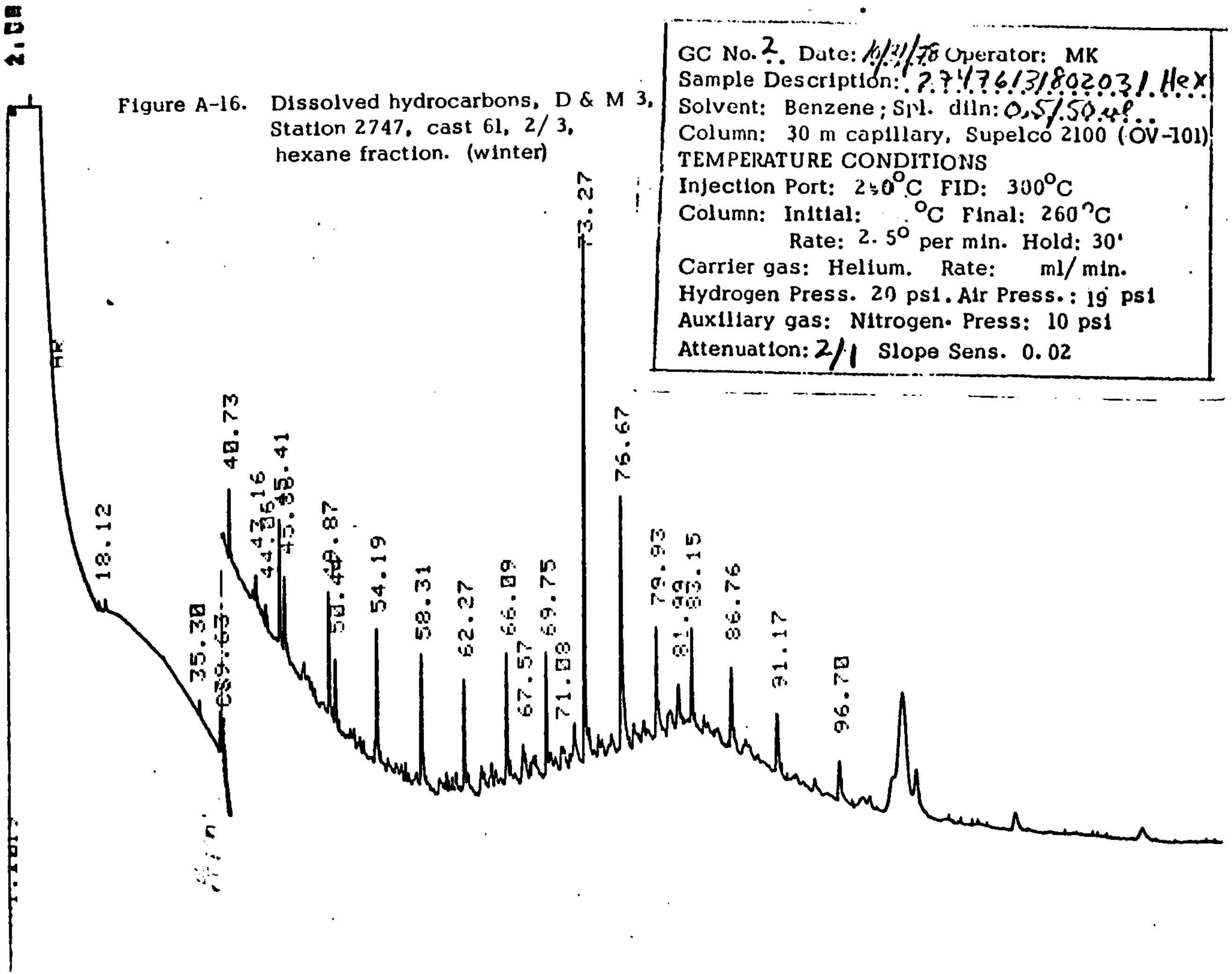
GC No. 2 Date: 10/20/78 Operator: MK
Sample Description: 2639613180220-1. H.
Solvent: Benzene; Spl. diln: 0.5/50 ml
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 250°C FID: 300°C
Column: Initial: 90 °C Final: 260 °C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: 1 ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 2 Slope Sens. 0.02



GC No. 3. Date: 10/26/78 Operator: MK
Sample Description: 263961.31.80.270-1 . B
Solvent: Benzene; Spl. diln: 0.5/50 µl
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 280°C FID: 300°C
Column: Initial: 100°C Final: 260°C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: 1 ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 2 Slope Sens. 0.02

Figure A-15. Dissolved hydrocarbons,
D & M 3, Station 2639,
cast 61, 2/20, benzene fraction. (winter)

Figure A-16. Dissolved hydrocarbons, D & M 3, Station 2747, cast 61, 2/ 3, hexane fraction. (winter)



GC No. 2. Date: 10/21/78 Operator: MK
Sample Description: 27476131802031.Hex
Solvent: Benzene ; Spl. diln: 0.5/50 ul
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 250°C FID: 300°C
Column: Initial: °C Final: 260°C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: ml/ min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 2/1 Slope Sens. 0.02

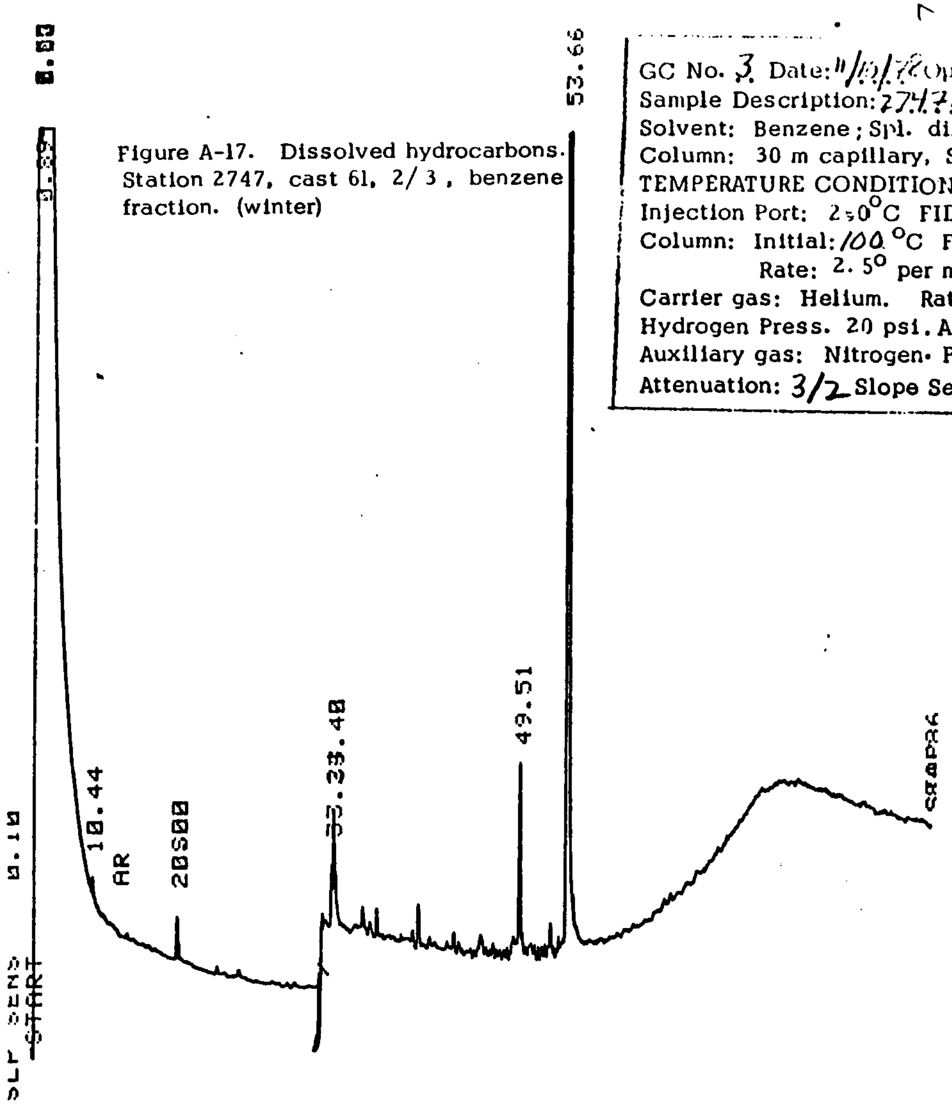
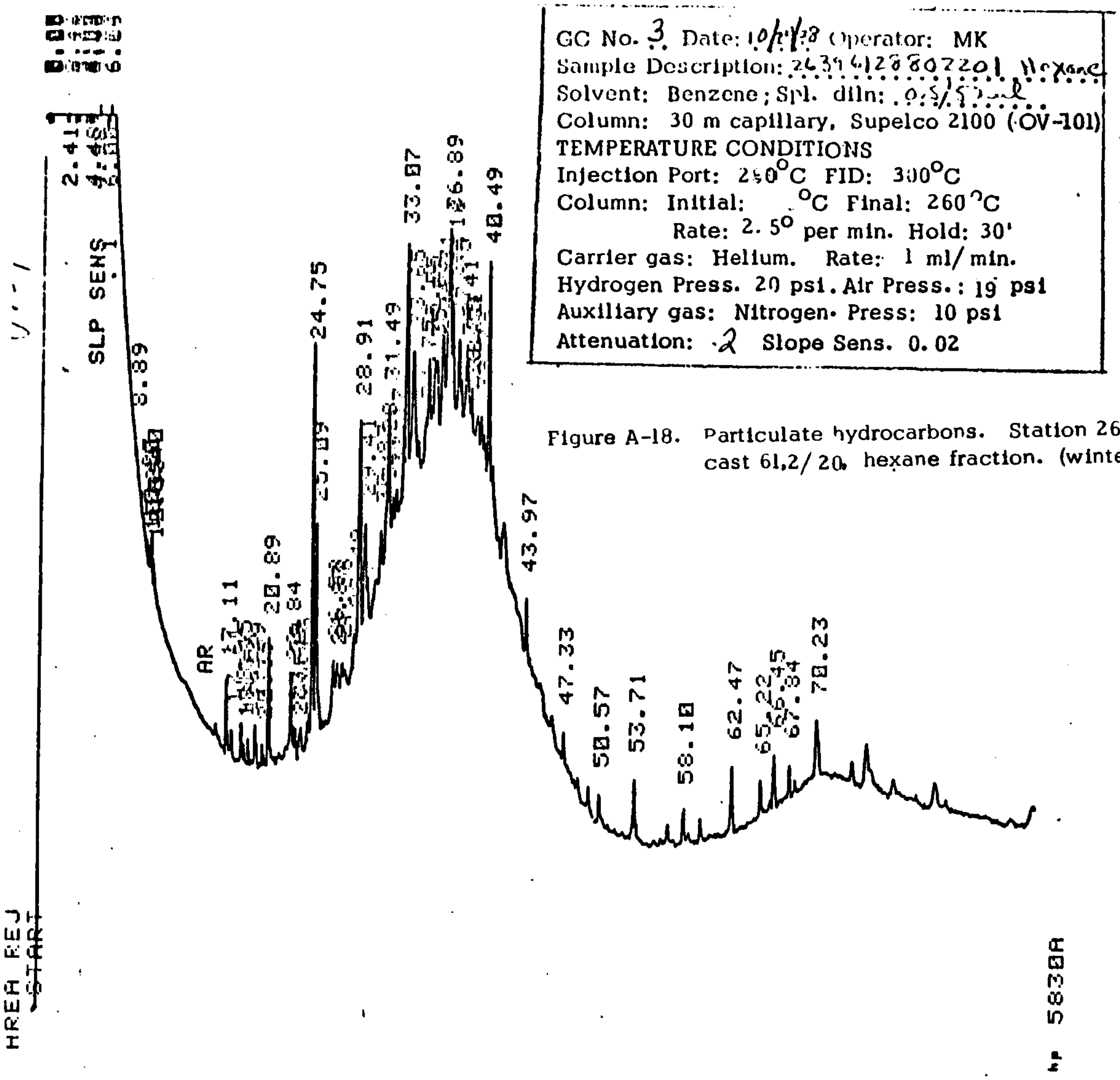


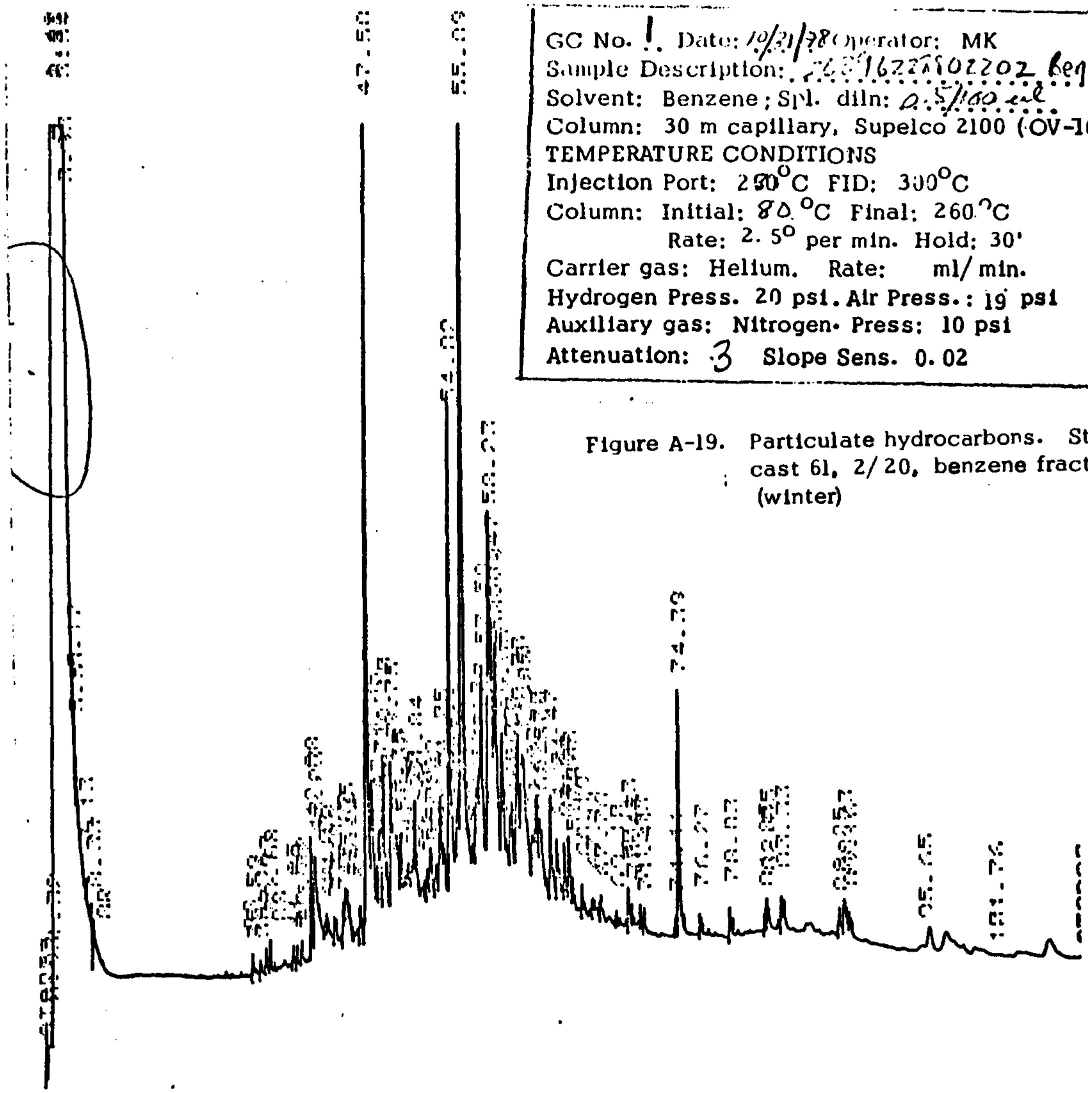
Figure A-17. Dissolved hydrocarbons. Station 2747, cast 61, 2/3, benzene fraction. (winter)

GC No. 3 Date: 11/12/78 Operator: MK
Sample Description: 27476131802031 Benz.
Solvent: Benzene ; Spl. diln: 0.5/50 ml.
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 250°C FID: 300°C
Column: Initial: 100 °C Final: 260°C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 3/2 Slope Sens. 0.02



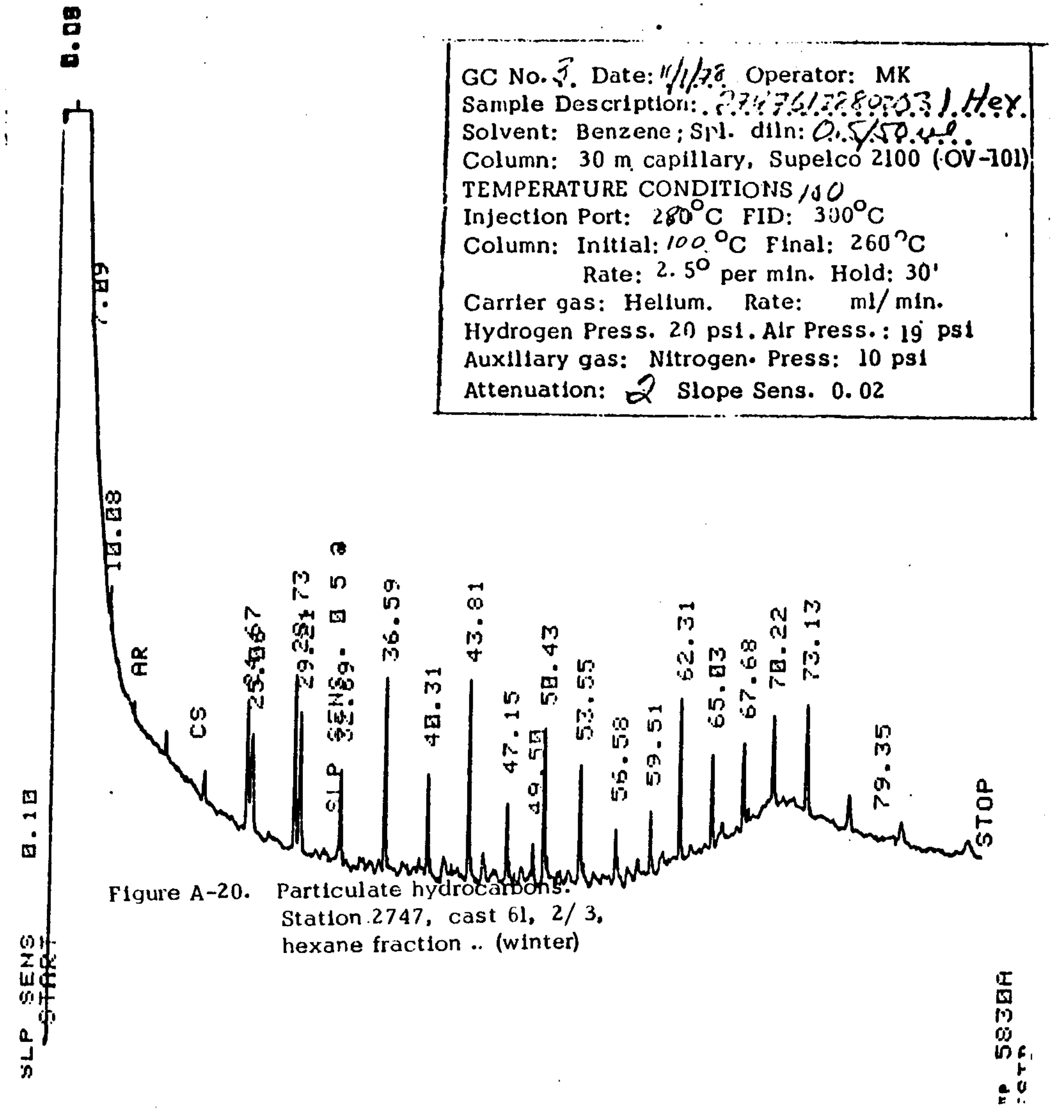
GC No. 3 Date: 10/1/78 Operator: MK
Sample Description: 2639 6123 802201 Hexane
Solvent: Benzene; Spl. diln: 0.5/5 ml
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 250°C FID: 300°C
Column: Initial: °C Final: 260°C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: 1 ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 2 Slope Sens. 0.02

Figure A-18. Particulate hydrocarbons. Station 2639, cast 61,2/20, hexane fraction. (winter)



GC No. 1. Date: 10/31/78 Operator: MK
Sample Description: [illegible]1622[illegible]02202 benz.
Solvent: Benzene; Spl. diln: 0.5/100 ml
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 250°C FID: 300°C
Column: Initial: 80 °C Final: 260 °C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 3 Slope Sens. 0.02

Figure A-19. Particulate hydrocarbons. Station 2639, cast 61, 2/20, benzene fraction. (winter)



GC No. 3. Date: 11/1/78 Operator: MK
Sample Description: 2747612280203 1. Hex.
Solvent: Benzene; Spl. diln: 0.5/50 ul.
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS /10
Injection Port: 280°C FID: 300°C
Column: Initial: 100 °C Final: 260 °C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 2 Slope Sens. 0.02

Figure A-20. Particulate hydrocarbons. Station 2747, cast 61, 2/3, hexane fraction .. (winter)

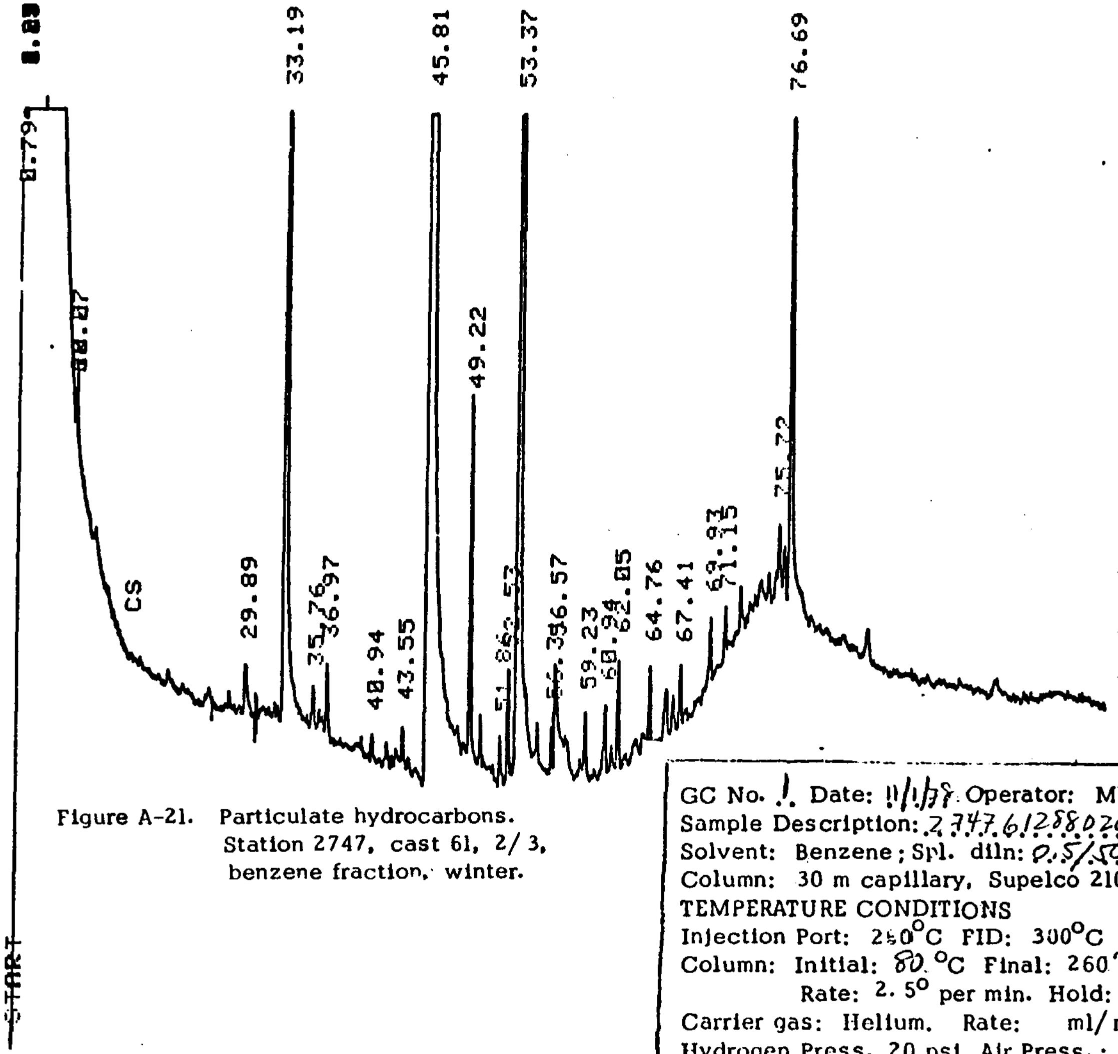


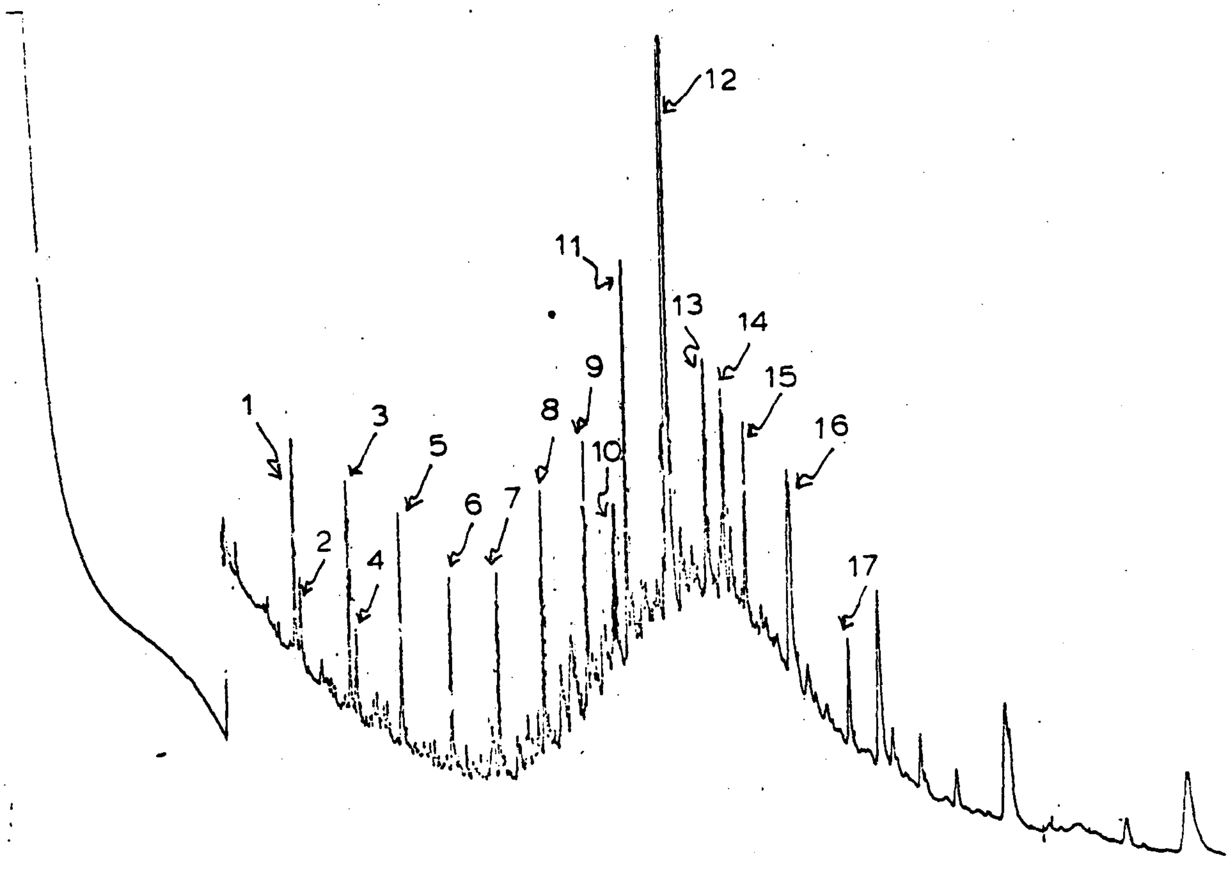
Figure A-21. Particulate hydrocarbons. Station 2747, cast 61, 2/3, benzene fraction, winter.

GC No. 1. Date: 11/1/78 Operator: MK
Sample Description: 2747.61258802031 Benz.
Solvent: Benzene; Spl. diln: 0.5/50 µl
Column: 30 m capillary, Supelco 2100 (OV-101)
TEMPERATURE CONDITIONS
Injection Port: 250°C FID: 300°C
Column: Initial: 80 °C Final: 260 °C
Rate: 2.5° per min. Hold: 30'
Carrier gas: Helium. Rate: ml/min.
Hydrogen Press. 20 psi. Air Press.: 19 psi
Auxiliary gas: Nitrogen. Press: 10 psi
Attenuation: 1 Slope Sens. 0.02

Figure A-22.

Peak No.	Identification	Kovats Index
1	n-C17	1700
2	pristane	1710
3	n-C18	1800
4	phytane	1812
5	n-C19	1900
6	n-C20	2000
7	n-C21	2100
8	n-C22	2200
9	n-C23	2300
10	di-octyl adipate	2370
11	n-C24	2400
12	n-C25, phthalate	2500
13	n-C26	2600
14	Unknown	2644
15	n-C27	2700
16	n-C28, phthalate	2800
17	n-C29	2900

Figure A-22.

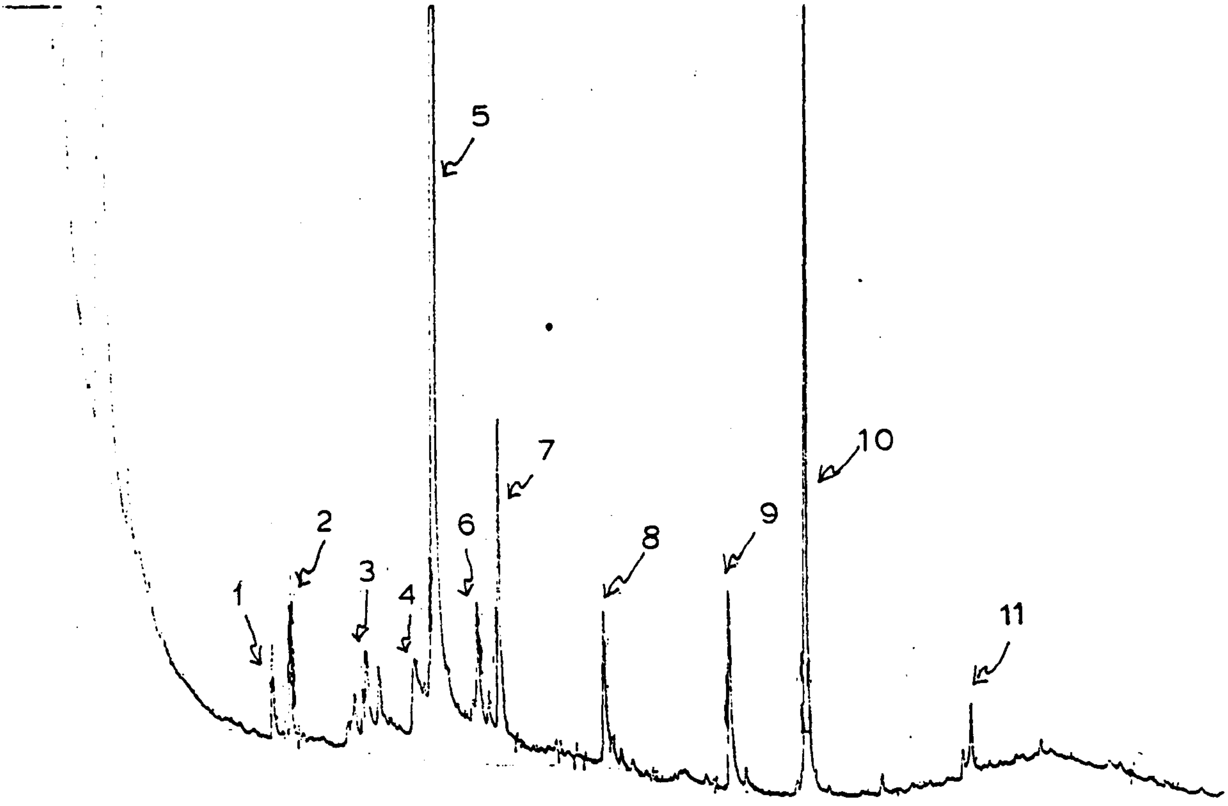


DISSOLVED HYDCARBON SAMPLE
HEXANE FRACTION
(sample 252861311802182)

Figure A-23.

Peak No.	Identification	Kovats Index
1	Unknown	1697
2	Unknown	1720
3	Myristic acid derivative	1821
4	Ethyl pentadecanoate	1880
5	Phthalate ester	1922
6	Ethyl palmitate	1974
7	Palmitic acid derivative	2026
8	Ethyl stearate	2185
9	Dioctyl adipate	2370
10	Phthalate ester	2500
11	Dioctyl phthalate	2800

Figure A-23.



DISSOLVED HYDRCARBON SAMPLE
BENZENE FRACTION

(sample 25295231710302)

Figure A-24.

Peak No.	Identification	Kovats Index
1	n-C16	1600
2	n-C17	1700
3	Pristane	1710
4	n-C18	1800
5	Phytane	1812
6	n-C19	1900
7	dibutyl phthalate	1910
8	n-C20	2000
9	n-C21	2100
10	n-C22	2200
11	phthalate ester	2250
12	n-C23	2300
13	dioctyl adipate	2370
14	n-C24	2400
15	n-C25 and phthalate	2500
16	n-C26	2600
17	n-C27	2700
18	n-C28	2800
19	n-C29	2900
20	n-C30	3000
21	n-C31	3100
22	n-C32	3200
23	n-C33	3300
24	n-C34	3400

Figure A-24.

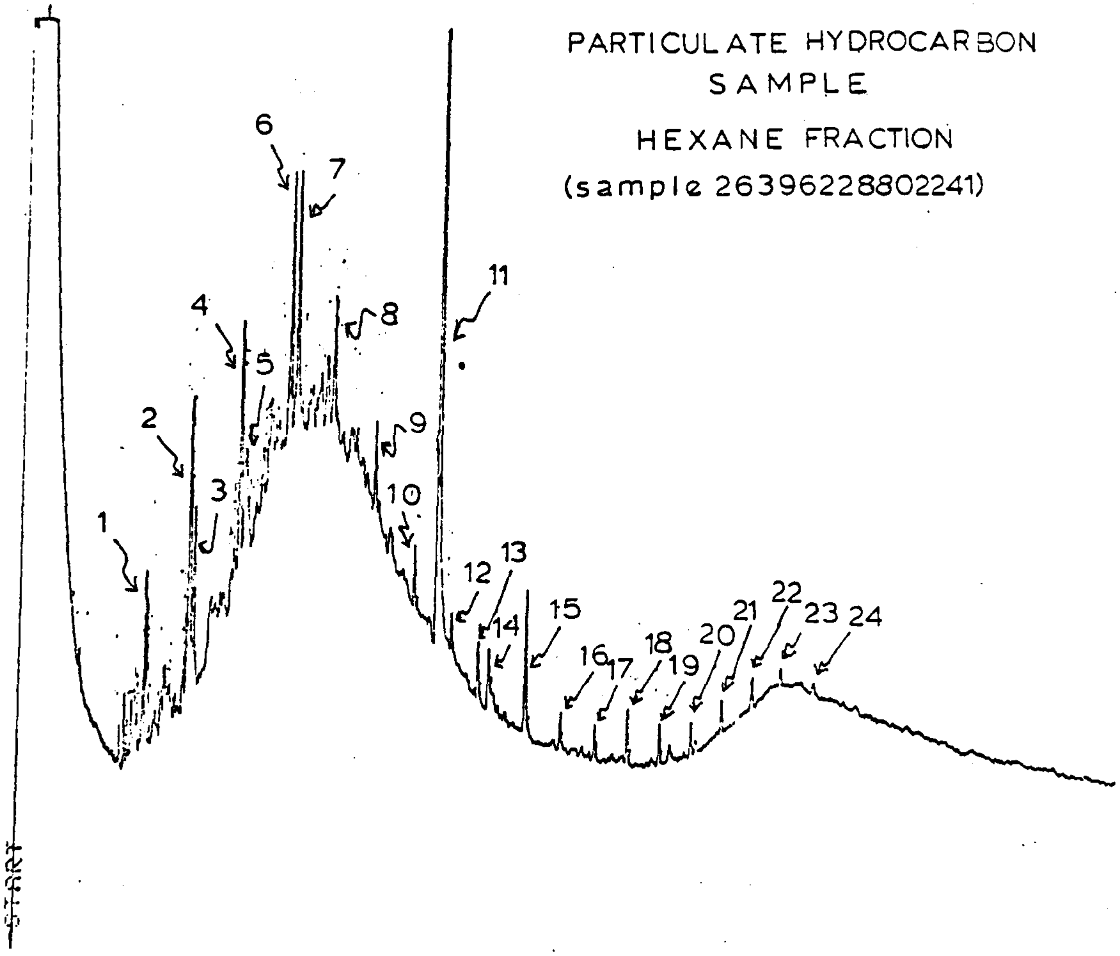

PARTICULATE HYDROCARBON
SAMPLE
HEXANE FRACTION
(sample 26396228802241)
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
START

Figure A-25.

Peak No.	Identification	Kovats Index
1	Diethyl phthalate	1610
2	(2, 4 Bis-1-methyl butyl phenol?)	1634
3	(2, 5 di-t-amyl quinone)	1646
4	isomer of above	1658
5	1, 3, 5 tri-t-butyl benzene ?	1687
6	dodecyl phenol ?	1732
7	Ethyl myristate	1795
8	Ethyl pentadecanoate	1872
9	Methyl palmitate	1911
10	Ethyl palmitate	1974
11	Ethyl margarate	2071
12	Ethyl stearate	2185
13	Ethyl nonodecanoate	2285
14	Dioctyl adipate, ethyl arachidate	2370
15	Phthalate ester	2500
16	Dioctyl phthalate	2800

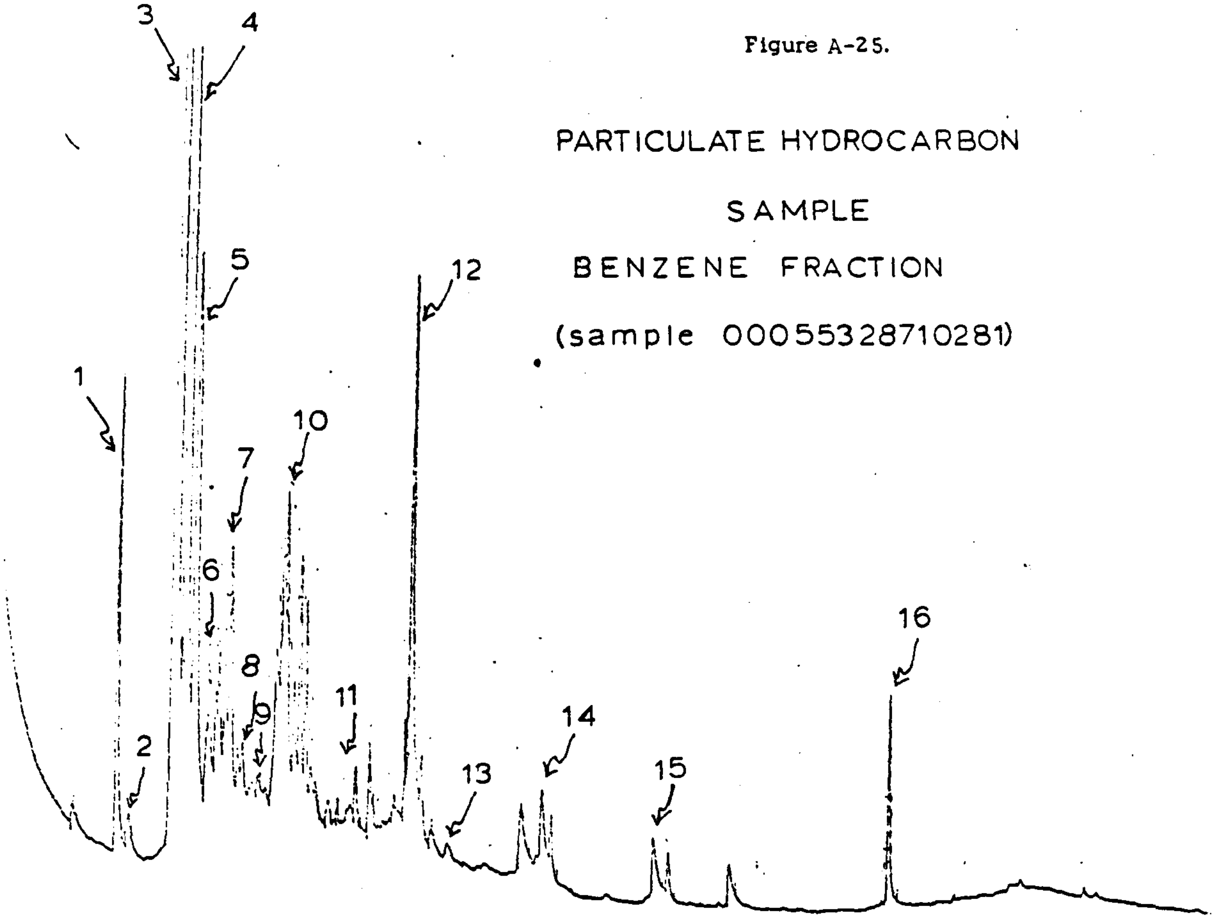


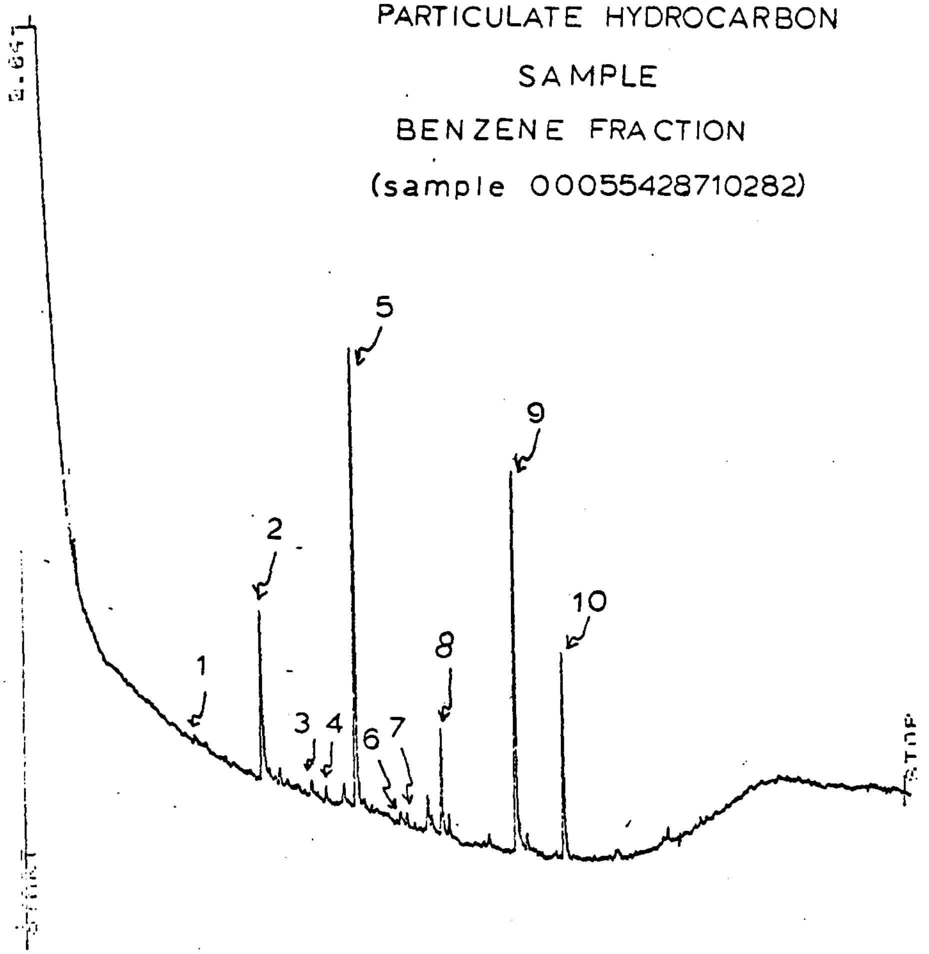
Figure A-25.

PARTICULATE HYDROCARBON
SAMPLE
BENZENE FRACTION
(sample 00055328710281)

Figure A-26

Peak No.	Identification	Kovats Index
1	Ethyl laurate	
2	Ethyl myristate	1795
3	Ethyl pentadecanoate	1880
4	Methyl palmitate	1911
5	Ethyl palmitate	1974
6	Ethyl margarate	2071
7	Methyl stearate	2106
8	Ethyl stearate	2185
9	Dioctyl adipate	2370
10	Phthalate ester	2500

Figure A-26.



PARTICULATE HYDROCARBON
SAMPLE
BENZENE FRACTION
(sample 00055428710282)

VOLUME II

CHAPTER 26

WATER COLUMN DISSOLVED AND PARTICULATE ORGANIC CARBON

DR. LELA M. JEFFREY
TEXAS A&M UNIVERSITY

CONTRACT NO. AA550-CT7-34

WATER COLUMN DISSOLVED AND PARTICULATE ORGANIC CARBON IN THE MAFLA SURVEY AREA

By

Lela M. Jeffrey
Texas A&M University
Department of Oceanography

ABSTRACT

The DOC and POC of the water column of the MAFLA area vary seasonally, with POC exhibiting the largest variation. During the fall 1977 sampling, both parameters were almost oceanic in nature. However, during the winter the POC levels rose considerably, seemingly because of an increased phytoplankton concentration. During the winter 1978, the DOC's in the northern portion of the area were somewhat more variable because apparently of increased fresh water influence. The majority of the MAFLA area, however, exhibited relatively uniform DOC's, compared to similar areas in the central and northwestern Gulf of Mexico continental shelf. Our results compare reasonably well with those of Knauer and Aller's (1976) when station locations and collection times are considered.

INTRODUCTION

Particulate (POC) and dissolved (DOC) organic carbon are commonly measured oceanographic parameters, particularly in organic pollution surveys. The ratio of a measured organic pollutant to total dissolved or particulate organic carbon is often useful in determining if the organic pollutant is of natural or anthropogenic origin. These measurements can be made with relative ease and speed on a routine basis and are as necessary as salinity measurements in continental shelf organic pollutant surveys.

Particulate organic matter in sea water consists of a variable mixture of living organisms, debris, and organic matter on or in mineral particles. In some cases, the particulate matter may be petroleum residues, but these most often are found floating on the surface. The particulate organic matter may have terrestrial, riverine, marine, atmospheric or anthropogenic origins, particularly on continental shelves. The dissolved organic carbon has similar origins. It represents organic material from decay of plankton, excretion of secretion of plankton, and may have riverine or marine origins. Both dissolved and particulate organic carbon concentrations are two to five times higher in rivers than in open-ocean surface water. In the open ocean DOC concentrations are in the range of 0.7 to 1.2 mgC $\cdot \ell^{-1}$ and POC is in the range of 0.02 to 0.06 mgC $\cdot \ell^{-1}$. The concentration of coastal waters is dependent on the amount of river input and is intermediate between that of river water and open ocean water.

The purpose of this study of DOC and POC concentrations in the MAFLA OCS area was to determine the level and variability of these parameters with time and location and to relate these, if possible, to soluble and particulate hydrocarbons. This work is an extension of Knauer and Aller's 1975 and 1976 studies of the same parameters in the MAFLA area. In this work, 40 DOC and POC samples were collected and analyzed on the fall DM II cruise at four stations, both near the surface (3 m) and near the bottom. One hundred sixty were collected and analyzed at approximately the same locations on the winter DM III cruise near the surface and near the bottom. A persulfate oxidation method was used to oxidize the organic mater to CO_2, and the latter was quantitated with an infrared CO_2 analyzer.

RESULTS

Both dissolved and particulate organic carbon concentrations for the November, 1977 sampling were comparable to open-ocean levels. The concentration range for DOC for all stations was 1.14 to 1.18 mgC $\cdot \ell^{-1}$ for near surface and 1.13 to 1.17 mgC $\cdot \ell^{-1}$ for near bottom samples. The POC concentrations were more variable, but very low for a coastal area, ranging from 0.0297 to 0.0519 mgC $\cdot \ell^{-1}$ at the near surface levels and from 0.0277 to 0.0497 mgC $\cdot \ell^{-1}$ near the bottom. The station nearest shore (2639) had the highest POC concentrations, but the DOC at that location was about the same as for the other three. The DOC and POC levels of our fall 1977 water samples correspond reasonably well with Knauer and Aller's (1976) results. The range of DOC values for their September/October 1975 survey was 0.96 to 1.30 mgC $\cdot \ell^{-1}$ and the range of POC concentrations was 0.049 to 0.116 mgC $\cdot \ell^{-1}$.

The surface 1978 winter DOC station average concentrations were also low for coastal water, ranging from 0.95 at the southernmost station (2747) to 1.49 mgC $\cdot \ell^{-1}$ for the northernmost station (2639). The higher levels for winter 1978 for the latter station reflect some river influence. Corresponding winter 1978 bottom averages for DOC ranged from 0.87 at Station 2747 to 1.14 mgC $\cdot \ell^{-1}$ at Station 2528 to the north. However, the winter 1978 POC average concentrations were considerably higher than in the fall 1977 season. Average surface winter 1978 POC concentrations ranged from 0.092 to 0.169 mgC $\cdot \ell^{-1}$ and average bottom POC's ranged from 0.086 to 0.180 mgC $\cdot \ell^{-1}$. The highest POC station averages were found at the Middle Grounds (Station 2315) and for Station 2528 (near Panama City, Fla.).

The 1978 winter DOC and POC conentrations were comparable to Knauer and Aller's (1976) data, if station locations were considered. Their winter DOC ranges were from 1.67 to 2.33 mgC $\cdot \ell^{-1}$ and their POC's ranged from 0.063 to 0.190 mgC $\cdot \ell^{-1}$. As can be seen, the DOC's were somewhat higher than those for winter, 1978, but this may be due to the fact that there was more fresh water input, and also, the stations may not be quite comparable.

One of the purposes of this study was to determine the variability with time of DOC and POC at a given location since the chemical parameters in a coastal area are often variable. The fall 1977 DOC's and POC's at a given station showed no statistically significant variations with time or depth over a 24 h period. All variations could be attributed to sampling and analysis errors. There was considerably more variability with time (five days) for the winter samples for both DOC and POC at a given location, because there appeared to be more river influence and the phytoplankton appeared visibly to be more abundant. The range of DOC concentrations was greatest at the northernmost station (2639) and decreased to an almost negligible variation at the southernmost station (2747). For Station 2639, the five day range was 1.15 to 2.43 mgC $\cdot \ell^{-1}$ and for 2747 the range was 0.78 to 1.22 mgC $\cdot \ell^{-1}$, with the other stations intermediate between these two. For POC variations the picture was different. The largest variations in POC over a five day period were at the Middle Grounds station (2315) and at Station 2528 off Panama City, Florida. The smallest variations were at 2639 and 2747, the northernmost and southernmost stations, respectively. In all cases there was no statistically significant difference between surface and bottom values for POC. See Table 115 for summary of data.

CONCLUSIONS

The DOC and POC concentrations in the water column of the MAFLA survey area vary with season, with the fall concentrations being significantly lower and less variable than the winter values. Knauer and Aller (1976) found essentially the same situation. They found that DOC exhibited low levels during the summer and fall, and was at a maximum during the winter, but POC was highest during the summer and winter and was at a minimum during the fall. POC was found in this and Knauer and Aller's work to be much more variable than DOC. Also, both investigations indicated that POC is closely related to phytoplankton productivity. DOC seems to us to be more related to salinity than any other measured parameter.

TABLE 115. Summary of the average and ranges of DOC and POC for the fall, 1977 and winter, 1978 water column surveys in the MAFLA area.

Station	Average POC mgC/l	Range of POC mgC/l	Average DOC mgC/l	Range of DOC mgC/l
		Fall, 1977		
2639 (top)	0.0519	0.0440-0.0588	1.13	1.06-1.17
(bottom)	0.0537	0.0518-0.0567	1.13	1.11-1.15
2529 (top)	0.0469	0.0313-0.0584	1.18	1.12-1.29
(bottom)	0.0321	0.0272-0.0385	1.15	1.07-1.24
0005 (top)	0.0297	0.0254-0.0342	1.14	1.09-1.21
(bottom)	0.0232	0.0103-0.0294	1.15	1.08-1.21
2747 (top)	0.0324	0.0208-0.0467	1.11	1.00-1.15
(bottom)	0.0328	0.0269-0.0422	1.13	1.10-1.18
		Winter, 1978		
2639 (top)	0.142	0.104-0.182	1.49	1.15-2.43
(bottom)	0.133	0.096-0.166	1.12	0.81-1.94
2528 (top)	0.159	0.106-0.243	1.16	0.94-1.74
(bottom)	0.180	0.136-0.226	1.14	0.92-1.39
2315 (top)	0.169	0.117-0.241	1.02	0.84-1.37
(bottom	0.158	0.088-0.212	0.88	0.77-1.20
2747 (top)	0.092	0.039-0.152	0.95	0.78-1.22
(bottom)	0.086	0.044-0.168	0.87	0.77-1.03

From the available data published by Fredericks and Sackett (1970) and by Maurer and Parker (1972), it appears that POC concentrations in the central and northwestern Gulf of Mexico continental shelf regions is higher than in the MAFLA area, and that DOC levels are somewhat the same in range and average values. It appears that river influence is stronger in the central and northwestern Gulf than in the MAFLA area. However, seasonal studies of these other areas might lead to different conclusions.

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VOLUME II

CHAPTER 27

ZOOPLANKTON TAXONOMY OF THE FLORIDA MIDDLE GROUNDS

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UNIVERSITY OF FLORIDA
CONTRACT NO. AA550-CT7-34

ANALYSIS OF ZOOPLANKTON FROM THE FLORIDA MIDDLE GROUNDS (MAFLA OCS) AREA

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September 8, 1978

Final Report

Prepared For
Dames & Moore and the Bureau of Land Management
Contract No. AA550-CT7-34

TABLE OF CONTENTS

ABSTRACT

Geographical affinities of calanoid copepods collected from the Florida Middle Grounds during the summer of 1976 and the winter of 1978 are examined. The calanoid copepods do not appear to be unique or endemic to this area, as they are reported to have a worldwide distribution, occurring from boreal (cold-temperate) to tropical waters. A smaller group appears to be generally confined to warmer waters, indicating that temperature may be a limiting factor in their distribution. Calanoids, grouped according to the water type classification of Fleminger (1956), indicate a shelf water (inshore) influence during the sumemr and an oceanic (offshore) influence during the winter.

Recommendations by the PI include discontinuation of any future zooplankton programs, at the level of effort of this work element, and suggestions for development of future programs.

INTRODUCTION

The zooplankton community is an important component of marine water column ecosystems. In addition to containing permanently planktonic forms which play a major role in the primary food chain, the zooplankton is composed of the larvae of commercially important finfish and shellfish. Not only are many of these holo- and meroplanktonic components sensitive to environmental perturbations resulting from gas and oil exploration, but they can also serve as transport mechanisms for pollutants within the water column itself and between the benthos and water column.

Before any analyses of pollutant fate-and-effects can be made, however, characterization of the system (zooplankton) in terms of composition and structure of community components, estimation of biomass, correlation with physical parameters, and documentation of seasonal and areal variation must be accomplished.

In an effort to delineate the zooplankton community in the Eastern Gulf of Mexico, several investigations have been undertaken in the past (King, 1950; Khromov, 1965; and Bogdanov et al., 1969). In addition, several of these earlier studies emphasized taxonomic and distributional reporting of selected groups of zooplankton (Fleminger, 1956; Grice, 1960; Cruise, 1971). Little or no effort was made to statistically correlate these components with the physical environment. However, these studies were a useful descriptive addition to the literature.

With the onset of exploration for gas and oil in the Eastern Gulf of Mexico (MAFLA) Outer Continental Shelf (OCS) area, benchmark studies were initiated in 1974 under the jurisdiction of the Bureau of Land Management. The general aims of these studies were to establish and document existing physical and biological conditions and relationships. In an intensive one-season sampling of the water column, attempts were made to correlate statistically the biological (zooplankton) and physical parameters (Maturo et al., 1975). Efforts at characterizing the zooplankton community during 1975 were reduced to sampling at selected stations along each of four transects. Although sampling was done on a seasonal basis, no replicates were collected, which precluded any detailed statistical documentation of the zooplankton community.

For the 1977/78 MAFLA Benchmark Survey (Contract No. A550-CT7-34) it was determined that the Florida Middle Grounds (FMG) were an "environmentally sensitive" area and, as such, the former general characterizations of the MAFLA zooplankton community would be confined specifically to this region. Although seasonal (summer, 1976; winter, 1978) diurnal samples were collected over a five-day period, unfortunately the total number collected (38) was insufficient to make any reliable quantitative statements regarding the FMG zooplankton. As a result, findings reported in this work element are qualitative and serve only to suggest possible trends in a selected group (calanoid copepods) of the zooplankton community of the Florida Middle Grounds.

METHODS AND MATERIALS

FIELD SAMPLING

Summer zooplankton samples analyzed under this subcontract were collected by personnel on board the R/V *Tursiops* on BLM Cruise No. 45 during the period July 22 to July 28, 1976. Single samples were collected at approximate 6 h intervals over the time period (20 samples total) on the Florida Middle Grounds (Station 2315). Sampling for taxonomic purposes was accomplished by a surface-to-bottom oblique tow utilizing a one-half metre diameter net with a mesh size of 202 μm. Water volume filtered was monitored by a General Oceanics Model 2030 flowmeter mounted in the net mouth.

Upon retrieval of the sample, the contents of the net were washed into the cod end jar, transferred to a glass container, and preserved with buffered 5% formalin in seawater.

Winter zooplankton samples for taxonomic analyses were collected by personnel aboard the M/V *Pacific Seal* on Leg I of the winter water column cruise (DM III) on the Florida Middle Grounds only (Station 2315). Single samples were collected at approximate 6 h intervals during the cruise until a total of 18 samples were collected. Two samples were missed due to bad weather.

Samples were collected with a one-half metre diameter net with a mesh size of 202 μm. Water volume filtered was measured by a General Oceanics Model 2030 flowmeter mounted in the net mouth.

Double oblique tows (surface-bottom-surface) were utilized for sample collection. Two closed nets were mounted on the wire (one for hydrocarbon and trace metal analyses, one for taxonomic analysis) and lowered to approximately 2 m below the surface. The nets were then opened, lowered to the bottom, raised to within 2 m of the surface, and then closed before being brought on deck. Tow time ranged from 10 to 20 min depending on the depth of the station. Towing speed was 2 to 4 knots. Samples for taxonomic work-up were washed to the net cod end, transferred to glass jars, and preserved with 10% buffered formalin in seawater.

LABORATORY ANALYSIS

Each sample was split initially in a Folsom plankton splitter, one-half retained as the archived sample portion, the other half used for counting, identification, and biomass determinations. The counting sample was then split repeatedly until an aliquot of approximately 200 animals was attained. The aliquot was placed in a channeled counting chamber, enumerated, and identified to the lowest possible taxon.

Dry weight biomass was determined by washing the entire counting half of the sample in distilled water, placing it in a tared container, and drying to constant weight at 60°C.

Ash-free weights were determined by placing the sample in a crucible and then in a muffle furnace at 500°C for one hour. The samples were cooled, rewetted with distilled water, and dried to constant weight at 105°C. Subtraction of the crucible and ash weights from the dry weight yielded ash-free weight.

RESULTS

Required tabulations of relative organism density, dry weight biomass, and ash-free biomass are contained on the Dames & Moore data tape. These data showed trends similar to those encountered in other years. Dry and ash-free biomass estimates were not calculated for the winter, 1978 samples (DM III) due to the presence of large quantities of a chain diatom which would bias the biomass determinations.

Statistical correlcations between the zooplankton community and selected physical parameters are contained on the Dames & Moore data tape. Due to the extremely small zooplankton sample size, no attempt is made to further report these correlation results. The data are included for information purposes only.

Table 116 shows the worldwide distribution, as reported in the literature, of the calanoid copepod species collected from the Florida Middle Grounds during the summer of 1976. All the calanoids are shown to be generally circumglobal in their distribution with the possible exception of _Paracalanus crassirostris_. This species is a common Gulf and western North Atlantic coastal copepod but it shows a rather disjuct offshore distribution in that it has not been reported from the Florida Straits and questionably from the Caribbean.

Table 117 shows the reported world wide distribution of the calanoid copepods collected from the FMG during the winter of 1978. The winter calanoids are shown to be a generally circumglobal group, again with the exception of _Paracalanus crassirostris_. The winter group appears to be basically the same as the summer forms with ten of thirteen species found during both seasons.

The latitudinal distribution in the western hemisphere of the calanoids collected from the FMG during the summer is shown in Table 118. Nine of the thirteen FMG calanoid species are recorded from boreal (cold-temperate) to tropical waters; the other four species, which include _Paracalanus crassirostris_, are generally more warm temperate-tropical species.

Table 119 shows the reported latitudinal distribution of the calanoids collected at the FMG during the winter. As in the summer group, the bulk of the winter species (8 of 13) occur from boreal (cold-temperate) to tropical waters. The remaining five species have been reported to occur in warm temperate-tropical areas suggesting the possibility of a slightly larger group of warmer water calanoids present at the FMG during the winter than during the summer.

Table 120 presents the calanoids collected during the summer at the FMG grouped according to the water type classification developed by

TABLE 116

WORLDWIDE DISTRIBUTION OF THE CALANOID COPEPOD SUMMER SPECIES GROUP FROM THE FLORIDA MIDDLE GROUNDS (1976).

REPORTED DISTRIBUTION IN LITERATURE

	FLORIDA STRAITS	CARIBBEAN	N. ATLANTIC WEST/EAST		S. ATLANTIC WEST/EAST		MEDITERRANEAN	INDIAN	PACIFIC WEST/EAST	
Eucalanus elongatus	X	X	X	X	X	X	X		X	
Calanopia americana	X	X	X	X	X				X	
Paracalanus crassirostris		X (?)	X			X (?)		X	X	
Temora turbinata	X	X	X		X	X				X
Temora stylifera	X	X	X	X	X	X	X		X	X
Undinula vulgaris	X	X	X		X			X	X	X
Paracalanus parvus	X	X	X	X			X	X	X	
Centropages cf. *furcatus*	X	X	X		X			X		X
Acartia danae	X	X	X	X	X					
Euchaeta marina	X	X	X	X	X			X	X	X
Scolecithrix danae	X	X	X	X	X		X	X	X	X
Mecynocera clausi	X	X	X	X	X			X	X	
Pontella atlantica	X	X	X							

TABLE 117

WORLDWIDE DISTRIBUTION OF THE CALANOID COPEPOD WINTER SPECIES GROUP FROM THE FLORIDA MIDDLE GROUNDS (1978).

	REPORTED DISTRIBUTION IN LITERATURE									
	FLORIDA STRAITS	CARIBBEAN	N. ATLANTIC WEST/EAST		S. ATLANTIC WEST/EAST		MEDITERRANEAN	INDIAN	PACIFIC WEST/EAST	
Eucalanus elongatus	X	X	X	X	X	X	X		X	
Paracalanus crassirostris		X (?)	X			X (?)		X	X	
Temora turbinata	X	X	X		X	X				X
Temora stylifera	X	X	X	X	X	X	X		X	X
Undinula vulgaris	X	X	X		X			X	X	X
Paracalanus parvus	X	X	X	X			X	X	X	
Centropages cf. *furcatus*	X	X	X		X			X		X
Euchaeta marina	X	X	X	X	X			X	X	X
Scolecithrix danae	X	X	X	X	X		X	X	X	X
Pontella atlantica	X	X	X							
Rhincalanus cornutus	X	X	X	X	X	X			X	X
Clausocalanus cf. *furcatus*	X	X	X		X					
Euaetideus giesbrechti	X	X	X							

TABLE 118

LATITUDINAL DISTRIBUTION OF THE CALANOID COPEPOD SUMMER SPECIES GROUP FROM THE FLORIDA MIDDLE GROUNDS (1976).

CALANOID SPECIES	REPORTED DISTRIBUTION IN LITERATURE	
Eucalanus elongatus	Nova Scotia - Caribbean	
Temora turbinata	Gulf of Maine - Brazil	Boreal (Cold Temperate)-Tropical
Temora stylifera	Gulf of St. Lawrence - Brazil	
Undinula vulgaris	Nova Scotia - Argentina	
Paracalanus parvus	Gulf of St. Lawrence - Brazil	
Acartia danae	Nova Scotia - Brazil	
Euchaeta marina	Gulf of St. Lawrence - South America	
Scolecithrix danae	Gulf of St. Lawrence - Brazil	
Mecynocera clausi	Gulf of Maine - Argentina	
Calanopia americana	Bermuda - Brazil	Warm Temperate-Tropical Possibly only Tropical-Subtropical
Paracalanus crassirostris	Woods Hole - Brazil	
Centropages c.f. *furcatus*	Cape Hatteras - Argentina	
Pontella atlantica	∿Cape Cod - Brazil	

TABLE 119

LATITUDINAL DISTRIBUTION OF THE CALANOID COPEPOD WINTER SPECIES GROUPS FROM THE FLORIDA MIDDLE GROUNDS (1978).

CALANOID SPECIES	REPORTED DISTRIBUTION IN LITERATURE	
Eucalanus elongatus	Nova Scotia - Caribbean	
Temora turbinata	Gulf of Maine - Brazil	Boreal (Cold Temperate)-Tropical
Temora stylifera	Gulf of St. Lawrence - Brazil	
Undinula vulgaris	Nova Scotia - Argentina	
Paracalanus parvus	Gulf of St. Lawrence - Brazil	
Euchaeta marina	Gulf of St. Lawrence - South America	
Scolecithrix danae	Gulf of St. Lawrence - Brazil	
Rhincalanus cornutus	Nova Scotia - Brazil	
Paracalanus crassirostris	Woods Hole - Brazil	Warm Temperate-Tropical Possibly only Tropical-Subtropical
Centropages c.f. *furcatus*	Cape Hatteras - Argentina	
Pontella atlantica	∿Cape Cod - Brazil	
Clausocalanus c.f. *furcatus*	Cape Hatteras - Argentina	
Euaetideus giesbrechti	Cape Hatteras - Caribbean	

TABLE 120

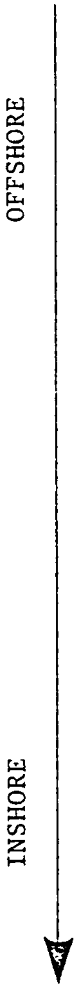
INSHORE-OFFSHORE DISTRIBUTION TRENDS OF SUMMER CALANOID COPEPOD SPECIES COLLECTED FROM THE FLORIDA MIDDLE GROUNDS, 1976 (after Fleminger, 1956).

OCEANIC SPECIES

Euchaeta marina

Scolecithrix danae

Mecynocera clausi



SLOPE WATER - OCEANIC SPECIES

Centropages cf. *furcatus*

Undinula vulgaris

SHELF WATER SPECIES

Calanopia americana

Centropages cf. *furcatus*

Paracalanus parvus

Acartia danae

COASTAL - NERITIC SPECIES

Paracalanus crassirostris

ESTUARINE SPECIES

Paracalanus crassirostris

Fleminger (1956). Organisms grouped into these categories can be considered qualitative quasi-indicators of particular water masses. This grouping can also be viewed as a horizontal distribution (inshore-offshore) record of the summer calanoid components of the FMG zooplankton. These data show that a majority of the calanoid species fall into the shelf water category followed by the truly oceanic species group and the mixed slope water-oceanic species. There appears to be little influence on the FMG by coastal waters as evidenced by the presence of only one species (P. crassirostris) from this group.

Table 121 indicates the FMG winter calanoids grouped according to Fleminger's classification. This winter grouping suggests a shift from the summer classification with most of the species present appearing in the oceanic and mixed slope water-oceanic groups. Only two species, Centropages cf. furcatus and Paracalanus parvus are represented in the shelf water group followed by a single species (P. crassirostris) in the two coastal groups. This indicates a further decreased influence on the FMG by coastal waters during the winter.

DISCUSSION

As stated previously, due to the extremely small number of samples collected during the study, any discussion of the data should be viewed as a suggestion only of possible trends in the seasonal distribution and affinities of calanoid copepods from the Florida Middle Grounds.

It appears that the FMG calanoid copepods are not unique or endemic to that area since the majority of them have been reported from most of the major seas of the world. It should be pointed out, however, that no real attempt at a coordinated species verification program has been made to document that a particular organism collected in the Mediterranean is the same as those collected in the Caribbean. Assuming species identifications are correct, the reported presence of a particular calanoid from a given area may be a result of freak hydrographic conditions bringing an organism into an area in which it normally would not be found nor survive. On the other hand, the absence of a calanoid from an area may only reflect a lack of sampling or inappropriate (net too small, mesh too large, etc.) sampling gear usage. All of these factors only serve to show that to reliably document the zooplankton community from a given area, a seasonal, replicated sampling program needs to be undertaken.

The reason for the seemingly disjunct offshore distribution of Paracalanus crassirostris is unclear. Since it is a small calanoid its absence in some of the offshore areas may be a reflection of the sampling gear used. Also, it is a common coastal species; it may not be able to tolerate the higher salinities encountered offshore, although lower salinities are generally considered to be more important distribution limiting factors. It is also possible this species may be outcompeted by the oceanic calanoids in the offshore regions.

The reported latitudinal ranges of the FMG calanoids indicate the distribution of the majority of the species is not temperature limited. Again, the extremes of the ranges of these species may represent unusual

TABLE 121

INSHORE-OFFSHORE DISTRIBUTION TRENDS OF WINTER CALANOID COPEPOD SPECIES COLLECTED FROM THE FLORIDA MIDDLE GROUNDS, 1978 (after Fleminger, 1956).

OCEANIC SPECIES

Scolecithrix danae

Euchaeta marina

Rhincalanus cornutus

SLOPE WATER - OCEANIC SPECIES

Centropages cf. *furcatus*

Undinula vulgaris

Clausocalanus cf. *furcatus*

SHELF WATER SPECIES

Centropages cf. *furcatus*

Paracalanus parvus

COASTAL - NERITIC SPECIES

Paracalanus crassirostris

ESTUARINE SPECIES

Paracalanus crassirostris

hydrographic conditions rather than a functioning population. The presence of a fewer number of warmer water organisms may indicate these are temperature limited and that hydrographic conditions at the FMG are more temperate-oriented, reducing the number of warm water species present. This may be another factor explaining the distribution of P. crassirostris.

The majority of more shelf water species present on the FMG during the summer suggests a possible larger inshore influence during this season. This may indeed be a reflection of changing water masses during this time or it may simply be an artifact of the sampling program. The presence of more oceanic species and the corresponding decrease in shelf water species during the winter may indicate a further water mass change; the FMG being influenced by more offshore or oceanic factors.

PI OPINIONS AND RECOMMENDATIONS

At the outset of this study, the PI realized that little additional quantitative information about the FMG zooplankton would be gained. Not only were the sample numbers too low to even begin to approach a "time-series analysis", any efforts to look at the interesting problem of diurnal variation were eliminated due to the use of oblique tows which effectively removed any traces of diurnal movement which could be utilized as a possible clue to community dynamics and variation. However, it was felt that perhaps a new or rare species or at the least a range extension would be found, thereby, providing some useful additional taxonomic information and a mild thrill for the PI. This was not the case, as apparently no new taxonomic information evolved from this study. Based on these factors, the PI recommends discontinuation of any future studies contemplated in this area at this level of effort.

The return from any survey study of an extremely complex system is doubtful even if adequately funded; at the level of this work element it is probably nil. If at some point in the future interest in the zooplankton does arise, the PI has included in Appendix A a list of recommendations for long term monitoring of the zooplankton. These recommendations were developed by our group at the end of the first year's MAFLA effort and should provide some guidelines regarding the approach to developing a meaningful (and therefore useful) zooplankton program.

CONCLUSIONS

Calanoid copepods collected from the Florida Middle Grounds during the summer of 1976 and the winter of 1978 do not appear to be unique or endemic to that area. Most of the species have a reported worldwide distribution in addition to occurring latitudinally from boreal (cold-temperate) to tropical waters. A smaller group shown to be generally confined to warmer waters is present on the FMG suggesting temperature may be a limiting factor for these organisms. Species grouped according to Fleminger's (1956) water type classification indicate a shelf water (inshore) influence during the summer and an oceanic (offshore) influence during the winter.

Opinions of the PI include the recommendation that any contemplated future zooplankton survey studies at the level of effort of this work element be discontinued. Suggestions for a meaningful program include replicate (36), seasonal sampling from an area of concern with concurrent measurement of physical parameters.

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APPENDIX A

(SEE DAMES & MOORE DATA TAPE)

RECOMMENDATIONS FOR LONG TERM MONITORING

A minimum of 36 zooplankton samples should be taken at each lease tract site, 12 per master station, with simultaneous collection of associated environmental data. This recommendation assumes no radical departures from the previous sampling scheme as to number or location of master stations. As envisioned, a sampling scheme of this size would allow us to detect changes in densities of selected zooplankton components (the most numerous of the plankters and those which were planktonic forms of commercially valuable fish and shellfish) equal to or greater than 0.25 of the log adjusted mean with 99% confidence as determined by our original data.

All water column parameters need to be collected concurrently. Multivariate analysis is best performed on simultaneously collected parameters, since any correlations made between these factors describe a picture based on a given set of co-existing conditions. When the various parameters are collected over different periods of time, localized conditions may change, thus making one set of factors not relatable to another. Finally, it is important that any multivariate analysis performed in future studies be done after other data in the area of study are available. Since this type of analysis involves a simultaneous examination of measured parameters, it is desirable to have all data available in order to "explain" as much of the variation in the system as possible.

The lease tract areas should be sampled at least on a seasonal basis (four times per year). This would allow for documentation of seasonal shifts in species/physical parameter associations. Attention should also be given to sampling in specific water masses as determined by physical oceanographic methods, rather than collections made in geographic areas. Abiotic and biotic factors are water-mass specific, rather than geographically oriented in a fixed location.

If control stations are to be included in future research, they should be sampled at the same frequency, time frame, and in the same water mass as the lease tract master stations. If these stations are not sampled in this manner, they should be discontinued, as they offer no real analyzable comparison with the master stations.

VOLUME II

CHAPTER 28

NEUSTON

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CONTRACT NO. AA550-CT7-34

The Draft Report for neuston collection and interpretation was not received by the time of submission; it will be forwarded upon receipt.

VOLUME II

CHAPTER 29

DATA MANAGEMENT AND DATA SYNTHESIS

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CONTRACT NO. AA550-CT7-34

FINAL WORK ELEMENT REPORT

DATA SYNTHESIS

Data Manager

Peter H. Feldhausen
Dames & Moore
New Orleans

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF LAND MANAGEMENT
CONTRACT NO. AA550-CT7-34

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ABSTRACT

Data mangagement performed three primary tasks: (1) inventory and control of scientific data, (2) data synthesis and analysis of validated data, and (3) archiving of the 1974-1978 MAFLA data base. A data inventory and control program was instituted to track and validate data as they moved from the point of development through keypunching to eventual entry into the appropriate data base file. Basically, the data management system can be reduced to the following main points:

1. Each data entry was assigned a 13-digit sample number. When required, this identifier was augmented by a 12-digit taxonomic ID number and a 2-digit specimen number.
2. The National Oceanographic Data Center (NODC) Taxonomic Code was used as a guide in the assignment of taxonomic ID numbers. These numbers served as a flexible method for sorting and retrieving specimen count, chemical analysis, and other taxonomic measurements at any desired taxonomic level.
3. Taxonomic names were assigned to the data base entries on magnetic tape by utilizing columns 81-175.
4. Data base files were established by program element or finer category without regard to which PI performed the analysis.

Data from the SUSIO 1974-1976 program was entered into the comprehensive data base if it was amenable to meaningful, quantitative manipulation by digital computer, and if it was compatible with entries from the current program. The data base was subjected to a carefully formulated synthesis/analysis strategy patterned after Park and Feldhausen (1969). This strategy was composed of several univariate and multivariate statistical techniques which were applied in a logical manner. Data synthesis/analysis was designed to aid the PI by maximizing the information extracted from his environmental benchmark data by combining his investigative ability with the ease of computation and display afforded by the computer.

INTRODUCTION

The primary function of the data management effort was to (a) provide a single interface between Bureau of Land Management (BLM) and the principal investigators relative to all parametric data, and (b) to coordinate the collection, processing, dissemination, and status-reporting for all data produced by each of the scientific teams. In addition, data management was responsible for assisting principal investigators in the interdisciplinary data analyses as authorized by the Program Manager. Data management was also charged with the responsibility for coordinating data output for BLM with the National Oceanographic and Atmospheric Administration/Environmental Data System (NOAA/EDS) as specified by BLM.

These functions were accomplished by performing three primary tasks during the course of this benchmark study:

1. Inventory and control of scientific data;
2. Data synthesis and analysis;
3. Record and data archiving.

In turn, these tasks were performed by adhering to the following basic objectives:

1. To provide Program Management with the status of sample inventories, shipboard analyses, laboratory analyses, and synthesis activities to ensure that data were collected, validated, and processed in compliance with the schedule and performance requirements of BLM;
2. To implement data management systems which will ensure the accurate and reliable processing of the data generated during the field efforts;
3. To ensure that all appropriate data can be made directly available to all PIs in formats which will aid in their data assessment in a timely, orderly, and efficient manner;
4. To review with BLM, and revise as appropriate, all existing data formats (those utilized or devised under Contract 08500-CT5-30), and to coordinate with PIs and COAR on the arrangement of new data formats where no formats existed, or where none were supplied by BLM;
5. To make provisions for archiving of the Dames & Moore data tape with EDS through BLM;
6. To report to NOAA/EDS, through BLM, within 30 days of the end of each sampling phase an inventory of data and sample collection activities;

7. To conduct all data management activities in accordance with schedules specified by BLM, and to aid Management in assuring that the principal investigators completed their data assessment efforts in time for presentation in the final draft report.

A flow chart of the data management system instituted to accomplish the primary tasks of inventory-control, data synthesis-analysis, and archiving is presented in Figure 267. It relates the three primary tasks of data management to data input, data base management, and data output. Details of the inventory control, data synthesis-analysis, and archiving tasks are discussed in the paragraphs which follow.

INVENTORY AND CONTROL

INTRODUCTION

The function of the inventory and control effort was (a) to coordinate the collection of data by each of the scientific teams, (b) to perform sample inventories of all field and laboratory data, (c) to implement data management and quality control systems for tracking and validating data as it was prepared for entry into the data base, and (d) to institute effective and efficient data file management systems and to assure the integrity and security of all data base entries. Overlapping both the inventory control and data synthesis-analysis tasks was the assignment to coordinate monitoring of analytic progress and status reporting for all data produced by the principal investigators and processed by data management.

Inventory and control activities were performed aboard ship by the Chief Scientist and by the Dames & Moore Onboard Representative, and in the laboratory by the scientific team members. Similar activities were performed in Dames & Moore offices and computer facilities by the data management group. Inventory control was organized, coordinated, and supervised by the Data Manager.

SHIP AND LABORATORY

Inventory and control activities of the data management group depended on the cooperation and attention to detail of every member of the program team, whether aboard ship or working in the laboratory ashore. Shipboard personnel prepared sample inventory sheets and maintained logs and journals, whereas in the laboratory, data were enscribed in keypunch ready form on 80 column coding sheets (see Figure 267).

Shipboard

Sample recovery was measured against the sampling plan by use of a preprinted log maintained by the Chief Scientist of each cruise. A separate log sheet was prepared in advance showing the sampling plan for a given station. The Chief Scientist used this sheet to measure his progress as samples were obtained. Appropriate entries were made to describe the samples and subsamples extracted from them. In addition, the station log documented (a) station number, position, and depth, (b) date and time on and off station, (c) time of sampling, and (d) pertinent weather information and

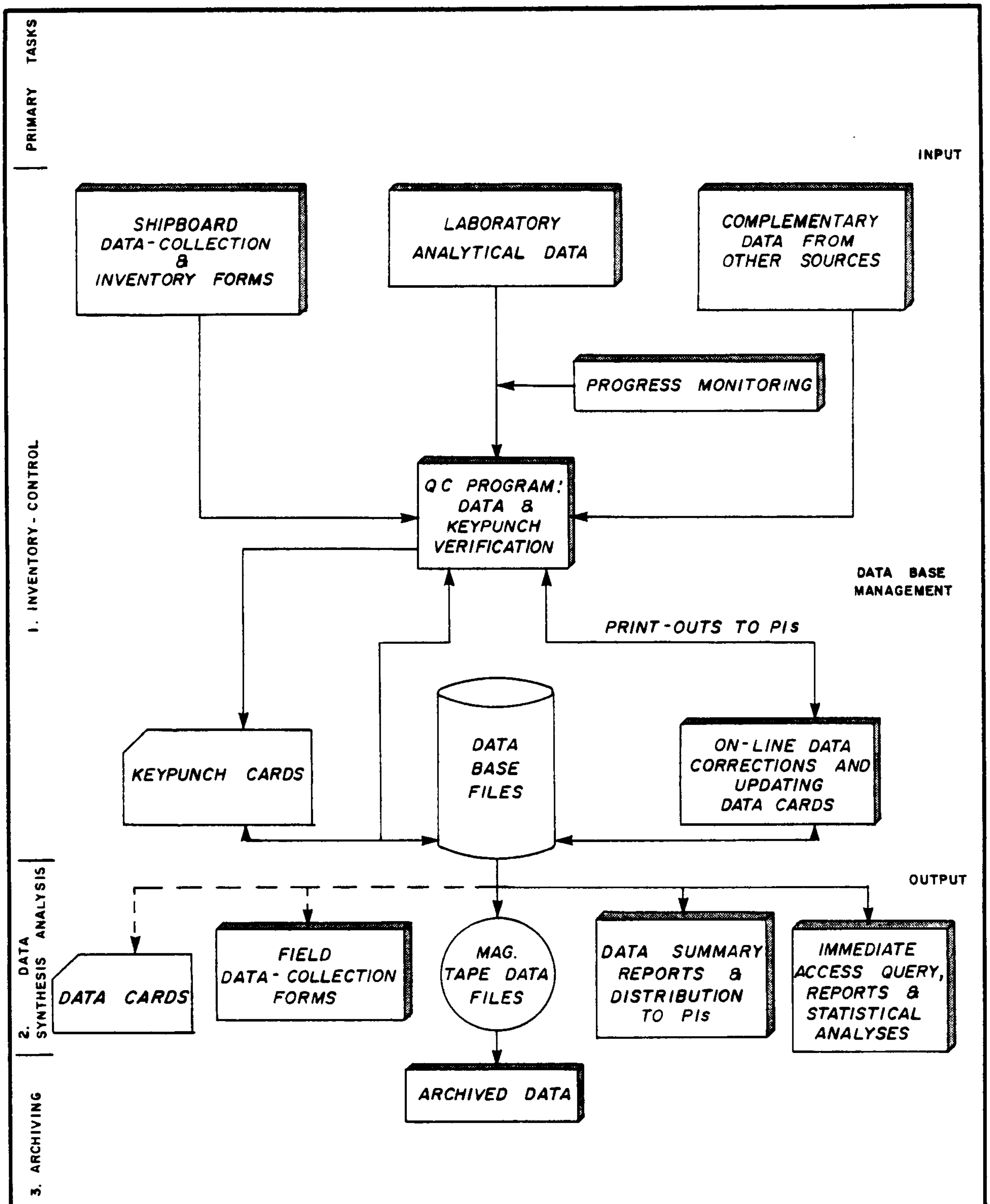


FIGURE 267

DATA MANAGEMENT SYSTEM

remarks. Separate journals were maintained by the Chief Scientist and by the Dames & Moore Onboard Representative.

A sample inventory report form was maintained aboard ship by the program work element team leaders under the direction of the Chief Scientist. Each sample was assigned a unique 13-digit sample number and recorded on the form together with a brief description of the sample, its mode of preservation, container code, storage location, inventory dates, and ultimate destination. These sample inventory reports served as (a) a shipboard inventory, (b) a packing list when the samples were shipped for analysis, and (c) as an inventory document by the data management group.

Data Coding Sheets

Requisite scientific data obtained aboard ship or generated in the laboratory that were amenable to meaningful quantitative data manipulation by digital computer were encoded by principal investigators on formatted keypunch coding sheets. Formats for these sheets were established by the data management group, in coordination with COAR and principal investigators, to ensure ease of data coding and to optimize data retrieval and processing. Prior to adoption for program use, the formats were reviewed by Mrs. Maxine Jackson of the NOAA, Atlantic Meteorologic and Oceanographic Laboratory in Miami. Coordination with NOAA on data formats was required by the terms of our contract with BLM.

Progress Monitoring

Sample and data exchange between principal investigators, and the analytic progress of each sample, was monitored by means of the Weekly Analysis Progress Report. This report was compiled weekly by the Program Manager and his adminsitrative staff to track the actual progress and the rate of progress during each phase of analysis.

Sample numbers and other pertinent information were extracted from cruise logs, journals, and inventories, and were utilized to prepare a check list for each program work element. This list contained a tabulation of sample numbers, and space for the principal investigator to check off, step-by-step, his analytic progress on each sample or to record the exchange of samples with other investigators. Program Management updated the lists weekly and transmitted them to the principal investigators, who returned the annotated check lists received the previous week.

Weekly Analysis Progress Reports prepared from the check lists by the administrative staff were distributed to the data management group and other members of the program management team. Data management was particularly interested in these reports because (a) they provided confirmation of sample numbers and receipt of samples, and (b) they facilitated planning of staffing requirements, work load distribution, and data base management.

DATA BASE MANAGEMENT

Introduction

Scientific information was received by the data management group in the form of station logs, cruise journals, sample inventory reports, and analytic results, including those contained in previous MAFLA reports and/or data tapes. From this information data were selected for entry into the data base by applying the criteria:

1. The data must be amenable to meaningful, quantitative manipulation by digital computer; and

2. The data must be compatible with data base entries from the current program.

Data from the current MAFLA program entered the data base via punched cards prepared from coding forms as described above in DATA CODING SHEETS.

All data entering the data base were carefully inventoried, controlled, and verified for accuracy. This was accomplished, in part, by assigning each sample a unique set of identification numbers and ensuring that the sample identification and corresponding data entry were never separated. An extensive quality control program was maintained throughout the program in order to assure the accuracy of the data placed in the data base.

A flip-card record system was used to track the movement of data through the various steps from keypunching to entry into the data base files and subsequent data processing during the synthesis-analysis phase of the program. An inventory-control system was also instituted to manage the data base when it was entered on the computer.

These aspects of data base management are detailed in the paragraphs which follow.

Sample Numbering System

Assignment (and retention) of a unique identification number to each data entry was the corner stone of the data base management system employed during this program. In the most general case, a data entry may be identified by a 13-digit sample number, a 12-digit taxonomic identification (ID) number, and a 2-digit specimen number. Numerical identifiers were utilized instead of alphabetic or alpha-numeric identifiers in order to assure maximum computer efficiency, and hence, to minimize computer costs.

Station Numbers

Station numbers which appeared in the contract documents and were related to box-core sampling performed under this contract were preserved. Whenever possible, those associated with box-core stations from previous studies were also preserved. These station numbers were designated by a 4-digit number, for example, 2101.

From Figure 104, in the introduction to this volume, it may be observed that Station 2101 is the shoreward most station on Transect I. Historically, the number 2101 was derived from 2 = box-core program, 1 = Transect I and 01 = Station 01. Thus, the second number of this 4-digit sample number identifies the transect on which the station lies.

Many of the dredge/trawl stations were initially identified by a combination of Roman numerals and alphabetic designations, for instance, Station II-B (see Figure 104, Transect II). Station numbers such as these were converted to solely numeric entities, such as 0001 for Station II-B.

In order to maintain a 4-digit sample numbering system, the 1974 box-core stations were numbered 40xx, except where their location was coincident with that for the present field studies. Similarly, it was necessary to assign 4-digit station numbers to many of the stations occupied during 1975 and 1976.

Table 3 (Volume I-A of this report) is a station number correspondence chart and may be used to convert station numbers utilized in previous studies to those employed in this program. In addition, Table 3 presents the position and depth values assigned to all stations.

Sample Numbers

Each sample was given a 13-digit sample number to represent the four main elements associated with the sample, namely:

1. Station number (location) - 4 digits;
2. Replicate and method of samling code - 2 digits;
3. Program element code - 2 digits; and
4. Date of sampling - 5 digits,
    a. Year - 1 digit,
    b. Month - 2 digits,
    c. Day of month - 2 digits.

Tables 122 and 123 list the replicate, and method of sampling codes and program element codes, respectively.

From the sample number alone, one may obtain considerable information about the data entry, e.g., its location, replicate-method of sampling, program element assignment, and date of sampling. This point is illustrated by considering the sample number 2103171970823. This number may be decoded as follows:

1. Station 2103, Transect I;
2. Replicate 17, first trawl at the above station;

TABLE 122

SAMPLE REPLICATE CODE

CODE	DESCRIPTION
01-16	Box-core
17	Trawl
18-19	Dredge
20-29	Extra box-core or grabs
30-39	Extra trawls
40-49	Extra dredges
50-67	Water samples
60-84	Transmissometer, STD, calibrations of above
85-96	Observations in support of zooplankton neuston, etc. (Meteorological, oceanographic, light intensity-penetration)
97	Fuel oil, lube oil, bilge water, paint, etc.

TABLE 123

PROGRAM ELEMENT CODES

CODE	DESCRIPTION
01	Bottom sediment standard grain size parameters
02	Bottom sediment long-term archive
03	Bottom sedimment clay mineralogy
04 (52, 60)	Foraminifera taxonomy (see designated codes)
05 (50)	Meiofauna taxonomy (see designated code)
06	Macorinfauna sorting and biomass
07 (09)	Bottom sediment trace metals (code 09 for Ba & V split)
08	Bottom sediment HMW Hydrocarbon
09	Bottom sediment trace metals; Ba & V
10	Bottom sediment TOC
11	Bottom sediment ATP subsamples (in sets of 3/sample)
12	Bottom sediment trace metal QC
13	Benthic cruise STD trances
14 (39)	Macroepifauna trace metals (code 39 for Ba & V split)
15	Macroepifauna HMW Hydrocarbon
16 (40)	Demersal fish trace metals (code 40 for Ba & V split)
17	Demersal fish HMW Hydrocarbon
18	Macroepifauna taxonomy
19	Demersal fish taxonomy

TABLE 123 (CONTINUED)

CODE	DESCRIPTION
41	Zooplankton trace metals; Ba & V
42	Suspended particulate trace metal; Ba & V
43	Bottom sediment HMW-HC Quality Control
44	Fuel oil HMW Hydrocarbon
45	Lube oil HMW Hydrocarbon
46	Bilge water HMW Hydrocarbon
47	STD calibrations (bucket samples)
48	Paint trace metals
49	Detergent
50	Meiofauna taxonomy second plug (see code 05)
51	Unassigned
52	Foraminifera taxonomy second plug (see codes 06 and 60)
53	Unassigned
54	Unassigned
55	Polychaete taxonomy (infauna)
56	Mollusc taxonomy (infuana)
57	Echinoderm taxonomy (infauna)
58	Miscellaneous macroinfauna taxonomy
59	Arthropod taxonomy (infauna)
60	Foraminifera taxonomy, 12-15 cm (see codes and 52)
61	Surface water salinity (see code 36)
62	Near bottom water temperature (see code 37)
63	Light scattering measurements (see code 38)

TABLE 123 (CONTINUED)

CODE	DESCRIPTION
20	Benthos histopathology
21	Benthos TM/HC Quality Control
22	Suspended sediment clay mineralogy
23	Neuston taxonomy
24	Zooplankton taxonomy
25	Zooplankton HMW Hydrocarbon
26 (41)	Zooplankton trace metals (code 41 for Ba & V Split)
27	Zooplankton HC/TM Quality Control
28	Suspended particulate HMW-HC
29 (42)	Suspended particulate trace metals (code 42 for Ba & V split)
30	Suspended particulate organic carbon, POC
31	Dissolved HMW-HC material
32	Dissolved material corganic carbon, DOC
33	Water column cruise STD
34	Water column transmissometry
35	Meteorological observations
36	Near bottom salinity (see code 61)
37	Surface water temperature (see code 62)
38	Light intensity and penetration in water (see code 63)
39	Macroepifauna trace metals; Ba & V
40	Demersal fish trace metals; Ba & V

3. Program element 19, demersal fish taxonomy; and
4. Sample collection date of 23 August 1977.

Taxonomic ID Numbers

A taxonomic numbering system modeled after that established by NOAA was adopted for this program to rapidly sort and retrieve taxonomic information held in the data base. Their numbering system and Taxonomic ID number assignment tabulated prior to August 1977 were incorporated directly into our system (NODC, Taxonomic Code, 1977). However, few MAFLA area taxa were contained in the Taxonomic Code, and many code assignments were necessitated as the data base was created. Because a long response time was required by NOAA, temporary assignments were made by principal investigators, and confirmed by data management. Subsequently, the National Oceanographic Data Center (under NOAA) was furnished a copy of the taxonomic ID numbers and name files as utilized in this program. Close coordination between program management and investigators was required to avoid the use of two different numbers for the same taxon and vice versa.

The NODC taxonomic coding system permits any taxon to be represented by an ID number consisting of 2 to 12 digits. The first 4 digits indicate the taxonomic classification above the family level, and vary with the size of the phylum. The next digits, taken in pairs, indicate the family, genus, species, and subspecies levels. For example, the taxonomic ID number 6177010102 corresponds to the shrimp species _Peneaus duorarum_ which is a member of class Crustacea (61), order Penaeidea (6177), family Penaeidae (617701), and genus _Penaeus_ (61770101).

Ten digits were used to designate species. An 8-digit ID number was used when it was desired to imply identification could not be carried beyond the generic level. Similarly, a 6-digit number was used to imply identification could not be carried beyond the family level. Sorting of taxa was usually performed to select only taxa with 10 or 12 digits for data processing. This was particularly important when calculating species diversity.

Specimen Numbers

On occasion, it was necessary to assign a 2-digit specimen number in addition to the taxonomic ID number and the sample number in order to uniquely identify the sample. This was particularly true for chemical analysis of the demersal fish _Syacium papillosum_. Specimens of this fish caught during the sumemr 1977 were analyzed individually and many specimens were obtained at the same station.

Entry Into Data Base

Sources of Data

Sources of scientific data for the MAFLA area included station logs, cruise journals, sample inventory reports, and analytic results in three different forms (Figure 267):

1. Keypunch ready coding sheets;

2. Magnetic computer tapes; and

3. Reports prepared for this and previous MAFLA studies.

Almost all of the shipboard and laboratory analytic data developed for this program were encoded by principal investigators on 80-column coding sheets. This data base included archived data for the summer 1976 (S76) and data associated with cruises DM I, DM II, DM III and DM IV for sampling periods, summer 1977 (S77), fall 1977 (F77), and winter 1978 (W78), respectively (see Dames & Moore 1977a, 1977c, 1978a and 1978b). Formats for these coding sheets were established by the data management group in coordination with COAR, NOAA, and principal investigators to ensure ease of data coding and of data retrieval/processing, and at the same time keep investigator calculations at a minimum. These formats were also designed to be compatible with the formats of the computerized data base files.

Analytical Research Laboratory, Incorporated (ARLI) submitted their high molecular weight hydrocarbon (HMW-HC) data in computer generated tabular form. Minor manipulation was required to arrange their data in a keypunch ready format. Scientific Applications, Incorporated (SAI) submitted their barium and vanadium trace metal analytic results on magnetic computer tape in a format ready for immediate entry into the data base.

MAFLA data for the sampling periods summer 1975 (S75), fall (F75), and winter 1976 (W76) were recieved on magnetic computer tape from BLM. This tape is frequently referred to as the SUSIO Data Tape (SUSIO, 1977), because it contains MAFLA data from the period of management control by the State University of Florida System Institute of Oceanography (SUSIO) (Contract AA550-CT5-30). The conversion of this data into formats used in the current program is discussed in the section CONVERSION OF THE SUSIO DATA TAPE.

Other data for the summer 1974 (S74) sampling period was encoded by the data management group from the final report for the period (SUSIO, 1974). Bottom sediment grain size and calcium carbonate data, total digest bottom sediment trace metal data, and foraminifera data were extracted from the five volume report set and added to the data base.

Positioning information prepared from shipboard records by the navigation subcontractor, Decca Navigation, Limited (Decca, 1976, 1977a, 1977b, and 1978) was encoded by the data management group. Universal transverse mecator (UTM) coordinates for the sampling events were used to construct (a) large scale computer post-plots of the box-core drops and of the start-stop dredge/trawl points (corrected for cable length and depth of water), and (b) data plots to show the geographic distribution of calcium carbonate, salinity, temperature and other measured parameters. Station location information (latitude and longitude) was placed in the computer data base and reported in the first level sample inventory reports.

Inventory-Control

Three broad categories of data base management were performed:

1. Sample inventorying;
2. Data tracking;
3. File managing.

Inventories of samples obtained during cruise DM I through DM IV (see Dames & Moore 1977a, 1977b, 1978a, and 1978b for a description of the cruises) were carried out at two levels. The first level sample inventory was reported on NOAA Form 24-23 (ROSCOP II) "Oceanography-General Cruise Inventory". In addition to providing the general inventory information required by the form, a station sample matrix was appended to each ROSCOP II submitted (Dames & Moore 1977b, 1977d, and 1978c). This matrix presented a tabulation by program element (see Table 123) of the samples obtained at each station, as well as positioning information.

Second level sample inventories were prepared from sample inventory report forms filled out aboard ship during each of the four cruises. These inventories listed all the sample numbers obtained for each program element. As these second level sample inventories are presented in the quarterly reports (Dames & Moore 1977e, 1977f, and 1978d) they will not be again presented here.

A flip-card system was used to track the data as they moved through the various stages, from keypunching to eventual entry into the appropriate data base file. This system permitted retrieval of the data at any desired stage as well as retrieval of specific data products that might be required for review. Items in this latter category included original keypunch coding sheets, verified card image listings, data listings, and other documents.

Data file management is described in a separate section entitled Data File Management.

Quality Control

A comprehensive quality control program was instituted at the onset of the program. The objective of this program was to ensure, to the extent possible, that all data entering the data base accurately reflected the results reported by the responsible principal investigator (Figure 267).

Principal investigators were responsible for submitting their data in keypunch ready form. Exceptions made for the ARLI HMW-HC data and the SAI trace metal data to be reported via tape have been noted previously. Coding sheets were inspected on receipt and minor corrections made if the entries were unclear or in improper columns.

The encoded data forms were then sent to our subcontractors for keypunching on standard 80-column computer punch cards. All keypunching was subjected to 100 percent verification. The keypunch subcontractors also furnished an unformatted listing of the card images. Card images listings supplied by the keypunch subcontractors were carefully compared against the original coding sheets and any required corrections noted. Copies of proofed and corrected card image listings were sent to responsible principal investigators for approval and/or correction.

Corrections compiled in this manner were made to the data cards prior to their entry into the computer data base. Errors detected at a later date were corrected during routine data file maintenance.

Data Base Entry

Corrected data was placed into the data base by assigning it to the appropriate data base file, reading the associated data cards and transferring the data to magnetic tape as 80-column card images. Access to the data base was made by reading from tape to temporary disc storage. As data processing was only performed on the temporary file in disc storage, integrity of the data base was preserved. Corrected data cards provided requisite backup to taped data.

Criteria for screening data for entry into the data base were:

1. The data must be amenable to meaningful, quantitative manipulation by digital computer; and
2. The data must be compatible with data base entries from the current program.

Thus, qualitative data and data in raw form were not included in the data base. Another example of excluded data is the HMW-HC gas chromatograph trace. Quantitative data from the trace, however, such as the concentration of pristane, were included. Excluded data that are germane to the contract have been reported in the individual work element reports. Certain data developed under SUSIO management was also excluded from the data base (see CONVERSION OF THE SUSIO DATA TAPE, below, for a complete discussion of SUSIO tape data included in or excluded from the Dames & Moore data base). For example, barium and vanadium trace metal concentrations were not transferred into the present data base because the analytic method specified in their contracts did not produce results compatible with results produced by the neutron activation methodology utilized in this program.

Data Base Files

More than 65 data base files were created to permit rapid access and ease in storage of the 1974-1978 Dames & Moore data base (Figure 267). Descriptions of these files and their format specifications are presented in Appendix A.

Formats for the individual files were designed to correspond as closely as possible to the coding sheets utilized by the principal investigators. Consequently, little, if any, data processing was performed during construction of the data base.

The data base file system was organized in the following manner:

1. File 020 contains information on the date, position and depth observed at each station occupation;
2. 100 series files contain all data on bottom sediment trace metal, total organic carbon (TOC), and HMW-HC chemistry;
3. 200 series files contain all data on macroepifauna trace metal and HMW-HC chemistry;
4. 300 series files contain all data on demersal fish trace metal and HMW-HC chemistry;
5. 400 series files contain all data on water column trace metal, suspended particulate and dissolved organic carbon (POC and DOC), and HMW-HC chemistry;.
6. 500 series files contain all data on zooplankton trace metal and HMW-HC chemistry;
7. File 610 contains all data on living microbal biomass, adenosine triphosphate (ATP);
8. 700 series files contain all data on meiofauna, zooplankton, demersal fish, foraminifera, macroinfauna, macroepifauna, and neuston taxonomy, meristics, and biomass;
9. 800 series files contain all data on bottom sediment textural properties, calcium carbonate concentrations, and clay mineralogy, as well as suspended clay mineralogy;
10. 900 series files contain all data on physical oceanographic parameters, including temperature, salinity, transmissometry, and light penetration;
11. T-series files contain listing of taxonomic ID numbers and corresponding taxonomic names.

The HMW-HC data is recorded in the same general format regardless of the material analyzed. Files for analyses performed on nonbiologic material (bottom sediment, water and suspended particulates) contain blanks where the taxonomic ID number and specimen number are inserted for analyses performed on macroepifauna and demersal fish. Taxonomic identification was not required for either HMW-HC or trace metal analyses of zooplankton.

Data requiring taxonomic identifiers were initially encoded and entered in the data base with taxonomic ID numbers only. The taxonomic name was omitted because of the space limitations of an 80-column card. However, to optimize name retrieval, taxonomic names have been assigned to the data by utilizing columns 81-130. File 725 is unique, in that the names associated with the larval codes used for the various taxonomic groups have been written in columns 131-175.

Data File Management

Computer Facilities

Dames & Moore has implemented a nationwide contract with United Computing Systems, Incorporated (UCS) of Kansas City, Missouri. This contract was negotiated with UCS in order to optimize service at minimum cost. The contract enabled Dames & Moore's offices from geographically separate areas to utilize the same programs and to operate on the same data sets when required. This was an important feature for this program, because (a) the firm's proprietary data synthesis-analysis programs were available for use, and (b) the routine computerized data-base management, performed from our offices in Washington, D.C., received occasional specialized assistance from the Advanced Technology Group located in Los Angeles.

Although the Advanced Technology Group provided specialized data management assistance and had direct access to the data, the data remained secure. Access to the data files was permitted only to those individuals with both the proper account number and password. In addition, the original data was maintained on magnetic tape, and data listing, synthesis, and analysis were performed from temporary disc files created by reading from tape.

Large memory and a high calculation rate were provided by our contract with UCS through access to large, high speed computers. Available to the data management group in both the interactive, online time-share and remote batch processing modes were Control Data Corporation (CDC) mainframe equipment, CDC 6500 and CDC 6600 computer systems. The program team utilized portable desk-top, remote-access terminals, and Data 100 Model 74 remote batch terminals to access the mainframe equipment at UCS.

Another important feature of the contract with UCS was access to a wide variety of proprietary software packages. Thus, it was unnecessary for the data management group to incur the cost of software develpment for data file management.

File Management System

A UCS propietary software package, entitled Interactive File Manager (IFM), served as the primary computer file management tool (UCS, 1975). IFM is a system level language for organizing, sorting, merging, printing, and performing similar sophisticated file structuring from either the time-share or batch mode of operation. All data listings and reports were generated through IFM. Similarly, all systematic corrections and assignment of taxonomic names to individual data entries were performed with IFM. In contrast, individual data corrections were performed in the time-share editor mode using the UCS UNIDIT system (UCS, 1977a and 1977b).

As indicated in the earlier section Entry Into Data Base, data were primarily loaded into the appropriate data base files from punched cards to temporary disc storage utilizing the Data 100 remote batch terminal. They were then transferred to magnetic tape. SAI's trace metal data, and that from the SUSIO Data Tape, were read directly from magnetic tape into the temporary files.

Inventory-control of the data base files was performed with tape logs. UCS assigned unique tape numbers to tapes held in their tape library and maintained their own tape logging system. The data management group also maintained a tape log of the data base files. This log recorded the UCS tape number, data base file code, and file description, as well as the position of the file on tape and the length of the file in both number of lines and number of characters on file.

Upon request UCS would print on remote time-share or batch terminal a catalog of files on disc storage and/or magnetic tape.

Security of the Data Base

Security of the data base files was provided by:

1. Limiting access through use of an account number and password;
2. Use of temporary storage files for data editing and processing;
3. Alternate data tapes of disc storage provided by normal UCS practice; and
4. Punch card backup to magnetic tape storage which was stored separately from the magnetic tapes.

DATA SYNTHESIS AND ANALYSIS

INTRODUCTION

General

The function of the data synthesis and analysis effort was as follows:

1. To perform accurate and reliable data processing;
2. To distribute all appropriate data to principal investigators that was required for their data assessment; and
3. To assist principal investigators in their performance of interdisciplinary data analysis to the extent authorized by the Program Manager.

Associated with this function were the inventory-control activities required to (a) track and control data products, (b) perform data file management, and (c) report the status of all data products produced by data management. Data file management was particularly important during the synthesis of interdisciplinary data, as this effort required the extraction and matching of data from more than one file.

Definition

In the most general sense, data synthesis and analysis may be considered any data processing that was undertaken, including both the simple listing of data and statistical analysis of data. However, in a more limited sense, data management performed data synthesis for the principal investigators by combining parts of single or diverse parts of several work elements in order that they might perceive a coherent whole. Similarly, statisticale analysis was performed to resolve the large, complex data matrices into simpler more basic ones.

Whenever possible, the output of synthesis-analysis was (a) descriptive parameters and graphical relationships ameanable to interpretation, and (b) as required, statistical tests to evaluate the significance of these interpretations.

Approach

Our approach to data synthesis-analysis has been an interactive feedback loop between Principal Investigators and the Data Manager that assured optimal interpretive advantage and prevented use of statistical programs as "black boxes". The data synthesis-analysis strategy employed during this benchmark study provided for full use of the Principal Investigators' investigative ability couple dwith the ease of computation and display afforded by the computer.

Location

Data synthesis and analysis were performed primarily at the Dames & Moore offices and computer facilities in Washington, D.C. When required by schedule and work load distribution, these activities were also performed by program staff from our Los Angeles offices. All data synthesis and analysis, and ancillary inventory-control and quality control activities, were directed from the Dames & Moore program offices in New Orleans by the Data Manager in close coordination with the Program Manager.

DATA PROCESSING CONTROL

Inventory Control

Procedures that were instituted to track and control input data from collection to their entry into the data base, and to perform data-file management, were continued throughout the synthesis-analysis phase of this study.

Requests for data processing were made by principal investigators; these requests were reviewed by Management to ensure that they were germaine, and that the results would be useful in the assessment of the data analyzed. Blanket requests which were searching in nature and without a clearly defined objective were not granted.

All data processing was initiated by the Data Manager, who issued data processing requests to members of the data management staff. These

As proposed by Park (1974), these objectives can be met in an optimal manner by sequentially applying four multivariate statistical techniques:

1. Variable mode (R-mode) cluster analysis to determine redundancy (bias or overweighting) of sample variables;
2. Sample mode (Q-mode) cluster analysis to partition the samples into discrete, environmentally significant classes;
3. Sample mode (Q-mode) ordination to assist in the interpretation of the classification developed with cluster analysis, and to examine gradational relationships among the samples based on their resemblance to one another.
4. Stepwise discriminant analysis to statistically evaluate the classification, to identify key species for distinguishing among the classes, and to classify new samples of unknown affinity.

Gradational relationships among the samples may be quantified by the application of trend surface analysis, which fit mathematical surfaces to the data displayed in two dimensions.

This strategy has been proven successful in paraecologic studies (Park and Feldhausen, 1969; Gervirtz et al., 1971), in sedimentologic studies (Feldhausen and Ali, 1975 and 1976), and in baseline studies of foraminifera and macroepifauna (Feldhausen and Ali, in preparation; Feldhausen, 1977).

Sources of Programs

A library of computer programs was acquired from several sources in order to have at hand the tools required to accomplish the primary synthesis-analysis objectives stated in the preceding section. Sources of computer programs included:

1. "Canned" program packages held by UCS:
   a. Statistical Programs for the Social Sciences (Nei et al., 1975);
   b. Biomedical Computer Programs (Dixon, 1973).
2. Proprietary programs in the UCS library:
   a. Interactive File Manager (UCS, 1975);
   b. Computer contouring and plotting packages.
3. Dames & Moore proprietary programs accessed through special UCS files:
   a. Modular Multivariate Statistical Package;

- b. Data digitization program;
- c. Temperature-Salinity-Density relationships program.

These programs were verified under the quality assurance umbrellas of both UCS and Dames & Moore. Minor programs to generate summary statistics and histograms were prepared and verified by the data management group.

Dames & Moore's Modular Multivariate Statistical Package (MMSP) served as the primary program package utilized in synthesis-analysis. Our MMSP can be divided into seven program categories as follows:

1. Data transformation and scaling routines (usually performed under SIMATX)
    - a. Transformations (binary, log, square root)
    - b. Scaling (standardization, normalization, ranging, expanded relative scaling).
2. Calculation of similarity or dissimilarity matrices (SIMATX)
    - a. Selection of mode of analysis, either R-mode (association of variables) or Q-mode (association of samples);
    - b. Similarity indices (correlation coefficient, distance coefficient, Sorensen's coefficient or Bray Curtis percent similarity coefficient, simple matching coefficient, Fager's coefficient, Jacard coefficient taxonomic distance, cosine theta, and covariance).
3. Classification routines
    - a. R-mode and Q-mode cluster analysis by the weighted pair group method (CLUSTWP);
    - b. Stepwise discriminant function analysis (SDISFA).
4. Ordination routines
    - a. Principal components analysis (PCA);
    - b. Wisconsin ordination (ORDER);
    - c. Canonical analysis (SDISFA).
5. Predictive routines (including the quantification of gradients within an ordination)
    - a. Trend surface analysis (TREND);
    - b. Multiple regression analysis, single step (RMULT) and stepwise (SMULTR).

6. Testing routines
    a. Stepwise discriminant function analysis (SDISFA);
    b. Multivariate analysis of variance (MVA).
7. Miscellaneous routines
    a. Standard grain size analysis (MEASURE);
    b. Plotting packages (PLOTDND, PLOTREN);
    c. Sorting samples and variables into preassigned order to construct rectangular input data matrices (SORTER);
    d. Diversity and evenness calculations (DIVER).

Data Matrices

Most of the scientific data in the data base were multivariate in nature, that is, the samples were described by more than one variable. The bottom sediment trace metal data were multivariate because the samples represented the measured concentrations of nine metals. In contrast, the ATP data were univariate, as the samples represented only measured concentration of ATP.

In general, the data base files were considered as data matrices composed of t-samples and n-variables. Univariate samples were represented by only one variable and n was equal to unity; multivariate samples had n values greater than one. Each element in the matrix was defined by x_{ij}, where x is the data value in the i-th row and the j-th column. Traditionally the matrix is said to be n·t meaning that it has n rows, one for each variable, and t columns, one for each sample. A typical data matrix is shown in Figure 268.

R-Mode and Q-Mode

Data matrices such as that shown in Figure 268 were examined from two points of view. In the R-mode, the variables (rows) were compared on the observed similarities of the samples (columns). The converse view is termed Q-mode, wherein, the samples (columns) are compared on the basis of the observed similarities of their variables. Analyses which examined all associations among species, or which extracted all stations associated with a particular species, could be considered R-mode analyses. In contract, analyses which partitioned stations into distinct classes, or which calculated, for instance, the mean and standard deviation of the nine trace metal concentrations at a station could be considered Q-mode analyses.

For further discussion on this topic, the reader is referred to Sneath and Sokal (1973, Chapters 4 and 5).

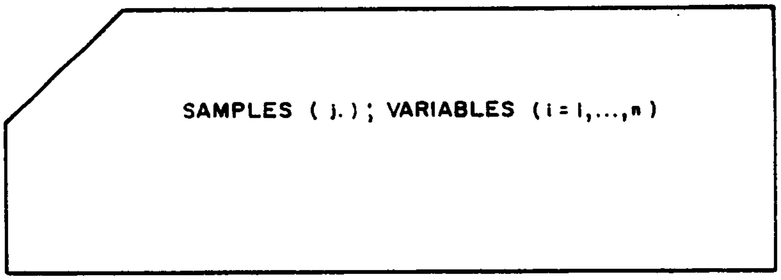
A. DATA MATRIX

t-SAMPLES
(j-COLUMNS)

n - VARIABLES
(i ROWS)

$$\begin{array}{c|ccccc} & 1 & 2 & 3 & & t \\ \hline 1 & x_{11} & x_{12} & x_{13} & & x_{1t} \\ 2 & x_{21} & x_{22} & & & \\ 3 & x_{31} & & x_{33} & & \\ n & x_{n1} & x_{n2} & x_{n3} & & x_{nt} \end{array}$$

B. R MODE TYPE ENTRIES



C. Q MODE TYPE ENTRIES

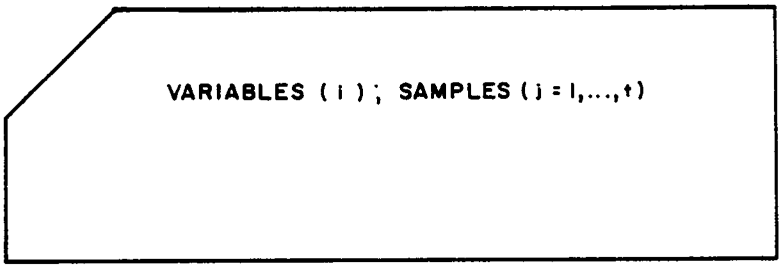


TABLE 268

REPRESENTATIONS OF DATA MATRIX

processing requests were numbered serially and issued in writing. They delimited (a) the general nature of the processing to be performed, (b) specific data sets and programs to be utilized, and (c) schedule and distributional requirements.

A flip-card logging system was used to track and control the data processing activities. Products of data processing were distributed under letter of transmittal. Information copies of the data processing requests and transmittal letters were routed to the Program Manager and then placed in the program files.

Quality Control

Quality control was implemented through the following steps:

1. Performing work only as directed by the Data Manager;
2. Using only validated data from appropriate data base files;
3. Employing only verified computer programs; and
4. Reviewing data output for accuracy and completeness.

DISCUSSION OF METHODS

Introduction

Analytic Strategy

The data base, composed of cruise-collected samples, analytical laboratory test data, and complementary data from previous MAFLA programs, was subjected to a carefully formulated analytic strategy for data synthesis patterned after Park and Feldhausen (1969) and Park (1974). The strategy is composed of several univariate and multivariate statistical techniques which were applied sequentially to the data in logical manner. As described below, these techniques have been selected, and their manner of application designed, to aid the Principal Investigator maximize the information extracted from his environmental benchmark data.

Primary objectives of the statistical data processing performed under our contract were twofold:

1. To reduce the complex data matrices to descriptive parameters and graphical relationships that:
    a. Quantitatively describe the baseline data;
    b. Define, identify, and display environmentally significant relationships.
2. To test the statistical significance of these relationships, when appropriate.

Input Matrices

Inasmuch as the computer programs utilized for this study had fixed algorithms, it was necessary to read input data in either R-mode or Q-mode form. Data matrices in R-mode form were stored by listing each variable, followed by each of the samples in which it was found. The data were stored as rows (Figure 268a and 268b). This was the case for most of the taxonomic (700-series) data files. Data matrices in Q-mode form were stord by listing each sample followed by each of the variables found in the sample. The data were stored as columns (Figure 268a and 268c). This is the mode of data storage that is most familiar to the occassional computer user.

With rare exception, the data base files contained variable data values only when the variable was observed, that is, nonoccurrences were neither reported nor stored. However, to perform either R-mode or Q-mode analyses a rectangular data matrix was required. This means that space had to be provided in the matrix for all sample and variable entries entering into the analysis. Not only were the matrices required to be rectangular ($t \cdot n$) but, in the case of Q-mode analysis, the variables were required to be listed in the same order in each sample (i.e., the index i had to apply to the same variable in all samples). The converse was true for R-mode analysis (the index j had to apply to the same sample for all variables).

Input matrices were constructed by first accessing the appropriate data files and performing preliminary file organization and structuring with IFM. When required, data stored in R-mode format was converted to Q-mode, and vice versa. The SORTER program of MMSP was then employed to sort the samples and variables into pre-assigned orders. Rectangular matrices ready for input into data processing programs were constructed in this manner.

It should be pointed out that the data were carefully edited and screened before input matrices for elaborate analyses were prepared. This screening process to audit, code, and validate the data was performed during data base management. In this manner, the generation of ineffectual data matrices was avoided. In conjunction with this effort, the data were examined for outliers and redundant variables, as well as for violation of testing assumptions such as constant variance or normality. When required, outliers and redundant variables likely to bias the analyses were removed, and appropriate data scaling and/or transformation performed.

Listing

Input matrices, as described above, were used to prepare data listings required for data validation and data synthesis (see Figure 267). Taxonomic data were usually listed in both R-mode and Q-mode type printouts. R-mode listings tabulated all the stations associated with the occurrence of a given taxa, whereas Q-mode tabulated all taxa occurring at a given station. These forms of presentation provided the Principal Investigator with a quick overview of the distribution of his taxa (R-mode) and of taxa occurrence at a given station (Q-mode).

When listing taxonomic data, both the ID number and Latin name were printed. At the same time, the taxonomic names were assigned to the appropriate data entries (see, for example, the 700-series data base files).

Species lists and listings of the taxonomic code were prepared at frequent intervals. Those for the taxonomic code were sorted numerically by taxonomic ID number, as well as alphabetically by taxonomic name, for the convenience of Management and Principal Investigator alike.

Species abundance lists were also prepared. These tabulations were prepared on a program element code basis for individual and pooled sampling periods. Within a sampling period, the total abundance of each species was presented as well as the number of stations at which it was found. Species abundance lists were sorted in three ways:

1. Taxonomic order (numerically on the taxonomic ID number);

2. Total abundance in the time period examined;

3. Total number of stations in which a species occurred.

Univariate Statistical Analyses

Species abundance lists bridge the gap between pure data listing and univariate statistical analysis, in that they report the frequency of occurrence at stations. However, for this program, univariate statistical analyses were not primarily concerned with frequency of occurrence, but with variable means, variances and standard deviations, maximums, minimums, and ranges. These descriptive statistical parameters were usually reported in an output labeled Stations Statistics.

Station statistical outputs, and other univariate statistical analyses (histograms, one-way analysis of variance, required number of replicates, moment measures, diversity indices, and outlier analysis), performed for Management and/or Principal Investigator are described in the subsections which follow.

Station Statistics

Descriptive statistics of the variables found at a station during a sampling period, or for pooled sampling periods, were reported in several different formats in order to accommodate the several types of data in the data base. Regardless of format, the following statistical parameters were calculated to quantify and characterize the data at each station:

1. Arithmetic mean;

2. Variance and standard deviations;

3. Maximum and minimum values;

4. Range of values.

5. Sample Arithmetic Mean.

The arithmetic mean ($\overline{x}$) is the most common measure of central tendency for variables measured on an interval or higher scale of measurement (Davis, 1973). Often referred to as the "average," it is merely the sum of the individuals for each case divided by the sum of the cases. For a given sample, the arithmetic mean was expressed by:

$$\overline{x}_{ij} = \sum_{k = 1}^{L} x_{ij}k/L \qquad (1a)$$

where i is the index of the variable under consideration in sample j, and k....L are the cases being averaged. The above notation corresponds to that used to described a data matrix, where x_{ij} is an element of the matrix. To simplify notation the i and j indices will be dropped. Thus, the arithmetic mean may be expressed as:

$$\overline{x} = \sum_{k = 1}^{L} xk/L \qquad (1b)$$

Zero values were counted when appropriate and the value L reported for comparison of results. As L increases without bound, the value of the sample arithmetic mean, $\overline{x}$, approaches the true population mean, usually designated by μ.

Variance; Standard Deviation

Variance, denoted by s^2, is a measure of the dispersion of a variable about the sample mean. It is one way of measuring how closely the individual scores of a variable cluster about the mean. Mathematically, the variance is the average squared deviation from the mean. To minimize the use of computer time, the following equation was used in actual computations:

$$s^2 = [(\sum_{k = 1}^{L} x \quad k^2 - L x]/L - 1 \qquad (2)$$

The use of L-1 provides an unbiased estimate of the population variance.

In its role as a measure of dispersion, the variance plays an important part in many statistical tests and procedures, as for example, in the analysis of variance and in the determination of the number of replicates required to detect the "true" difference between the means of two samples. These methods of analysis will be discussed in subsequent paragraphs.

The standard deviation, s, is another measure of the dispersion about the mean of an interval scale measurement. The standard deviation was defined by:

$$s = (s^2)^{1/2} \qquad (3)$$

Range

The range of a variable is the absolute value of difference between its maximum, x_{max}, and minimum, x_{min}, values. It was computed from the formula:

$$x_R = x_{max} - x_{min} \tag{4}$$

The Range is also a measure of data dispersion.

Histograms

Histograms (bar diagrams) are graphical representations of the absolute or relative frequency of occurrence of a variable in each of several class intervals. The abscissa of such a graph represents the variable and is divided into several, usually equal, class intervals, whereas the ordinate represents the frequencies. The height of each bar represents the frequency of its class interval.

Histograms of demersal fish lengths were prepared in a nontraditional manner in order that one algorithm and graph size could be used for all species of fish. The demersal fish ranged in length from a few tens of millimeters for some species to a meter for other species.

The methods of histogram construction applied to demersal fish lengths calculated, for any species, both the mean length (equation 1) and the standard deviation (Equation 3). The interval ± 3s about the mean was divided into 30 class intervals. A histogram bar diagram was then plotted from these intervals. Finally, the actual tally in each class, and a separate scale that showed the class limits in mm, were provided on the graph (see for example Figure 269).

Analysis of Variance

One-way analysis of variance (1-way ANOVA) was performed to evaluate the equivalence of samples composed of several replicates, i.e., where the samples were drawn from the same population. The null hypothesis

Ho: $\mu_A = \mu_B = \mu_C = \mu_D$

was tested against the alternate hypothesis

Ha: At least one mean is significantly different from the others,

(where μ_A is the mean of the replicates comprising sample A) by applying SPSS program ONEWAY (Nie et al., 1975, Chapter 22). As the method is adequately described in available literature, it will not be discussed here.

Testing of Ho against Ha was performed by comparing the calculated F-ratio against the value tabulated in a two-tailed table of critical values of degrees of freedom (see Rohlf and Sokal, 1969; Table S and instructions on pp. 168-169). If the calculated F-ratio was greater than the tabulated

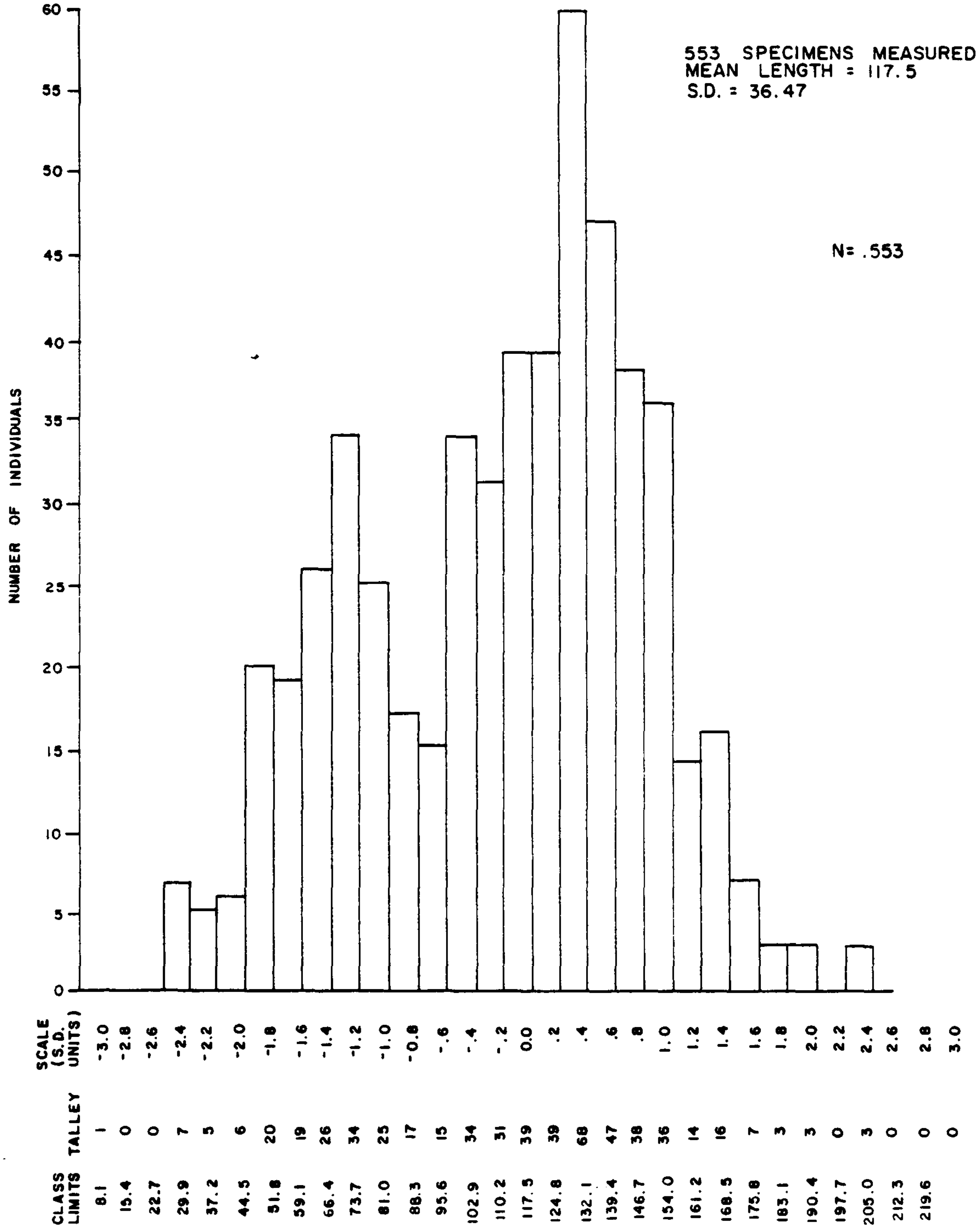


FIGURE 269

LENGTH FREQUENCY HISTOGRAM OF SYACIUM PAPILLOSUM

STATIONS POOLED, WINTER 1978

value, then Ho was rejected in favor of Ha, that is one of the sample means that was shown to be significantly different from the others.

In general, the test was applied only to pairs of samples in order to have a stronger test:

$$Ho: \mu_1 = \mu_2 \text{ against } Ha: \mu_1 \neq \mu_2$$

As suggested by Krumbein and Graybill (1965) the F-test was used in this latter case rather than the t-test.

ANOVA requires that the sampling of the individual replicates be random. Nonrandomness is usually reflected in lack of independence of the replicates, heterogeneity of variance, or nonnormal distribution of the replicate scores. Use of the program ONEWAY had the advantage that Bartlett's test for homogeniety of variances was performed (Sokal and Rohlf, 1969). The input data was also examined for highly skewed distributions. If the distribution of the original data was highly skewed or if the variance was not stable, transformations were made to symmetrize the distribution and/or stablilize the variance (see Krumbein and Graybill, 1965). These transformations were performed with either the SPSS package or MMSP (scaling and transformation routines). The logarithm transformation

$$X^1 = \log_{10} (X + 1) \qquad (5)$$

was found effective.

Required Number of Replicates

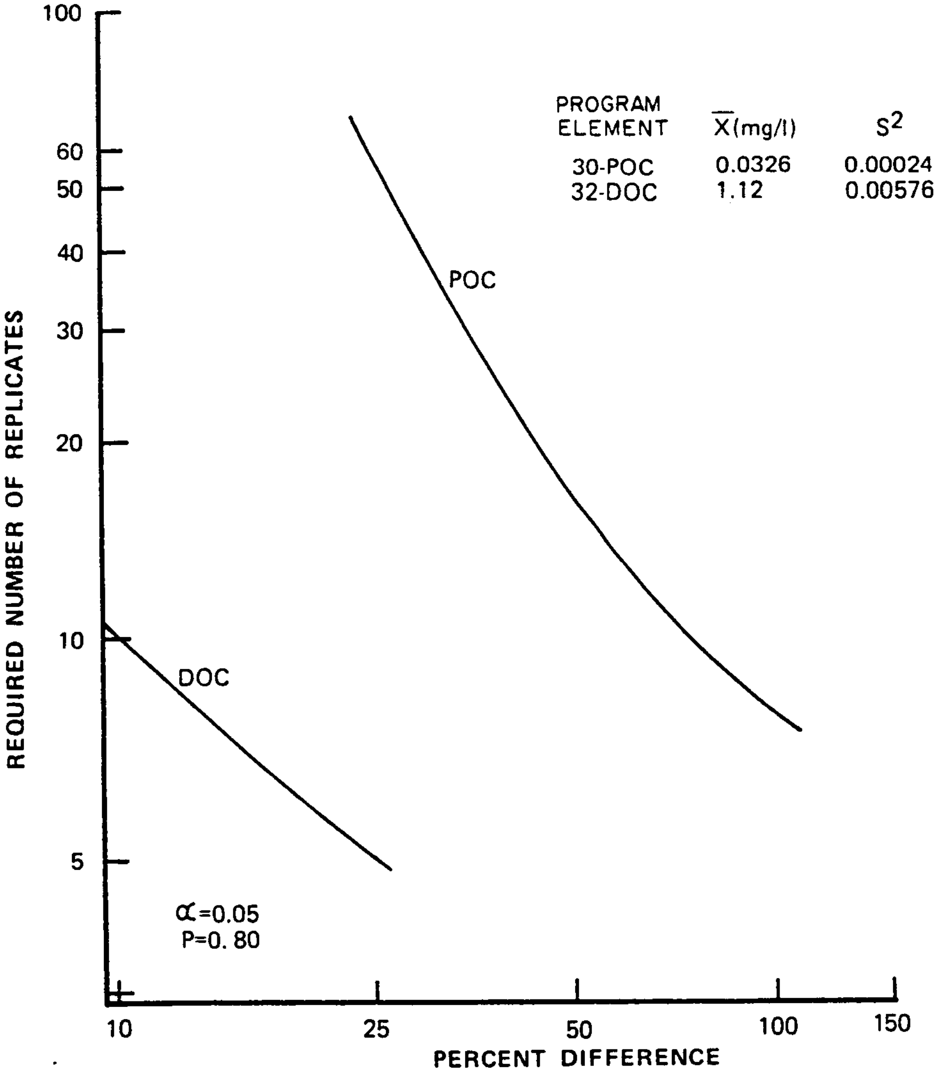
The number of replicates needed to detect a given "true" difference between sample means was calculated as described in Sokal and Rohlf (1969; Box 9.11, p. 247). The appropriate formula for this calculation is provided in that reference.

Results of these analyses were presented graphically, for example Figure 270. The curves for particulate organic carbon (POC) and dissolved organic carbon (DOC) were developed by applying this calculation to 200, 100, 50, 25, and 10 percent difference between the means of two samples.

Moment Measures

As reported in Chapter 2, the textural properties of the bottom sediment were assertained by means of grain size analysis. The first step in the grain size analyses performed under this contract was to determine the weight percent of sediment in each of eight phi (ϕ) size categories, where phi (ϕ) is defined by $\phi = -\log_2{}^{(d)}$, with d equal to the grain diameter in m.

Standard geologic practice requires that moment measures be calculated for each sample from the weight percent in each of the size (sieve and pipette) fractions. These calculations were performed with MMSP utilizing a program adapted from Pierce and Good (1966).



MINIMUM DETECTABLE DIFFERENCE (%)
BETWEEN TWO SAMPLES OF
POC/DOC

FIGURE 270

The most accurate method to obtain the moment measures, that is the mean size ($\bar{x}$), standard deviation (s, related to the coefficient of sorting), skewness (sk), and kurtosis (ku), for any series of grouped measurements is the method of moments. Geologists have often used the graphical approach. Our program, MEASURE, is based on the moment method. The statistical parameters s, sk, and ku are also known as the second, third and fourth moments of a distribution about its mean.

The weighted arithmetic mean, $\bar{x}$, or a series of related measurements was defined in MEASURE as

$$\bar{x} = \frac{1}{n} \sum_{i=1}^{k} f(x_i)x_i, \text{ in } \emptyset \text{ scale units} \qquad (6)$$

where n is the total weight of samples; $f(x_i)$ is the weight percent of a single size class; x_i is the midpoint of the same size class in phi (Ø) scale units; and k is the total number of size classes. The sample standard deviation, s, taken as the square root of the sample variance, was defined by

$$s = [\frac{1}{n} \sum_{i=1}^{k} f(x_i)\ (x_i - \bar{x})^2]^{1/2}, \text{ in } \emptyset \text{ scale units} \qquad (7)$$

Skewness and kurtosis are associated with the third and fourth moments about the mean, but have been defined by different authors in several ways. For the purposes of the MEASURE program, skewness, sk, was defined as

$$sk = \frac{1}{2n} \sum_{i=1}^{k} \frac{f(x_i\ (x_i - \bar{x})^3}{s^3} \qquad (8)$$

and kurtosis, ku, defined as

$$ku = \frac{1}{2} \sum_{i=1}^{k} \frac{f(x_i)\ (x_i - \bar{x})^4}{ns^4} - 3 \qquad (9)$$

The phi size class intervals and class midpoints (x_i) utilized by the MEASURE program are reported in Table 124.

In addition to presenting $\bar{x}$, s, sk, and ku, the weight percent of material in the sand fraction and the sand to fine ratio were also printed. The sand fraction includes grains with diameters of -1 to 4 Ø, whereas, the fine fraction includes all material > 4 Ø.

Regression Analysis

Linear regression analysis was performed (BMD program DMOIR for example) to examine the correlation between two variables and to establish a linear predictive relationship of the form

$$y = mx + b \qquad (10)$$

TABLE 124

GRAIN SIZE ANALYSIS - PHI SIZE CLASS INTERVALS AND MIDPOINTS

PHI SIZE CLASS (Ø)	MIDPOINT (Ø)	DESCRIPTION TEXTURAL
< -1	-2.0	Gravel
-1 to 0	-0.5	Very Coarse Sand
0 to 1	0.5	Coarse Sand
1 to 2	1.5	Medium Sand
2 to 3	2.5	Fine Sand
3 to 4	3.5	Very Fine Sand
> 4	7.0	Silt and Clay Sizes
4 to 8	6.0	Silt
> 8	9.0	Clay Size

In the above equation y is the dependent variable, x the independent variable, m the slope of the line and b the y-intercept. The correlation between the independent and dependent variables was given by the correlation coefficient, R. Strong correlations were evidenced by R^2 values above 0.75, implying equation 10 accounted for 75 percent of the variability in the data.

Diversity

MMSP program DIVERS was used to calculate several species diversity and evenness indices. These indices were distributed to Management and taxonomic Principal Investigators as tools for assessing environmental quality.

In its most simplistic interpretation, the concept of diversity pertains to the distribution of individuals among species. Arithmetically, it is the relationship of the number of species in a sampled habitat to the total number of individuals per species. The program DIVERS calculated this relationship as the eight indices defined below:

1. Relative Variety, S/N (11)

2. Species Richness (Margalef, 1968) (12)

   $D = (S - L)/\ln(N)$

3. Number of Moves (Fager, 1972) (13)

   $M' = 2M/(N - S)\ (S - 1)$; and

   $M = [N(S+1)/2] - R_i N_i$

4. Shannon-Weiner (Pielou, 1966) (14)

   $H = - \Sigma p_i \ln(p_i)$

5. Scaled Shannon-Weiner (Fager, 1972) (15)

   $H^1 = \frac{H - A}{\ln^S - A}$

   When $A = \ln N - \frac{(N-S+1)}{N} \ln(N-S+1)$

6. 1 - Simpsons' Index (Fager, 1972) (16)

$$\frac{-S\ [\Sigma n_i\ (n_i - 1)]\ (N - 1)}{N/(S - 1)\ (N(N - 1)}$$

7. Standard Deviation (Fager, 1972) (17)

$$SD = \left[\frac{\sum_{i=1}^{S} n_i^2 - N^2}{S(S-1)} \right]^{1/2}$$

8. Evenness Factor (Pielou, 1966) (18)

$$J = H^1/\ln_s$$

In the above equations, N is the number of individuals given by $N = n_i$, where n_i is the number of individuals in the i-th species; S is the number of species; R_i is the rank of the i-th species, the most abundant species being assigned a rank of 1; and P_i is given by $P_i = n_i/N$.

Outliers

Outliers, those replicates whose values depart markedly from the sample mean, were detected in accordance with the procedure presented in Dixon and Massey (1957; see in particular Table A-8a). Although this procedure strictly applies to univariate data, it was adopted to multivariate data through the application of ordination techniques. These techniques reduce the dimensionality of the sample space (n-dimensional, as n-variables describe each replicate in the sample) in such a manner that one dimension accounts for most of the variability in the data. The coordinate of the replicates along this major axis were then used as the replicate scores (Davis, 1973) and the procedure of Dixon and Massey (1957) applied. Ordination techniques and their use in outlier identification will be discussed more rigorously in the section which follows.

Multivariate Statistical Analysis

Introduction

As discussed above, both diversity and outlier detection are closely related to multivariate statistical analyses. In the case of diversity, the species variables were summarized into a single diversity or evenness index. Outlier detection was shown applicable to multivariate data, where the n-variables could be transformed into a single variable.

The truly multivariate statistical analyses performed during this benchmark study can be divided into four categories.

1. Classification
   - a. Cluster analysis (CLUSTWP);
2. Ordination
   - a. Principal Components analysis (PCA);
   - b. Wisconsin ordination (ORDER); and

   c. Canonical analysis (SDISFA);

3. Testing

   a. Stepwise Discriminant Function Analysis (SDISFA); and

4. Predicting

   a. Multiple regression analysis, single step (RMULT) and stepwise (SMULTR);

   b. Trend surface analysis (TREND)

An input matrix, as described in the section Data Matrices and generalized in Table 123, was used for all of the multivariate techniques listed above. Input data were transformed and/or scaled when required prior to the formation of the input matrix. Input and the details of each multivariate technique will be described in the following subsections.

Transformation and Scaling

Generally, the use of the data transformation and scaling routines was avoided. These two preprocessing data manipulations were avoided as they make it difficult to mentally visualize subsequent data processing procedures. However, transformation and/or scaling of input data were performed when it was necessary (a) to meet assumptions about the data for such programs as RMULT, SMULTR, and SDISFA; or (b) to remove the bias that would otherwise be introduced by one or more variables. An example of this latter point comes from the meiofauna data. Here the counts for nematodes were several orders of magnitude greater than the counts for the other species variables. The square root transformation was applied to reduce the nematode dominance. Binary transformation was applied to meristic data to reformat it as present-absent data.

Transformation

Three transformation routines were used on an as needed basis:

1. Logarithmic (LOG)

   $$x'_{ij} = \log^{10} (x_{ij} + 1) \qquad (19)$$

   where x_{ij} is the matrix element represented by row (variable) i and column (sample) j.

2. Square root (SQRT)

   $$x'_{ij} = (x_{ij} + 1)^{1/2} \qquad (20)$$

3. Binary

$$x'_{ij} = \begin{matrix} 1, \text{ if } x_{ij} \geq 1 \\ 0, \text{ if } x_{ij} = o \end{matrix} \quad (21)$$

Scaling

Three scaling routines were used on an as needed basis:

1. Normalization (NORM)

$$x'_{ij} = x_{ij}/x_{max_i} \quad (22)$$

2. Ranging (RANGIN)

$$x'_{ij} = (x_{ij} - x_{max_i})/(x_{max_i} - x_{min_i}) \quad (23)$$

3. Standardization, also known as Z-transformation (STAND)

$$x'_{ij} = (x_{ij} - \overline{x}_i)/S_i \quad (24)$$

where $\overline{x}_i$ and S_i are the mean and standard deviation for variable i, respectively

The routine NORM forced the variables to range between 1.0 and x_{min}/x_{max}. RANGIN forced the variables to range between 1.0 and 0.0, whereas STAND scaled the data so that each variable had a mean of 0.0 and a standard deviation of 1.0.

Coefficients of Resemblance (Similarity)

The pairwise resemblance or similarity among the variables (R-mode) and among the samples (Q-mode) was measured by one of four similarity coefficients, namely:

1. Taxonomic distance;
2. Bray-Curtis coefficient;
3. Jacard coefficient; and
4. Multiple product moment correlation coefficient.

Taxonomic Distance

The taxonomic distance coefficient (d_{jk}) is often used for comparing samples that are highly dissimilar. It is designated in MMSP as TDIST and defined in Q-mode by

$$d_{jk} = (\Delta^2{}_{jk}/n)^{1/2} \quad (25)$$

Where Δ_{jk} is the euclidean distance between samples j and k, and n is the number of variables. The euclidean distance is given by

$$\Delta_{jk} = \left[\sum_{i=1}^{n} (x_{ij} - x_{ik})^2 \right]^{1/2} \qquad (26)$$

In accordance with the recommendation of R.R. Sokal (personal communication) the variables were normalized with the routine NORM or RANGIN prior to the calculation of the taxonomic distance.

Bray-Curtis Coefficient

The Bray-Curtis coefficient (Bray and Curtis, 1957) is an association index of resemblance rather than a distance coefficient. It can be derived from Sorensen's coefficient (1948) by replacing present-absent scores with actual variable scores; thus:

$$(S_{BC})_{JK} = \frac{2(\sum_{i=1}^{n} \text{Min}(X_{ij}, X_{ik})}{\sum_{i=1}^{n} X_{ij} + \sum_{i=1}^{n} X_{ik}} \qquad (27)$$

where X is evaluated for the i-th variable in the j-th and k-th samples, respectively. This coefficient has been shown to be a robust tool for comparing samples in paleoecologic studies (Park, 1968), paraecologic studies (Park and Feldhausen, 1969; Gervirtz, et al., 1971), in sedimentologic studies (Feldhausen, 1970; Feldhausen and Ali, 1975 and 1976) and in epifauna baseline studies (Feldhausen, 1977).

Jacard Coefficient

The Jacard coefficient is also an association index of resemblance. It measures the resemblance between two objects over two-state (binary) data and is best defined for Q-mode application by use of a 2 x 2 frequency table.

		Sample j		
		1	0	
Sample k	1	a	b	a + b
	0	c	d	c + d
		a + c	b + c	

The values of a, b, c, and d in the above table are the sum of the matches that result by comparing sample j with sample k, variable by variable. If variable 1 is present in both j and k, then a "1" is scored in box "a". If variable 2 is present in j and not k, then a "1" is scored in box "c"; etc. Finally, the Jacard coefficient, J_{jk}, is computed from the formula

$$J_{jk} = a/(a + b + c)$$

where a, b, and c are the scores in the 2 x 2 frequency table that accumulated during the comparison of sample j and k over all variables i through n.

Jacard coefficient is particularly applicable in situations where the variable list contains many monoccurrences, (Erez and Gill, 1977).

Product Moment Correlation Coefficient

The product moment correlation coefficient was used in association with multiple linear regression programs RMULT and SMULTR. It is designated in MMSP as RCOEF and defined in Q-mode by

$$R_{jk} = \frac{\sum_{i=1}^{n} (X_{ij} - \bar{X}_j)(X_{ik} - \bar{X}_k)}{\left[\sum_{i=1}^{n} (X_{ij} - \bar{X}_j)^2 \sum_{i=1}^{n} (X_{ik} - \bar{X}_k)\right]^{1/2}} \tag{29}$$

The scaling routine STAND was usually employed in conjunction with RCOEF in order to reduce the heterogeneity of the column vectors (R.R. Sokal, personal communication).

Similarity Matrix

A similarity matrix was compiled from the pairwise comparisons made with one of the similarity coefficients described above. MMSP program SIMATX was used for this purpose. Output from SIMATX was used as input to CLUSTWP, ORDER, RMULT and SMULTR.

The method for generating a similarity matrix from input data is shown in Table 125. Part A of this table lists the input grain size data for summer 1976 (station means) and shows the calculation of a Bray-Curtis coefficient. (S_{BC}) jk for sample j equal to Station 2640 and sample k equal to Station 2641. The Bray-Curtis similarity matrix is shown in the upper half that the matrix depicted in Part B of Table 125. The corresponding dissimilarity matrix formed by subtracting each similarity element from 1.0 $(1.0 - S_{jk})$ is shown in the lower half.

Cluster Analysis

As used herein, cluster analysis is a classification technique which performs pairwise comparisons of vaiables (R-mode) or samples (Q-mode). It aggregates the objects by their decreasing similarity to form a hierarchical arrangement displayed as a dendrogram (Sokal and Sneath, 1963; Parks, 1966; Howarth and Murray, 1968; Warwick and Davies, 1977) Figure 271. "Natural breaks" in similarity levels allow the Principal Investigator to define groups at any desired similarity. In this manner he obtains a hierarchical classification that is both objective and unambiguous. As noted by Davis

TABLE 125

EXAMPLE DATA AND SIMILARITY MATRICES

A. DATA MATRIX: -

Bottom Sediment Grain Size Data, S76 Station Means

Weight Percent By Phi Size Class

STATION*	< - 1	-1 - 0	0 - 1	1 - 2	2 - 3	3 - 4	> 4
2640	7.50	6.29	6.19	20.16	48.37	6.11	5.38
2641	.59	.54	.98	8.34	70.38	12.88	6.30
2642	1.42	1.00	1.22	30.66	62.28	1.06	2.29
2643	7.53	12.14	14.39	41.70	10.95	1.43	11.84
2644	6.40	24.58	39.93	22.90	1.93	.19	4.08
2645	11.67	27.30	29.10	14.61	2.18	.76	14.37
2746	.86	2.74	4.53	17.78	23.89	15.84	34.36
2748	3.95	26.13	38.12	20.14	3.83	1.10	6.74
2852	15.45	8.43	20.98	35.03	12.80	2.66	4.64
2862	1.31	2.22	8.49	44.71	24.13	6.40	12.73

Bray-Curtis Coefficient - Example Calculation

IF 2640 = Sample j and 2641 = Sample k, THEN

$$(S_{BC})_{jk} = \frac{2(.59 + .54 + .98 + 8.34 + 48.37 + 6.11 + 5.38)}{100.00 + 100.01}$$

$$= 0.7031$$

---

*The matrix is shown as Q-mode card images; see Figure 268c.

TABLE 125 (Continued)

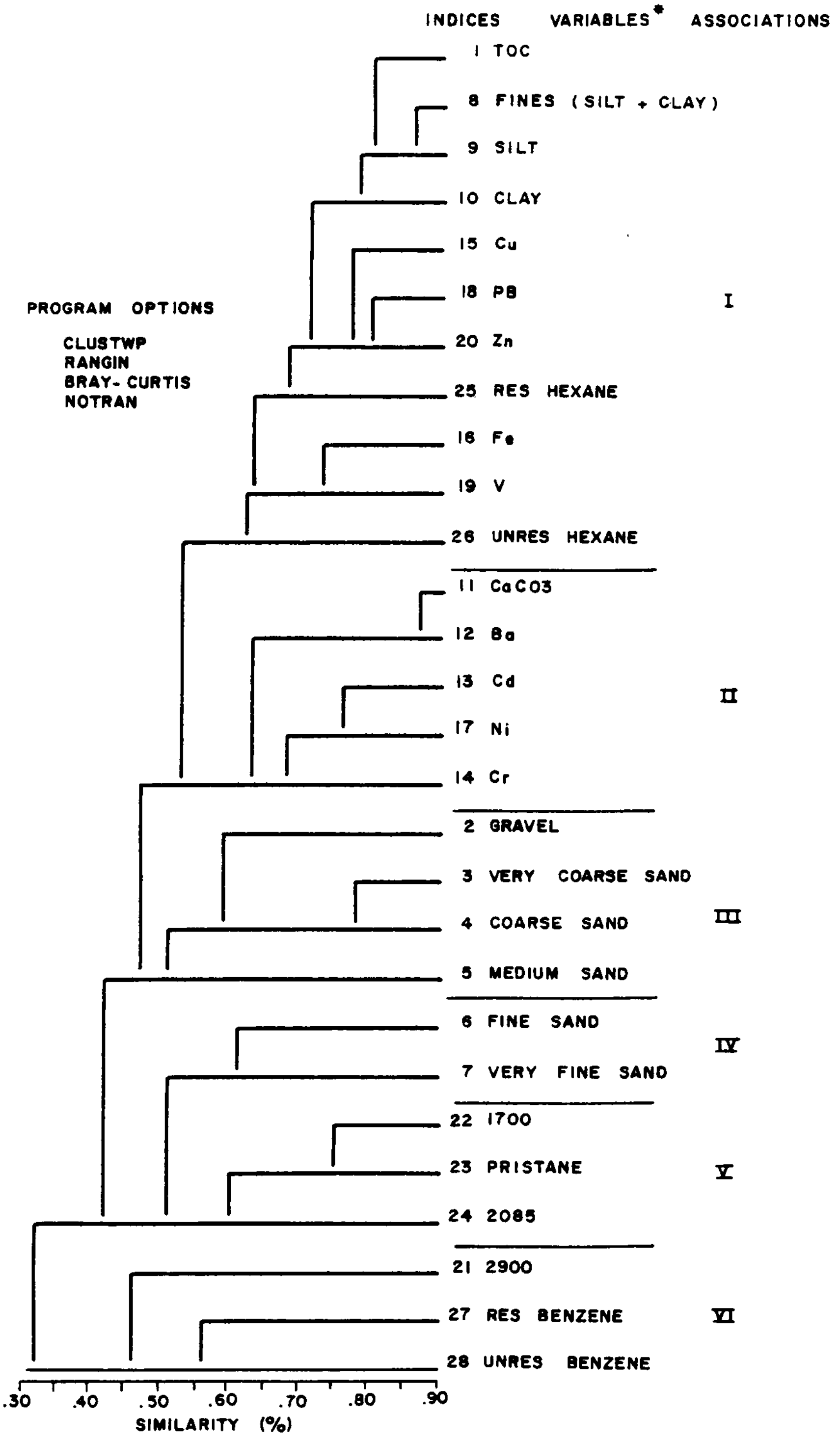
EXAMPLE DATA AND SIMILARITY MATRICES

B. SIMILARITY MATRIX: -

Based on Data Matrix, Part B and Bray-Curtis Coefficient

Index	1	2	3	4	5	6	7	8	9	10
STATION	2640	2641	2642	2643	2644	2645	2746	2748	2852	2862
1 2640	01 ^{1}	.703	.756	.579	.452	.429	.613	.469	.602	.655
2 2641	.297	0 ^{1}	.761	.291	.166	.197	.535	.217	.306	.473
3 2642	.244	.239	0 ^{1}	.487	.310	.235	.481	.310	.505	.617
4 2643	.421	.709	.513	0 ^{1}	.620	.635	.501	.623	.824	.780
5 2644	.548	.834	.690	.380	0 ^{1}	.809	.321	.930	.649	.411
6 2645	.571	.803	.765	.365	.191	0 ^{1}	.401	.835	.633	.423
7 2646	.387	.465	.519	.499	.679	.599	0 ^{1}	.376	.460	.684
8 2748	.531	.783	.690	.377	.070	.165	.624	0 ^{1}	.631	.438
9 2852	.398	.694	.495	.176	.351	.367	.540	.369	0 ^{1}	.672
10 2862	.345	.527	.383	.220	.589	.577	.684	.562	.328	0 ^{1}

$1 - S_{BC}$



*PARTIALLY DIGESTED BOTTOM SEDIMENT TM RESULTS USED; 1700, 2085, 2900 REFER TO CONCENTRATIONS FOR THOSE KOVAT INDICES

FIGURE 271

R-MODE DENDOGRAM SHOWING ASSOCIATION OF BOTTOM SEDIMENT TEXTURAL, HMW-HC, TOC, AND TRACE METAL VARIABLES
1976-1978 DATA

(1973) this method of classification follows the operational procedure intuitively employed by many taxonomists. It seems preferable to other methods of classification which assign arbitrary class boundaries, such as the sand, silt, clay classifications of Folk (1954) or Shepard (1954), in that cluster classes usually have higher within group homogeniety. Cluster analysis was used in this program as a tool to aid the Principal Investigator sharpen his perception of variable associations (R-mode) or environmental classes (Q-mode). Class boundaries were always subject to redefinition during the interpretative phase of synthesis-analysis performed by the Principal Investigator.

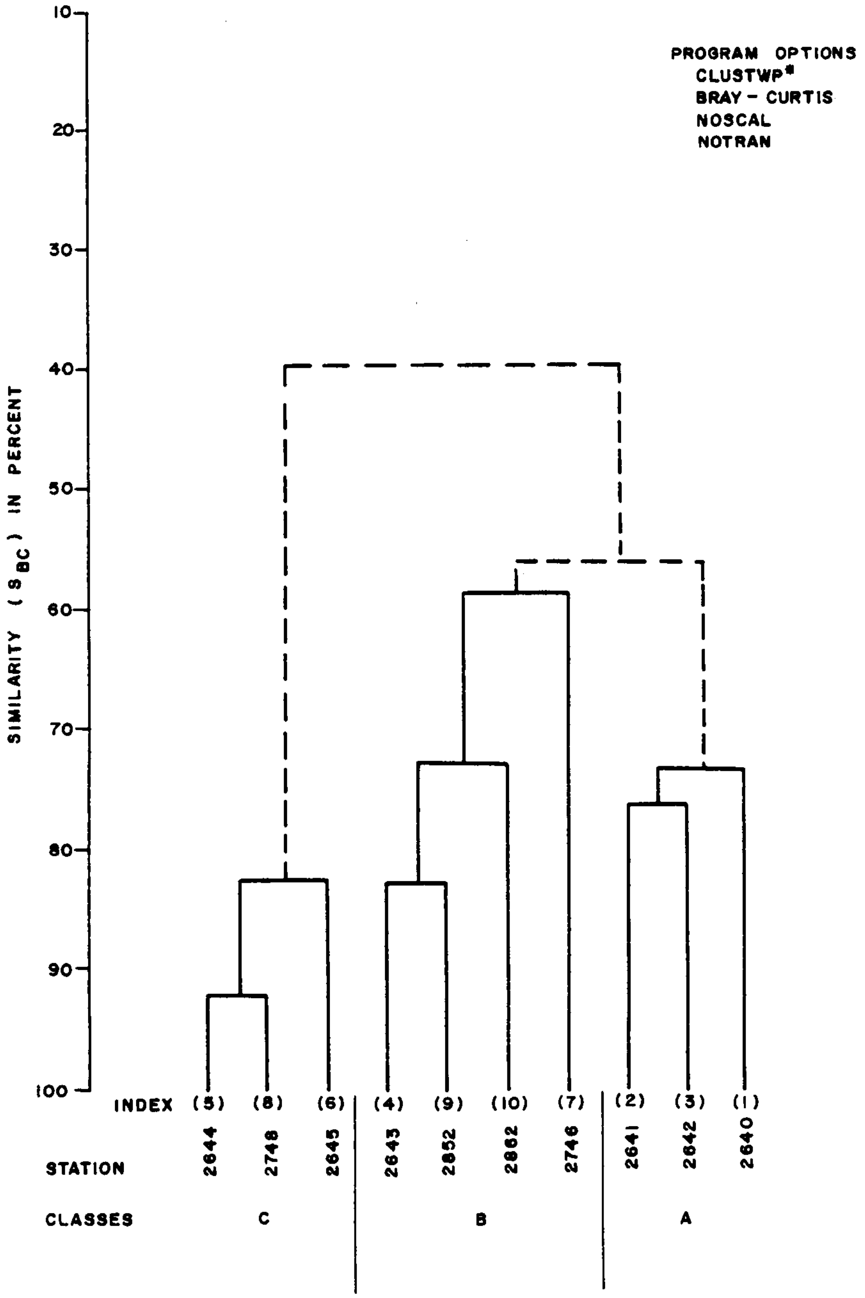
Economy of memory was achieved by using cluster analysis instead of optimal classification techniques that require enumeration of all possible classifications. Storage requirements of these latter techniques is given by Sterlings Number of the Second Kind (Feldhausen, 1978) and hence increases astronomically as the number of objects and possible classes increases slowly.

Cluster analysis was performed to organize unstructured data and to gain insight in the "natural laws" derived from the structure. Variable associations and sample classifications result from structuring the data. This implies a quasi-predictive model can be developed, if the data base has been collected for a sufficient length of time and sampling was performed frequently enough to define the species (or variable) list and to estimate the variability in the system.

The MAFLA 1974-1978 data base for demersal fish and for bottom sediment grain size parameters appears to meet the above specifications. In the case of demersal fish, the three principal clusters (Chapter 9, Volume II) which represent shallow, intermediate, and deep water environments may be sufficiently well defined that significant pertubations to the environment would be detected by a shift of a station to another cluster. For those stations that exhibited grain size stability over the four years of monitoring (see Chapter 2, Volume II), cluster analysis may be considered as a quasi-predictive model.

Many of the other data categories were subjected to R-Mode cluster analysis in order (a) to define species (or variables) associations; and (b) to identify redundant variables likely to bias further analysis performed in Q-mode (Sneath and Sokal, 1973; Section 3.7). Figure 272 is an example of a dendrogram resulting from R-mode cluster analysis performed on sediment grain size, total organic carbon (TOC), HMW-HC and partially digested trace metal data (S76 - W78). Inspection of the dendrogram indicates that none of the variables are correlated at higher than about 88%; thus none appear to be fully redundant. The dendrogram was also used to define six variable associations. A cutoff of about 55% similarity was used. Consequently, the variables within each of the associations were clustered at similarity levels of 55% or more.

Q-mode cluster analysis of the data set shown in Table 125 was performed to partition the samples into environmentally significant classes. The resulting dendrogram is graphed in Figure 273. Two very broadly defined classes were formed at about 40% similarity. However, three distinct



*EXAMPLE CALCULATIONS FOR SOLID LINES ARE SHOWN IN TABLE 24-6

FIGURE 272

Q - MODE DENDOGRAM OF 10 BOTTOM SEDIMENT SAMPLES

SUMMER 1976 STATION MEANS; SEE TABLE 24-5

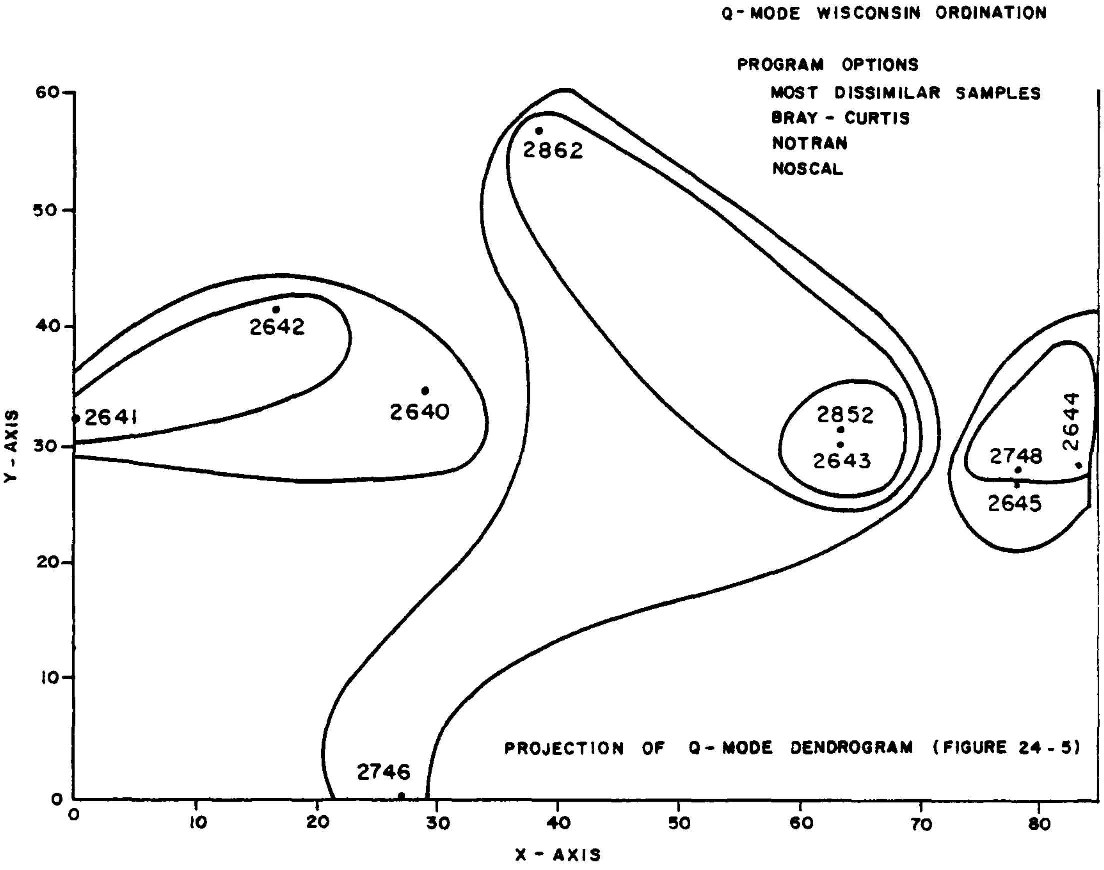


FIGURE 273

Q-MODE ORDINATION OF 10 BOTTOM SEDIMENT SAMPLES

SUMMER 1976 STATION MEANS; SEE TABLE 24-5 classes (A, B, and C) were obtained by considering a similarity level of about 57%.

In addition to examining the spatial distribution of the clusters, the method was extended to the temporal scale. This was achieved by entering as separate items to be clustered, samples collected at the same station during different sampling periods. When feasible, data from S74-W78 were included in the data matrix.

Cluster analysis was performed with MMSP program CLUSTWP. The method of clustering is known as sequential, agglomerative, hierarchic, nonoverlapping clustering with average linkage (Sneath and Sokal, 1973). the "WP" of CLUSTWP means that weighted pair averaging was employed. The essential features of this technique, as directed by Davis (1973), are as follows:

1. A coefficient of resemblance is first used to generate a similarity matrix (see Table 125);

2. The highest mutually similar objects are clustered (or linked) together first (note the circles entries of Table 125 and the corresponding calculations presented in Table 126);

3. Two objects can be connected only if they have mutually highest "correlations" with each other; and

4. After two objects are clustered, their correlations with all other objects are subjected to weighted averaging.

Weighted averaging was performed in an attempt to give merging branches of the dendrogram equal weight regardless of the number of objects i each branch. Weighting for each cluster grouping was performed with the formula

$$U_{jk} = \sum_{jk} w_j \, w_k \, U_{jk}, \qquad (30)$$

where w_j and w_k are the weights and are given by $(1/2)^c$, c is the number of clustering steps for j or k as appropriate, and U_{jk} is the similarity value (for example, Bray-Curtis coefficient).

Table 126 is a work sheet which provides the initial steps performed in the clustering for the Q-mode dendrogram shown in Figure 271. The input data and similarity matrices are provided in Table 125.

Ordination

Goodall (1954) described ordination as any number of methods for ordering objects in a uni- or multidimensional continuum. In geology ordination has been used for obtaining information about the autecology of fossil species (Park, 1968) and for studying sedimentary depositional

TABLE 126

EXAMPLE WORKSHEET FOR PREFORMING CLUSTWP

A. EQUATION FOR WEIGHTING:

$$u'_{j,k} = \sum_{jk} w_j \; w_k \; u_{jk}$$

$$w_{j,k} = \left(\frac{1}{2}\right)^{c_{j,k}}$$

B. INPUT DATA AND SIMILARITY MATRIX ARE PROVIDED IN TABLE 125

C.

INDICES CLUSTERED	CALCULATION
5 - 8	$w_j = (\frac{1}{2})^0 = 1$ $u' = 0.930$
(5 - 8) - 6	$\frac{1}{2}(0.809) + \frac{1}{2}(0.835) = 0.822$
4 - 9	$u' = 0.824$
(4 - 9) - 10	$\frac{1}{2}(0.780) + \frac{1}{2}(0.672) = 0.726$
[(4-9)-10 -7]	$\frac{1}{4}(0.501) + \frac{1}{4}(0.460) + \frac{1}{2}(0.684) = 0.582$
2 - 3	$u' = 0.761$
(2 - 3) - 1	$\frac{1}{2}(0.703) + \frac{1}{2}(0.756) = 0.730$

D. CLUSTWP RESULTS ARE GRAPHED IN FIGURE 271 environments (Davis, 1970; Feldhausen, 1970). It has also been used successfully in epifaunal baseline environmental studies (Feldhausen, 1977).

Q-mode ordinations were constructed by three different methods, namely;

1. Principal components analysis (PCA);
2. Canonical analysis (SDISFAC); and
3. Wisconsin ordination (ORDER).

In general, these methods of ordination may be visualized as a semi-rigid new orientation where the variance about each axis is minimized. One of these new axes (usually designated the x-axis) accounts for the maximum possible variance in the system (depending somewhat on the method used). Each remaining axis (y, z, etc.) accounts for decreasing amounts of the remaining variance. The result of this process is a spatial distribution of the samples in a multidimensional field such that the proximity of one sample to any other sample is directly proportional to their dissimilarity. Thus, close neighbors are highly similar. If the first two axes account for about 75% of the variability, then the dimensionality of the sample space can be reduced from n-dimensions to two. In this case, the x-axis coordinate of each sample may be considered a new and optimum descriptor of the sample (Davis, 1970; Feldhausen and Ali, 1974).

PCA and canonical analysis methods are abased on variance-covariance matrix (Reyment and Ramden, 1970; Davis, 1973) In the n-dimensional case, the elements of this matrix plot on the surface of n-dimensional ellipsoid; in the two-dimensional case, they form an ellipse. The major axis of the ellipse is associated with the principal or x-axis after rotation to its new position. The direction of the major axis of the ellipse is the principal eigenvector and the length of axis is its eigenvalue. The minor elliptical axis is orthogonal to the major axis and is related to the second principal or y-axis after rotation. Finally, the ordination is constructed by multiplying the original data by the eigenvectors.

MMSP performed principal components analysis with a program adopted from Wahlstedt and Davis (1968). Canonical analysis was performed as part of the SDISFA program, which was modified from BMD program BMD07M (Dixon, 1973). Canonical analysis ordinations were often used in synthesis-analysis because of their feature of plotting the sample centroid together with the distribution of the replicates about the centroid.

The Wisconsin ordination method (Bray and Curtis, 1957; Beals, 1960; Goff and Cottam, 1967) is performed by extracting endpoints from a dissimilarity matrix (for example, Table 125). They serve as endpoints to an x-axis, and the remainder of the samples are arrayed along this axis in accordance with their dissimilarity with the endpoints. Usually, two or three axes extracted in this manner will account for most of the variability in the data set. The Wisconsin ordination method is preferred to principal components analysis and canonical analysis, as these latter methods usually introduce distortion in the presentation of the data (Feldhausen, 1978).

Figure 273 was constructed from the data and dissimilarity matrices presented in Table 125. It is a Wisconsin ordination based on the most dissimilar samples criterion for selecting endpoints. The x-axis accounts for about 72% of the variability in the data set, and the y-axis for another 15%. Thus, the dispersion of samples in the x-direction is nearly five times as important as in the y-direction. The clustering shown in Figure 272 has been "projected" onto the ordination in order to show the relationship between the two methods of analysis. Class boundaries may be assessed in this manner.

As with cluster analysis, the ordination techniques were used to evaluate the spatial and temporal association of samples within the reduced sample space. Ordination was particularly useful in assessing within station (transect) and between station (transect) sediment grain size and sediment trace metal variability for single and multiple sampling periods. Canonical plots developed from SDISFA were frequently used for this purpose as they presented the station centroid and the distribution of replicates about it. In the case of sediment grain size data, the reduction is dimensionality from eight to two-dimensions was achieved with the result that two axes accounted for more than 80% of the variability. Within station variability was evidenced by the spread of the replicates about the station centroid. As all plots for an analysis were prepared to the same scale, it was then possible to make similar comparisons to assess between station and between transect variability. By looking at the distribution of centroid and replicates for a single station sampled over several sampling periods, it was further possible to detect small changes in bottom sediment textural properties as a function of time. This may be seen by examining Figures 18 and 20 in the Geology section of Volume I of this report. Figure 20 shows that major textural changes between sampling periods were apparent.

Canonical analysis plots were also used in outlier detection analysis (see section Univariate Statistical Analysis above). The x-axis coordinates of these plots were used in the procedure presented in Dixon and Massey (1957), as the coordinates are the best single descriptor of the multivariate data (Davis, 1970). The plotting of all replicates about the sample (station) centroid aided in the selection of candidate outlier replicates.

In many problems the nature of the ordination can be deduced by examination of variable or known environmental parameters with respect to sample position within the ordination. This was achieved by the application of gradient analysis techiques.

Gradient and Trend Surface Analyses

Gradient analysis has been practiced for many years by plant ecologists. Goff and Cottam (1967) discuss ordination as a quantitative tool for studying species gradients and for developing synthetic indices (also see Goff and Zedler, 1968; Davis, 1970; Feldhausen and Ali, 1974).

In this study ordinations were performed to examine the gradational relationships among samples to develop synthetic indices (1) for outlier analysis; and (b) for correlation with environmental parameters. Item (b) was particularly useful in assessing the behavior of bottom sediment trace metal data in relation to environmental parameters such as depth of water, sediment textural properties and calcium carbonate concentrations. The assessment was quantified by fitting trend surfaces of sample variable scores and scores for environmental parameters to sample locations within the ordination x-y plane. By comparing several trend surfaces the environmental significance of the ordination, and hence the conditions affecting the distribution of the trace metal samples in the natural environment, became apparent. Figure 274 illustrates this process and will be discussed after trend surface analysis has been defined.

Trend surfaces (Merriam and Harbaugh, 1964; Feldhausen and Ali, 1976, and in preparation) are mathematical surfaced fitted to two-dimensional data in much the same manner as a straight line may be fit to x, y data by the method of least squares. In their simplist form, trend surfaces are planes defined by the polynomial

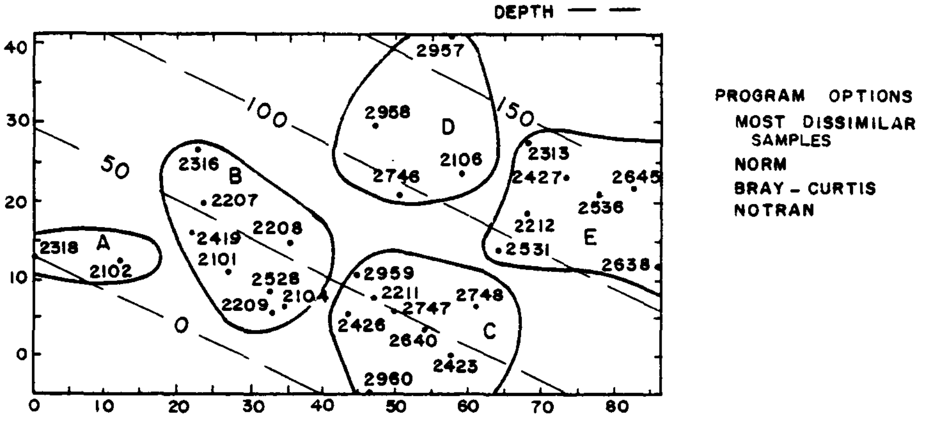
$$Z(x,y) = A_o + A_1 x + A_2 y$$

and hence are termed first degree surfaces. They are represented in two-dimensional plots by contours of Z(x,y) which are equally spaced, straight, parallel lines. Higher degree surfaces are curved and may be defined by higher order polynomials.

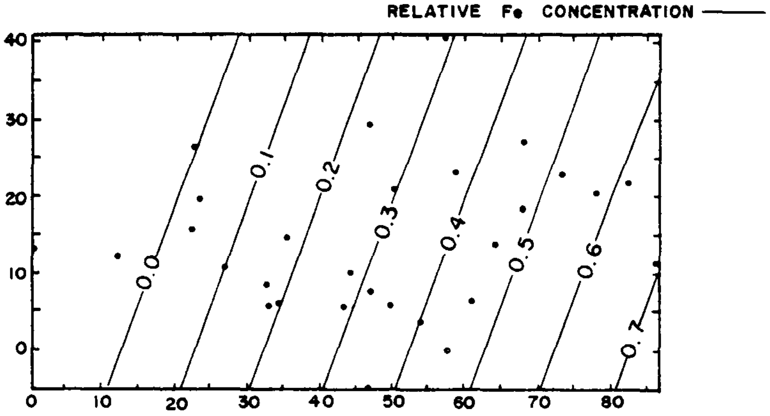
Trend surfaces were computed with MMSP program TREND, or for first order surfaces, it was often more convenient to employ RMULT or SMULTR. In either case goodness of fit (correlation of Z and x and y) criteria were also computed. These MMSP programs were adopted from Davis (1973) and Dixon (1973; DMDO1R and DMDO2R), and their computational methods will not be discussed here. It should be noted that RMULT and SMULTR were also used to develop correlations between a dependent and several independent environmental parameters, not just ordination coordinates. Both programs required input from SIMATX using the RCOEF routine. To meet the requirement of homogeneous column vectors, when applying RCOEF, the input data were scaled using STAND.

The ordination of partially digested bottom sediment trace metal values graphed in Figure 274 was constructed by the Wisconsin ordination method. The data (grand means at primary stations) were first normalized to remove the dominating effect of iron. Barium was deleted from the variable list, because its lack of appreciable variation in the data set biased the results (Sneath and Sokal, 1973; Section 3.7). The Bray-Curtis coefficient was used to compute the input dissimilarity matrix.

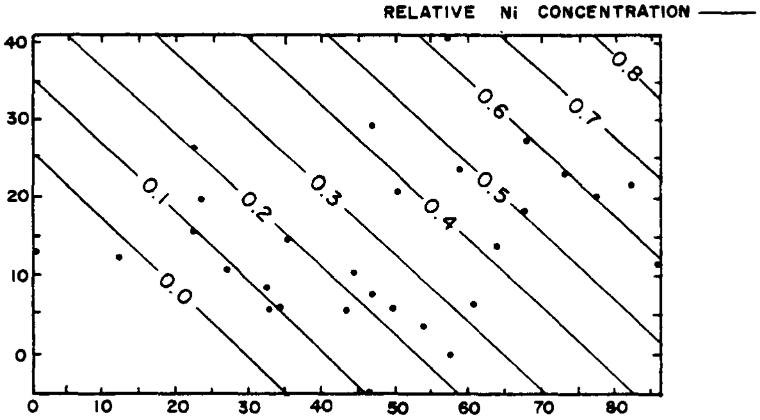
Figure 274a shows the distribution of the samples and their grouping into five environmentally significant classes. The first order trend surface for depth of water has been superimposed on this plot. Figures 274b and c show similar trend surfaces for the relative concentrations of iron (Fe) and nickel (Ni), respectively. Contours for nickel closely follow those for water depth, whereas the contours for iron do not. In the fact the contour lines for iron and nickel are almost orthogonal. This suggests that these two metals respond differently to environmental processes that are related to water depth; a point discussed further by Dr. Trefry in his work element report in this volume (Chapter 3).



A. ORDINATION WITH SAMPLE CLASSIFICATION AND FIRST ORDER TREND SURFACE OF WATER DEPTH (m), $R^2 = 0.64$



B. ORDINATION WITH FIRST ORDER TREND SURFACE OF RELATIVE Fe CONCENTRATION, $R^2 = 0.74$



C. ORDINATION WITH FIRST ORDER TREND SURFACE OF RELATIVE Ni CONCENTRATION, $R^2 = 0.76$

FIGURE 274

Q - MODE ORDINATION OF PRIMARY STATION PARTIALLY DIGESTED BOTTOM SEDIMENT TRACE METAL DATA SUMMER 1976 - WINTER 1978

Discriminant Analyses

Discriminant analysis (Klovan and Billings, 1967; Harbaugh and Merriam, 1968; Davies and Ethridge, 1975; Feldhausen, 1977) enable the principal investigator to evaluate the statistical significance of a classification and to derive an objective function for identifying samples of unknown affinity. In essence, discriminant analysis weighted the variables in order to achieve the maximum separation among points in previously defined groups of samples. These weightings were then used to generate linear equations that were used to calculate an approiximate F-ratio. This F-ratio, calculated from the multivariate data, was used to test whether or not the input classes were "drawn" from the same population. Because the analyses were performed in a stepwise manner (MMSP program SDISFA) the output also ranked the variables in order of their ability to discriminate between the input classes.

Discriminant analysis was primarily used to assess the variability in bottom sediment textural data at each station, between stations as well as along and between transects. This was accomplished by visual inspection of canonical ordination plots described above. In addition, the calculated F-ratios were used to test

Ho: Multivariate station means are not different
against
Ha: At least one multivariate station mean is different from at least one other.

This test, which is the multivariate extension of ANOVA discussed earlier, could be applied in a pairwise manner, one station agaist all the other stations. A two-tailed table of critical values of the F-distribution was used with appropriate degrees of freedom to compare tabulated and calculated values.

The F-ratio was calculated for each sample pair from:

1. Mahalanobis' distance $D^2{}_{jk}$, based on the discriminant function hyperplane;
2. Hotelling's T^2 test;
3. A transformation of Hotelling's T^2 into a multivariate F-ratio.

These procedures are adequately described in Morrison (1967; pp. 125-126), Davis (1973; pp. 430-456), and Dixon (1973; DMD07M) and will not be repeated here.

ANALYSIS PERFORMED

Table 127 is a summary of the analyses performed by Data Management during the synthesis-analysis phase of this program. The table is in the form of a present-absent matrix and as such associates analysis categories with each of the program elements (Table 122).

CONVERSION OF SUSIO DATA TAPE

INTRODUCTION

As discussed in the section on entry into data base above, the SUSIO data tape contained the data base files for the sampling periods S75 - W76, under SUSIO management, Contract AA550-CT7-30. The SUSIO Data Tape and tape listing were delivered to Management by COAR approximately six months after inception of this program, Contract AA550-CT7-34. However, at the time of delivery, the tape was incomplete and the data in a format incompitable with the ongoing data management system.

The purpose of the SUSIO Data Tape was to archive their scientific data. In relation to this program, it was to augment our data base in order that our final report would integrate and synthesize all MAFLA data, S74 - W78, in one comprehensive document. Applicable data representing S74 was encoded by the Dames & Moore data management group directly from SUSIO's final report for 1974 (SUSIO, 1974) to keypunch coding sheets. This was performed within the first two months of this program. However, authorization to obtain missing SUSIO Data Tape files and to reformat their data files into those of the present system was not received until March 6, 1978. Incorporation of the SUSIO Data Tape files into our data base was accomplished during the 18 week period between March 6 and July 10, 1978.

Incorporation of the SUSIO Data Tape files into the present system is the subject of the following paragraphs.

DIFFERENCES IN DATA BASE STRUCTURES

Important aspects of Dames & Moore's data management system are described in the sample numbering system and data base files sections of this report. Basically, the Dames & Moore system can be reduced to the following main points:

1. Each data entry was assigned a 13 digit sample number. When required, this data identifier was augmented by a 12 digit taxonomic ID number and a two digit specimen number.

2. The NODC Taxonomic Code was used as a guide in the assignment of ID numbers. The NODC numbering system served as a flexible system for sorting and retrieving data at any desired taxonomic level.

3. Taxonomic names were assigned to the data entries after transferring them from 80 columns punch cards to magnetic tape. Columns 81 through 175 of the tape were employed in the assignment of taxa and larval names to the data entries.

TABLE 127

ANALYSES PERFORMED

PROGRAM ELEMENT CODES	DESCRIPTION	STATION STATISTICS	SPECIES LISTINGS	NAME-TAXA ID LISTINGS	ABUNDANCE LISTING	HISTOGRAMS	1-WAY ANOVA	# REPS NEEDED	MEASURE	SINGLE & MULTIPLE REGRESSION	DIVERSITY	OUTLIER	R-MODE CLUSTER	Q-MODE CLUSTER	Q-MODE ORDINATION	GRADIENT-TREND ANALYSIS	DISCRIMINANT ANALYSIS	REMARKS
01	Bottom Grain Size & $CaCO_3$	X					X		X	X		X	X	X	X	X	X	Computer contour map of $CaCO_3$; special summary tables
03, 22	Clay Mineralogy	X																Semi-quantitative data
04,52,60	Foraminifera	X	X	X	X						X		X	X				
05,50	Meiofauna	X	X	X						X			X	X			X	
06	Macroinfauna Biomass	X																
07,09	Bottom Sediment Trace Metals	X								X	X	X	X		X	X		Cluster analysis was not an effective tool
08	Bottom Sediment HMW-HC	X				X		X		X		X	X		X	X		Special summary of 5 largest peaks; C.P.; Ratio; R-mode cluster with TM and grain size
10	Bottom Sediment TOC	X					X			X			X					Correlation with grain size; R-mode cluster with HMW-HC, grain size and TM
11	Bottom Sediment ATP	X																
14,39,16, 40	Macroepifauna & Demersal Fish Trace Metals	X						X			X	X			X	X		
15, 17	Macroepifauna & Demersal Fish HMW-HC	X				X		X			X	X	X	X				Special summary of 10 largest peaks; cluster analysis to relate location and feeding types of macroepifauna
18	Macroepifauna Taxonomy	X	X	X	X						X		X	X				
19	Demersal Fish Taxonomy	X	X	X		X					X		X	X				
20	Histopathology																	Qualitative data; no further analysis
23	Neuston Taxonomy	X	X	X		X									X			
24	Zooplankton Taxonomy	X	X	X														
25	Zooplankton HMW-HC	X																
26,41	Zooplankton Trace Metals	X					X											
28,31	Suspended & Dissolved HMW-HC	X						X										PI recommended no further analysis
29,42	Suspended Particulate TM																	PI performed all analysis at his request
30,32	Particulate & Dissolved Organic Carbon	X					X	X										
13,33 36,37 61,62	Temperature and Salinity Data																	Special data summaries and calculation of sigma-t
38	Light Intensity																	PI recommended no analysis by Data Management
55-59	Macroinfauna Taxonomy	X	X	X	X						X		X	X				Special data listings and R- & Q-mode cluster analysis performed for Management

The data base system employed by SUSIO was unlike that used for this program, in the following manner:

1. A unique sample identifier, which included information on station number, replicate-sampling method, program element, and date of sampling was not assigned by SUSIO to each data entry. Instead a four digit access number, termed the DMSAG sequence number was employed. Thus, there was no way to tie location, date of sampling or other important information to the data by inspection of the data. Instead, reference to a separate file was required. This cross-reference file tabulated DMSAG sequence numbers and the corresponding station number, position, depth, date and other pertinent sampling information; the cross file referencing proved to be non-unique in use.

2. The SUSIO data base was not organized by work element. Instead field and laboratory data were stored in files that were associated with individual PIs. For instance, there were three PIs that performed analysis of demersal fish taxonomy and meristics. Thus, three separate demersal fish taxonomy and three meristic data files were maintained by SUSIO; cross referencing could not be made between these files without reformatting.

3. Taxomonic information was entered by Latin name. The NODC Taxonomic Code was not used; frequent spelling and abbreviation inconsistencies led to mismatches between station or time comparisons.

4. Chemical analyses, biomass, and other measurement data associated with taxa were maintained in one set of PI specific files and the associated taxonomic names in another file. A numbering system was provided to connect the files, but this system was not universal and applied only to a single PI; failures to match led to loss of entire files of data.

Because the two data base systems were substantially different, considerable effort was required to reformat the SUSIO Data Tape files into our data base system.

REFORMATTING TAPE DATA

Methods

Data from the SUSIO Tape were converted to the Dames & Moore data base system in accordance with written instructions from the Data Manager, in much the same manner as data processing was accomplished (see above). Personnel assigned to the data management group performed the reformatting activities from Dames & Moore facilities in Los Angeles. IFM was the principal tool used to sort, merge, and otherwise restructure the SUSIO files and to change the prior data formats into those utilized for this program. In some instances it was necessary to perform minor calculations in order to obtain proper units and formats. This was achieved by writing small FORTRAN routines.

Problems Encountered

The following general problems were encountered during the reformatting of the SUSIO Data Tape files.

1. The 0100 series files, which served as the cross-referenced file for DMSAG sequence numbers and station number, position, depth, date, and other pertinent sampling information, were not included on the tape. Cards containing this information were received from SUSIO. However, a three week delay in initial reformatting efforts was encountered because of the delay in receiving those data. Also some positioning information for taped data was omitted from the 0100 series files.

2. Format descriptions contained in the final report for the S75 - W76 period of study (SUSIO, 1977) werr not always in agreement with the formats used in the tape. Occasionally, data were presented in two different formats within the same file. Internal codes, such as the sample codes used in the HMW-HC files, were not always defined. No format descriptions were available for XBT and STD water column data, nor were they for the macroepifauna taxonomic data. Alignment errors indicated a lack of thorough editing.

3. The XBT and STD data were assigned DMSAG sequence numbers and were without reference to station number; position information and an internal trace counter were provided.

4. Taxonomic files were often incomplete, so that a complete match could not be made with companion chemical analyses or other measurements, and extensive editing was required to correct spellings and abbreviations.

5. In one file the same data was entered twice.

6. Data had been modified from PI submitted raw data before entry so that back checking with raw data was not possible (no indication of how changes were made was provided).

7. The data were not proofed by PIs.

DATA INCORPORATED OR EXCLUDED

Data contained in the SUSIO Data Tape were in general incorporated into the comprehensive S74 - W78 data base if they were compatible with data generated under this program and if they were likely to be subjected to quantitative data processing. All rig monitoring and dive program data were excluded because there were no counterpart studies in the 1977/78 program.

The remainder of the data were evaluated on a file by file basis. Present Principal Investigators if different from the piror study group reviewed the work element reports for S75-W76 (SUSIO, 1976) in order to evaluate field, laboratory and analytic methodologies. When necessary, they discussed these methodologies with the original Principal Investigators. Data were included or excluded on the basis of their evaluations, and recommendations as to methodological compatibility.

HMW-HC data were reviewed by a special hydrocarbon committee headed by Dr. Lela Jeffrey. The two other members of this committee were Drs. Paul Boehm and Rudolf Bieri. It was their unanimous recommendation that none of the SUSIO hydrocarbon data be included in the comprehensive data base. However, ratios, such as the phytane to pristane ratio, were extracted from all but the macroepifauna HMW-HC file and distributed to the responsible Principal Investigators for their reference. These ratio data were utilized in their analysis of the HMW-HC characteristics of the MAFLA area. Hydrocarbon data for the macroepifauna were excluded because there was no information on tape, in the format descriptions, nor in the original HMW-HC analysis reports to permit identification of the taxa used in each analysis.

Table 128 lists those SUSIO Data Tape files incorporated into our data base as well as those that were excluded and the reason for exclusion.

ARCHIVING

The Dames & Moore Data Tape, containing the comprehensive summer 1974 through winter 1978 MAFLA computer data base has been transmitted to BLM as a separate deliverable. This tape was generated to the following specifications:

1. 7 track;
2. External BCD;
3. 800 bpi;
4. Even parity; and
5. Unlabeled and unblocked.

The tape and its contents are further described on NOAA Forms 24-13 and supplemental information appended to them.

Data base formats are discussed in the data base file section, and the actual formats are presented in Appendix A to this report. A special feature of the Dames & Moore Data Tape is the fact that these format descriptions have been entered as the first file on the tape. Thus, the detailed format descriptions are not likely to become separated from the data.

Shipboard station logs, cruise journals, inventory reports, and laboratory data keypunch coding sheets, as well as data listings have been identified, labeled and stored in the Dames & Moore program files.

TABLE 128

SUSIO DATA TAPE FILES INCLUDED IN - OR EXCLUDED FROM DAMES & MOORE DATA BASE

MAFLA ID	DESCRIPTION	FILE NO.	EXCLUDED	REMARKS
0100				
0101				
0103				
1014	Cruise Station & Misc	020		
203N	Neuston Trace Metal Data		X	Not performed in this program
203R	Suspended Particulate Refractory Trace Metal Data	415 (PE 29)		V excluded; not compatible
203W	Suspended Particulate Weak-Acid Trace Metal Data	410 (PE 29)		V excluded; not compatible
203Z	Zooplankton Trace Metal Data	510 (PE 26)		V excluded; not compatible
204M	Macroepifauna Trace Metal Data	210, 211 (PE 14)		V excluded; not compatible
204T	Macroepifauna Taxonomic Data for 204M	210, 211 (PE 14)		
205A	Mollusc Abundance Data	723 (PE 56)		
205B	Macroinfauna Biomass Data	733 (PE 06)		
206A, B	Foraminifera Abundance Data	721 (PE 04)		
206R	Foraminifera Relic Abundance Data		X	Not performed in this program

TABLE 128 (Continued)

SUSIO DATA TAPE FILES INCLUDED IN - OR EXCLUDED FROM DAMES & MOORE DATA BASE

MAFLA ID	DESCRIPTION	FILE NO.	EXCLUDED	REMARKS
207L	Demersal Fish Meristic Data	737 (PE 19)		
207N	Demersal Fish Taxonomic Data	717 (PE 19)		
209	Water Column HMW-HC Data		X	HMW-HC committee recommended exclusion
210	Neuston Taxonomic and Miscellaneous Data		X	PI recommended exclusion
211A	Bottom Sediment Grain Size Data	810 (PE 01)		
211B	Box-Core Color Descriptive Data		X	Not performed in this program
213A	Epifaunal - Epifloral Abundance Data		X	Not performed in this program
213D	Macroepifauna Taxonomic Data	724 (PE 18)	X	Presence - absence data
214A	Surface Sediment Clay Mineralogic Data	820 (PE 03)		
214B	Suspended Sediment Clay Mineralogic Data	825 (PE 22)		Depth of sampling not compatible with this program
215	Phytoplankton Primary Productivity Data		X	Not performed in this program

TABLE 128 (Continued)

SUSIO DATA TAPE FILES INCLUDED IN - OR EXCLUDED FROM DAMES & MOORE DATA BASE

MAFLE ID	DESCRIPTION	FILE NO.	EXCLUDED	REMARKS
216	POC and DOC Data	420 (PE 30, 32)		
217A	Polychaete Abundance Data	723 (PE 55)		
217B	Macroinfauna Biomass Data	733 (PE 06)		
218	Sediment ATP Data		X	PI recommended exclusion; laboratory methodology not compatible
219A	Sediment Total Organic	120 (PE 10)		Other organic carbon data excluded
219B-S	Bottom Sediment HMW-HC		X	HMW-HC committee recommended exclusion
221	Transmissometry Data			
222C	Zooplankton Biomass Data		X	PI recommended exclusion
222M	Meiofauna Taxonomic Data	722 (PE 05)		Laboratory methods not compatible and data assumed to be unnormalized; hence, kept in a file separate from meiofauna data from this program (File 712)
222Z	Zooplankton Taxonomy Data		X	PI recommended exclusion
223L	Demersal Fish Meristic Data	737 (PE 19)		
223N	Demersal Fish Taxonomy Data	717 (PE 17)		

TABLE 128 (Continued)

SUSIO DATA TAPE FILES INCLUDED IN - OR EXCLUDED FROM DAMES & MOORE DATA BASE

MAFLA ID	DESCRIPTION	FILE NO.	EXCLUDED	REMARKS
225	Macroepifauna HMW-HC Data		X	HMW-HC committee recommended exclusion
226A, R	Micro-Mollusc Abundance Data		X	Not performed in this program
227A	Bottom Sediment Total Digest TM Data	115 (PE 07)		
229L	Demersal Fish Meristic Data	737 (PE 19)		
229N	Demersal Fish Taxonomic Data	717 (PE 19)		
232A	Polychaete Taxonomic Data	737 (PE 19)		
232B	Macroinfauna Biomass Data	723 (PE 55)		
233N, P	Carbonate Skeletal Data		X	Not performed in this program
235S	STD Data		X	Data utilized but not included in computer data base
235X	XBT Data		X	PI recommended exclusion

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APPENDIX A

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 110 SEDIMENT CHEMISTRY-TRACE METAL DATA, PARTIAL DIGESTION

COLUMNS	ENTRY	DESCRIPTION
1- 3	110	File code.
4-16	XXX...XXX	Sample number.
18-23	IIIISE	PPM Barium (Ba).
24-29	IIIISE	PPM Cadmium (Cd).
30-35	IIIISE	PPM Chromium (Cr).
36-41	IIIISE	PPM Copper (Cu).
42-47	IIIISE	PPM Iron (Fe).
48-53	IIIISE	PPM Nickel (Ni).
54-59	IIIISE	PPM Lead (Pb).
60-65	IIIISE	PPM Vanadium (V).
66-71	IIIISE	PPM Zinc (Zn).

Notes:
S = Sign of exponent, E = Exponent value; thus IIISE = (III) x 10^{SE}
X = Unspecified numeric entry.
I = Integral value.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 020 DATE - STATION DATA

COLUMNS	ENTRY	DESCRIPTION
1- 3	020	File code.
4- 8	YMMDD	Date: Year (1 digit), Month (2 digits), & Day (2 digits).
9-13	XXXXX	Station number.
14-19	DDdddd	Latitude, degrees north
20-25	DDdddd	Longitude, degrees west
26-28	III	Water depth (m)
30-34	YMMDD	Date: Year (1 digit), Month (2 digits), & Day (2 digits).
35-39	XXXXX	Station number.
40-45	DDdddd	Latitude, degrees north
46-51	DDdddd	Longitude, degrees west
52-54	III	Water depth (m)
56-60	YMMDD	Date: Year (1 digit), Month (2 digits), & Day (2 digits).
61-65	XXXXX	Station number.
66-71	DDdddd	Latitude, degrees north
72-77	DDdddd	Longitude, degrees west
78-80	III	Water depth (m)

Notes:

DD = degrees, integral part; dddd = degrees, fractional part. Thus, DDdddd = xx.xxxx degrees.

I = Integral value.

X = Unspecific numeric entry.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 115 SEDIMENT CHEMISTRY-TRACE METAL DATA, TOTAL DIGESTION

COLUMNS	ENTRY	DESCRIPTION
1- 3	115	File code.
4-16	XXX...XXX	Sample number.
18-23	IIIISE	PPM Barium (Ba).
24-29	IIIISE	PPM Cadium (Cd).
30-35	IIIISE	PPM Chromium (Cr).
36-41	IIIISE	PPM Copper (Cu).
42-47	IIIISE	PPM Iron (Fe).
48-53	IIIISE	PPM Nickel (Ni).
54-59	IIIISE	PPM Lead (Pb).
60-65	IIIISE	PPM Vanadium (V).
66-71	IIIISE	PPM Zinc (Zn).

Notes:

S = Sign of exponent, E = Exponent value; thus IIISE = (III) x 10^{SE}
X = Unspecified numeric entry.
I = Integral value.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 120 SEDIMENT CHEMISTRY - TOTAL ORGANIC CONTENT (TOC) DATA

COLUMNS	ENTRY	DESCRIPTION
1- 3	120	File code.
4-16	XXX...XXX	Sample number.
18-21	IIFF	Total organic content (%).
23-35	XXX...XXX	Sample number.
37-40	IIFF	Total organic content (%).
42-54	XXX...XXX	Sample number.
56-59	IIFF	Total organic content (%).
61-73	XXX...XXX	Sample number.
75-78	IIFF	Total organic content (%).

Notes:

X = Unspecified numeric entry.

I = Integral value, F = Fractional value; thus IIFF = xx.xx.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 130 BOTTOM SEDIMENT - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; SAMPLE CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	130	File code.
4-16	XXX...XXX	Sample number.
18-64	AAA...AAA	In-house I.D. number and other information.
66-72	IIIIISE	Sample weight, grams (g).
74-80	IIIIISE	Non-saponifiable extract, grams (g).

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 131 BOTTOM SEDIMENT - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; LIQUID CHROMATOGRAPHY CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	131	File code.
4-16	XXX...XXX	Sample number.
32-38	IIIIISE	Weight test specimen, grams (g).
41-47	IIIIISE	Hexane fraction, grams (g).
50-56	IIIIISE	Benzene fraction, grams (g).
59-65	IIIIISE	Methane fraction, grams (g).

Notes:
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 132 BOTTOM SEDIMENT - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; GAS CHROMATOGRAPHY INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	132	File code.
4-16	XXX...XXX	Sample number.
32-38	IIIIISE	Resolved Hexane fraction, μg/g-Sample.
41-47	IIIIISE	Unresolved Hexane fraction, μg/g-Sample.
50-56	IIIIISE	Resolved Benzene fraction, μg/g-Sample.
59-65	IIIIISE	Unresolved Benzene fraction μg/g-Sample.

Notes:
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 133 BOTTOM SEDIMENT - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; RATIO CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	133	File code.
4-16	XXX...XXX	Sample number.
32-35	IIFF	Pristane to Phytane ratio.
37-40	IIFF	Pristine to n^{C}_{17} ratio.
42-45	IIFF	Pristane to n^{C}_{18} ratio.
68-71	IIFF	Odd-Even ration all nC_{xx}.
73-76	IIFF	Normal-Branched ratio.

Notes:

X = Unspecified numeric entry.

I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 134 BOTTOM SEDIMENT - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; HEXANE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	134	File code.
4-16	XXX...XXX	Sample number.
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	μg/g-Sample.
54-59	XX.XXX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.**

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

* "." indicates position of the decimal point.
** Peak name assignment based on GC trace and information contained in the ARLI computer peak-name library.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 135 BOTTOM SEDIMENT - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; BENZENE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	135	File code.
4-16	XXX...XXX	Sample number.
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	µg/g-Sample number*.
54-59	XX.XXX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.**

Notes:

A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

* "." indicates the position of the decimal point.
** Peak name assignment based on GC trace and information contained in the ARLI computer peak-name library.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 210 MACROEPIFAUNA CHEMISTRY - TRACE METAL DATA; PART I

COLUMNS	ENTRY	DESCRIPTION
1- 3	210	File code.
4-16	XXX...XXX	Sample number.
21-32	XXX...XXX	Taxonomic I.D. number.
33-34	XX	Specimen number.
35-40	IIIISE	PPM Barium (Ba).
43-48	IIIISE	PPM Cadmium (Cd).
51-56	IIIISE	PPM Chromium (Cr).
59-64	IIIISE	PPM Copper (Cu).
67-72	IIIISE	PPM Iron (Fe).
75-80	IIIISE	PPM Nickel (Ni).
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA50-CT7-34
SCIENTIFIC DATA FILE

FILE 211 MACROEPIFAUNA CHEMISTRY - TRACE METAL DATA; PART II

COLUMNS	ENTRY	DESCRIPTION
1- 3	210	File code.
4-16	XXX...XXX	Sample number.
21-32	XXX...XXX	Taxonomic I.D. number.
33-34	XX	Specimen number.
35-40	IIIISE	PPM Lead (Pb).
43-48	IIIISE	PPM Vanadium (V).
51-56	IIIISE	PPM Zinc (Zn).
81-130	AAA...AAA	Taxonomic name.

Notes:

A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 230 MACROEPIFAUNA - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; SAMPLE CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	230	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
31-64	AAA...AAA	In-house I.D. number, and other information.
66-72	IIIIISE	Sample weight grams (g).
74-80	IIIIISE	Non-saponifiable extract grams (g).
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 231 MACROEPIFAUNA - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; LIQUID CHROMATOGRAPHY CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	231	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-38	IIIIISE	Weight test specimen, grams (g).
41-47	IIIIISE	Hexane fraction, grams (g).
50-56	IIIIISE	Benzene fraction, grams (g).
59-65	IIIIISE	Methane fraction, grams (g).
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 232 MACROEPIFAUNA - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; GAS CHROMATOGRAPHY INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	232	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-38	IIIIISE	Resolved hexane fraction, μg/g-Sample.
41-47	IIIIISE	Unresolved hexane fraction, μg/g-Sample.
50-56	IIIIISE	Resolved benzene fraction, μg/g-Sample.
59-65	IIIIISE	Unresolved benzene fraction, μg/g-Sample.
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 233 MACROEPIFAUNA - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; RATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	233	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-35	IIFF	Pristane to phytane ratio.
37-40	IIFF	Pristane to nC_{17} ratio.
42-45	IIFF	Phytane to nC_{18} ratio.
68-71	IIFF	Odd-even ratio all nC_{xx}.
73-76	IIFF	Normal-branched ratio.
81-130	AAA...AAA	Taxonomic name.

Notes:

A = Alpha-numeric entry.
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 234 MACROEPIFAUNA - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; HEXANE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	234	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index number.*
45-52	XXXX.XXX	μg/g-Sample.*
54-59	XX.XXX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.**
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

* "." indicates position of the decimal point.
** Peak name assignment based on GC tract and information contained in the ARLI computer peak-name library.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 235 MACROEPIFAUNA - HIGH MOLECULAR WEIGHT HYDROCARBONS BENZENE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	235	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	µg/g-Sample.*
54-58	XX.XX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.**
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

* "." indicates position of the decimal point.
** Peak name assignment based on GC trace and information contained in the ARLI computer peak-name library.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 310 DEMERSAL FISH CHEMISTRY - TRACE METALS DATA; PART I

COLUMNS	ENTRY	DESCRIPTION
1- 3	310	File code.
4-16	XXX...XXX	Sample number.
21-32	XXX...XXX	Taxonomic I.D. number.
33-34	XX	Specimen number.
35-40	IIIISE	PPM Barium (Ba).
43-48	IIIISE	PPM Cadmium (Cd).
51-56	IIIISE	PPM Chromium (Cr).
59-64	IIIISE	PPM Copper (Cu).
67-72	IIIISE	PPM Iron (Fe).
75-80	IIIISE	PPM Nickel (Ni).
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 311 DEMERSAL FISH CHEMISTRY - TRACE METAL DATA; PART II

COLUMNS	ENTRY	DESCRIPTION
1- 3	310	File code.
4-16	XXX...XXX	Sample number.
21-32	XXX...XXX	Taxonomic I.D. number.
33-34	XX	Specimen number.
35-40	IIIISE	PPM Lead (Pb).
43-48	IIIISE	PPM Vanadium (V).
51-56	IIIISE	PPM Zinc (Zn).
81-130	AAA...AAA	Taxonomic name.

Notes:

A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 330 DEMERSAL FISH - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; SAMPLE CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	330	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
31-64	AAA...AAA	In-house I.D. number, and other information.
66-72	IIIIISE	Sample weight, grams (g).
74-80	IIIIISE	Non-saponifiable extract, grams (g).
81-130	AAA...AAA	Taxonomic name.

Notes:

A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 331 DEMERSAL FISH - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; LIQUID CHROMATOGRAPHY CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	331	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-38	IIIIISE	Weight test specimen, grams (g).
41-47	IIIIISE	Hexane fraction, grams (g).
50-56	IIIIISE	Benzene fraction, grams (g).
59-65	IIIIISE	Methane fraction, grams (g).
81-130	AAA...AAA	Taxonomic name.

Notes:

A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 332 DEMERSAL FISH - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; GAS CHROMATOGRAPHY INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	332	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-38	IIIIISE	Resolved hexane fraction, μg/g-Sample.
41-47	IIIIISE	Unresolved hexane fraction, μg/g-Sample.
50-56	IIIIISE	Resolved benzene fraction, μg/g-Sample.
59-65	IIIIISE	Unresolved benzene fraction, μg/g-Sample.
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 333 DEMERSAL FISH - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; RATIO CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	333	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-35	IIFF	Pristane to phytane ratio.
37-40	IIFF	Pristane to nC_{17} ratio.
42-45	IIFF	Phytane to nC_{18} ratio.
68-71	IIFF	Odd-even ratio all nC_{xx}.
73-76	IIFF	Normal-branched ratio.
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 334 DEMERSAL FISH - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; HEXANE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	334	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	µg/g-Sample.*
54-59	XX.XXX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.**
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

* "." indicates position of the decimal point.
** Peak name assignment based on GC tract and information contained in the ARLI computer peak-name library.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 335 DEMERSAL FISH - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; BENZENE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	335	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
29-30	XX	Specimen number.
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	µg/g-Sample.*
54-58	XX.XX	Weight percent eluate.
60-80	AAA...AAA	Assignment.**
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

* "." indicates the position of the decimal point.
** Peak name assignment based on GC tract and information contained in the ARLI computer peak-name library.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 410 WATER COLUMN CHEMISTRY - SUSPENDED PARTICLES, TRACE METAL DATA (WEAK ACID SOLUBLE FRACTION); PART I

COLUMNS	ENTRY	DESCRIPTION
1- 3	410	File code.
4-16	XXX...XXX	Sample number.
17-20	XXXX	LAB number.
22	I	1 = TOP.* 2 = BOTTOM.*
23-28	IIIISE	PPB suspended particulate matter.
31-36	IIIISE	PPM Barium (Ba).
39-44	IIIISE	PPM Calcium (Ca).
47-52	IIIISE	PPM Cadmium (Cd).
55-60	IIIISE	PPM Chromium (Cr).
63-68	IIIISE	PPM Copper (Cu).
71-76	IIIISE	PPM Iron (Fe).

Notes:

X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth);
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 411 WATER COLUMN CHEMISTRY - SUSPENDED PARTICULES, TRACE METALS DATA (WEAK ACID SOLUBLE FRACTION); PART II

COLUMNS	ENTRY	DESCRIPTION
1- 3	411	File code.
4-16	XXX...XXX	Sample number.
17-20	XXXX	Lab number.
22	I	1 = TOP.* 2 = BOTTOM.*
23-28	IIIISE	PPM Nickel (Ni).
31-36	IIIISE	PPM Lead (Pb).
39-44	IIIISE	PPM Vanadium (V).
47-52	IIIISE	PPM Zinc (Zn).

Notes:
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth);
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 415 WATER COLUMN CHEMISTRY - SUSPENDED PARTICLES, TRACT METAL DATA (REFRACTORY FRACTION); PART I

COLUMNS	ENTRY	DESCRIPTION
1- 3	415	File code.
4-16	XXX...XXX	Sample number.
17-20	XXXX	Lab Number.
22	I	1 = TOP.* 2 = BOTTOM.*
23-28	IIIISE	PPB Suspended particulate matter.
31-36	IIIISE	PPM Aluminum (Al).
39-44	IIIISE	PPM Barium (Ba).
47-52	IIIISE	PPM Cadmium (Cd).
55-60	IIIISE	PPM Chromium (Cr).
63-68	IIIISE	PPM Copper (Cu).
71-76	IIIISE	PPM Iron (Fe).

Notes:
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth);
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 416 WATER COLUMN CHEMISTRY - SUSPENDED PARTICLES TRACE METAL DATA (REFRACTORY FRACTION); PART II

COLUMNS	ENTRY	DESCRIPTION
1- 3	416	File code.
4-16	XXX...XXX	Sample number.
17-20	XXXX	Lab number.
22	I	1 = TOP.* 2 = BOTTOM.*
23-38	IIIISE	PPM Nickel (Ni).
31-36	IIIISE	PPM Lead (Pb).
39-44	IIIISE	PPM Silicon (Si).
47-52	IIIISE	PPM Vanadium (V).
55-60	IIIISE	PPM Zinc (Zn).

Notes:

X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth);
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 420 WATER COLUMN CHEMISTRY - SUSPENDED PARTICULATE ORGANIC CARBON AND DISSOLVED ORGANIC CARBON DATA

COLUMNS	ENTRY	DESCRIPTION
1- 3	420	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
21-26	IIIISE	FIRST Particulate organic carbon content (POC) (mg/l).
30-35	IIIISE	SECOND Particulate organic carbon content (POC) (mg/l).
39-44	IIIISE	THIRD Particulate organic carbon content (POC) (mg/l).
48-53	IIIISE	FIRST dissolved organic carbon content (DOC) (mg/l).
57-62	IIIISE	SECOND dissolved organic carbon content (DOC) (mg/l).
66-71	IIIISE	THIRD dissolved organic carbon content (DOC) (mg/l).

Notes:
mg/l = Milligram per liter.
X = Unspecified numeric value.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 430 SUSPENDED PARTICULATES - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; SAMPLE CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	430	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
18-64	AAA...AAA	In-house I.D. number, and other information.
66-72	IIIIISE	Sample volume (1).
74-80	IIIIISE	$CHCl_3$ extract (g).

Notes:
A = Alpha-Numeric entry.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.
X = Unspecified numeric entry.
I = Integral value.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 431 SUSPENDED PARTICULATES - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; LIQUID CHROMATOGRAPHY CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	431	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
32-38	IIIIISE	Weight test specimen, grams (g).
41-47	IIIIISE	Hexane fraction, grams (g).
50-56	IIIIISE	Benzene fraction, grams (g).
59-65	IIIIISE	Methane fraction, grams (g).

Notes:
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 432 SUSPENDED PARTICULATES - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; GAS CHROMATOGRAPHY INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	432	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
32-38	IIIIISE	Resolved Hexane fraction, μg/1-Sample.
41-47	IIIIISE	Unresolved Hexane fraction, μg/1-Sample.
50-56	IIIIISE	Resolved benzene fraction, μg/1-Sample.
59-65	IIIIISE	Unresolved benzene fraction, μg/1-Sample.

Notes:

X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 433 SUSPENDED PARTICULATES - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; RATIO CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	433	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
32-35	IIFF	Pristane to phytane ratio.
37-40	IIFF	Pristane to $n^C{}_{17}$ ratio.
42-45	IIFF	Pristane to $n^C{}_{18}$ ratio.
47-50	IIFF	Pristane + phytane to Σn alkanes ratio.
52-56	IIIFF	Σn alkanes to $n^C{}_{16}$ ratio.
58-61	IIFF	O-E ratio; $\leq n^C{}_{20}$.
63-68	IIFF	O-E ratio; $\geq n^C{}_{21}$.
68-71	IIFF	Odd-even ratio all $n^C{}_{xx}$.
73-76	IIFF	Normal-branched ratio.

Notes:
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 434 SUSPENDED PARTICULATES - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; HEXANE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	434	File Code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.** 2 = BOTTOM.**
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	μg/l-Sample.
54-59	XX.XXX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.***

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

* "." indicates position of the decimal point.
** Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.
*** Peak name assignment based on GC tract, calibration and interpolation between standards, and results of GC/MS analyses.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 435 SUSPENDED PARTICULATES - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; BENZENE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	435	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.** 2 = BOTTOM.**
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	μg/l-Sample number.*
54-59	XX.XXX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.***

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

* "." indicates the position of the decimal point.
** Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.
*** Peak name assignment based on GC trace, calibration and interpolation between standards, and results of GC/MS analyses.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 440 DISSOLVED HIGH MOLECULAR WEIGHT HYDROCARBON DATA; SAMPLE CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	440	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
18-64	AAA...AAA	In-house I.D. number, and other information.
66-72	IIIIISE	Sample volume (1).
74-80	IIIIISE	$CHCl_3$ extract (g).

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 441 DISSOLVED HIGH MOLECULAR WEIGHT HYDROCARBON DATA; LIQUID CHROMATOGRAPHY CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	441	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
32-38	IIIIISE	Weight test specimen, grams (g).
41-47	IIIIISE	Hexane fraction, grams (g).
50-56	IIIIISE	Benzene fraction, grams (g).
59-65	IIIIISE	Methane fraction, grams (g).

Notes:
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

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SCIENTIFIC DATA FILE

FILE 442 DISSOLVED HIGH MOLECULAR WEIGHT HYDROCARBON DATA; GAS CHROMATOGRAPHY INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	442	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
32-38	IIIIISE	Resolved Hexane fraction, μg/l-Sample.
41-47	IIIIISE	Unresolved hexane fraction, μg/l-Sample.
50-56	IIIIISE	Resolved benzene fraction, μg/l-Sample.
59-65	IIIIISE	Unresolved benzene fraction, μg/l-Sample.

Notes:

X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

MAFLA AA550-CT-7-34
SCIENTIFIC DATA FILE

FILE 443 DISSOLVED HIGH MOLECULAR WEIGHT HYDROCARBON DATA; RATIO CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	443	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
32-35	IIFF	Pristane to phytane ratio.
37-40	IIFF	Pristane to n^{C}_{17} ratio.
42-45	IIFF	Pristane to n^{C}_{18} ratio.
47-50	IIFF	Pristane + phytane to Σn alkanes ratio.
52-56	IIIFF	Σn alkanes to n^{C}_{16} ratio.
58-61	IIFF	O-E ratio; $\leq n^{C}_{20}$.
63-68	IIFF	O-E ratio; $\geq n^{C}_{21}$.
68-71	IIFF	Odd-even ratio, all n^{C}_{xx}.
73-76	IIFF	Normal-branched ratio.

Notes:

X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

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SCIENTIFIC DATA FILE

FILE 444 DISSOLVED HIGH MOLECULAR WEIGHT HYDROCARBON DATA; HEXANE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	444	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.** 2 = BOTTOM.**
32-36	XXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	μg/1-Sample.*
54-59	XX.XXX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.***

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

* "." indicates position of the decimal point.
** Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.
*** Peak name assignment based on GC trace, calibration and interpolation between standards, and results of GC/MS analyses.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 445 DISSOLVED HIGH MOLECULAR WEIGHT HYDROCARBON DATA; BENZENE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	445	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.** 2 = BOTTOM.**
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	μg/l-Sample number.*
54-59	XX.XXX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.**

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

* "." indicates the position of the decimal point.
** Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.
*** Peak name assignment based on GC trace, calibration and interpolation between standards, and results of GC/MS analyses.

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SCIENTIFIC DATA FILE

FILE 510 ZOOPLANKTON CHEMISTRY - TRACE METAL DATA

COLUMNS	ENTRY	DESCRIPTION
1- 3	510	File code.
4-16	XXX...XXX	Sample number.
18-23	IIIISE	PPM Barium (Ba).
25-30	IIIISE	PPM Cadmium (Cd).
32-37	IIIISE	PPM Chromium (Cr).
39-44	IIIISE	PPM Copper (Cu).
46-51	IIIISE	PPM Iron (Fe).
53-58	IIIISE	PPM Nickel (Ni).
60-65	IIIISE	PPM Lead (Pb).
67-72	IIIISE	PPM Vanadium (V).
74-79	IIIISE	PPM Zinc (Zn).

Notes:
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

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SCIENTIFIC DATA FILE

FILE 530 ZOOPLANKTON - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; SAMPLE CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	530	File code.
4-16	XXX...XXX	Sample number.
31-64	AAA...AAA	In-house I.D. number, and other information.
66-72	IIIIISE	Sample weight, grams (g).
74-80	IIIIISE	Non-saponifiable extract, grams (g).

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

FILE 531 ZOOPLANKTON - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; LIQUID CHROMATOGRAPHY CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	531	File code.
4-16	XXX...XXX	Sample number.
32-38	IIIIISE	Weight test specimen, grams (g).
41-47	IIIIISE	Hexane fraction, grams (g).
50-56	IIIIISE	Benzene fraction-grams (g).
59-65	IIIIISE	Methane fraction, grams (g).

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

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SCIENTIFIC DATA FILE

FILE 532 ZOOPLANKTON - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; GAS CHROMATOGRAPHY INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	532	File code.
4-16	XXX...XXX	Sample number.
32-38	IIIIISE	Resolved hexane fraction, μg/g-Sample.
41-47	IIIIISE	Unresolved hexane fraction, μg/g-Sample.
50-56	IIIIISE	Resolved benzene fraction, μg/g-Sample.
59-65	IIIIISE	Unresolved benzene fraction, μg/g-Sample.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IISE = (III) x 10^{SE}.

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SCIENTIFIC DATA FILE

FILE 533 ZOOPLANKTON - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; RATIO CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	533	File code.
4-16	XXX...XXX	Sample number.
32-35	IIFF	Pristane to phytane ratio.
37-40	IIFF	Pristane to $n^{C}{}_{17}$ ratio.
42-45	IIFF	Phytane to $n^{C}{}_{18}$ ratio.
68-71	IIFF	Odd-even ratio, all $n^{C}{}_{xx}$.
73-76	IIFF	Normal-branched ratio.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 534 ZOOPLANKTON - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; HEXANE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	534	File code.
4-16	XXX...XXX	Sample number.
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	µg/g-Sample.*
54-59	XX.XXX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.**

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

* "." indicates position of the decimal point.
** Peak name assignment based on GC trace and information contained in the ARLI computer peak-name library.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 535 ZOOPLANKTON - HIGH MOLECULAR WEIGHT HYDROCARBON DATA; BENZENE FRACTION PEAK INFORMATION CARD

COLUMNS	ENTRY	DESCRIPTION
1- 3	535	File code.
4-16	XXX...XXX	Sample number.
32-36	XXXX.	Retention time (sec).*
38-43	XXXXX.	Relative kovat index.*
45-52	XXXX.XXX	µg/g-Sample.*
54-58	XX.XX	Weight percent eluate.*
60-80	AAA...AAA	Assignment.**

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

* "." indicates position of the decimal point.
** Peak name assignment based on GC trace and information contained in the ARLI computer peak-name library.

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SCIENTIFIC DATA FILE

FILE 610 LIVING MICROBIAL BIOMASS - ADENOSINE TRIPHOSPHATE DATA

COLUMNS	ENTRY	DESCRIPTION
1- 3	610	File code.
4-16	XXX.XXX	Sample number.
20	X	Number of replicates per sample.
24-28	IIFFF	Wet sediment weight (g).
32-36	IIISE	Mean ATP value, (ng/ml).
40-44	IIIIF	1 s.d. (ng/ml).
48-52	IIISE	Mean ATP value, (ng/g).

Notes:
ng/ml = nanograms/milliliter.
ng/g = nanograms/gram.
s.d. = standard deviation.

X = Unspecified numeric entry.
I = Integral Value, F = Fractional value; thus, IIFF = xx.xx.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 712 TAXONOMY MEIOFAUNA - NUMBER OF SPECIMENS PER TAXON (NORMALIZED ABUNDANCE DATA)

COLUMNS	ENTRY	DESCRIPTION
1- 3	712	File code.
4-16	XXX...XXX	Sample number.
19-30	XXX...XXX	Taxonomic I.D. number.
32-37	IIIISE	Number of specimens.
39	C	6 = No estimate.* 1 = Estimated number of specimens.*
40-80	AAA...AAA	Taxonomic name.

Notes:
C = Nematoda estimate code (taxonomic I.D. no. 47).
Data normalized to the number of specimens per 10 CM^2 area of substrate.

A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

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SCIENTIFIC DATA FILE

FILE 716 TAXONOMY ZOOPLANKTON - NUMBER OF SPECIMENS PER TAXON (NORMALIZED ABUNDANCE DATA)

COLUMNS	ENTRY	DESCRIPTION
1- 3	716	File code.
4-16	XXX...XXX	Taxonomic I.D. number.
17-29	XXX...XXX	Sample number.
31-36	IIIISE	County per m^3.
39-51	XXX...XXX	Sample number.
53-58	IIIISE	Count per m^3.
61-73	XXX...XXX	Sample number.
75-80	IIIISE	County per m^3.
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

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FILE 717 TAXONOMY DEMERSAL FISH - NUMBER OF SPECIMENS PER TAXON

COLUMNS	ENTRY	DESCRIPTION
1- 3	717	File code.
4-15	XXX...XXX	Taxonomic I.D. number.
18-30	XXX...XXX	Sample number.
32-35	IIII	Number of specimens.
38-50	XXX...XXX	Sample number.
52-55	IIII	Number of specimens.
58-70	XXX...XXX	Sample number.
72-75	IIII	Number of specimens.
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
I = Integral value.
X = Unspecified numeric entry.

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SCIENTIFIC DATA FILE

FILE 721 TAXONOMY FORAMINIFERA - NUMBER OF SPECIMENS PER TAXON (ABUNDANCE DATA)

COLUMNS	ENTRY	DESCRIPTION
1- 3	721	File code.
4-16	XXX...XXX	Sample number.
19	I	1 = Card that has extra station data; otherwise (see columns 66-79).
21-32	XXX...XXX	Taxa I.D. number.
37-39	III	Number live, first count of 300.
45-47	III	Number dead, first count of 300.
54-56	III	Number live of this taxon out of 300 live foraminifera.
60-63	IIII	Number planktonic per 300 benthonic.
66-71	IIIISE	Number live per ml (total).
74-79	IIIISE	Number dead per ml (total).
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

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SCIENTIFIC DATA FILE

FILE 723 TAXONOMY MACROEPIFAUNA - NUMBER OF SPECIMENS PER TAXON (RELATIVE ABUNDANCE DATA)

COLUMNS	ENTRY	DESCRIPTION
1- 3	723	File code.
4-15	XXX...XXX	Taxonomic I.D. number.
16	I	Larval code.*
17-29	XXX...XXX	Sample number.
31-34	IIII	Number of specimens.
39-51	XXX...XXX	Sample number.
53-56	IIII	Number of specimens.
61-73	XXX...XXX	Sample number.
75-78	IIII	Number of specimens.
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
I = Integral value.
X = Unspecified numeric entry.

* Larval codes: 1 = zoca;
2 = post zoca;
3 = megalops;
4 = juvenal;
5 = fragment of live or recently alive organism;
6 = adult.

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SCIENTIFIC DATA FILE

FILE 724 TAXONOMY MACROEPIFAUNA - NUMBER OF SPECIMENS PER TAXON (RELATIVE ABUNDANCE DATA)

COLUMNS	ENTRY	DESCRIPTION
1- 3	724	File code.
4-15	XXX...XXX	Taxonomic I.D. number.
16	I	Larval code.*
17-29	XXX...XXX	Sample number.
31-36	IIIISE	Number of specimens.
39-51	XXX...XXX	Sample number.
53-58	IIIISE	Number of specimens.
61-73	XXX...XXX	Sample number.
75-80	IIIISE	Number of specimens.
81-130	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
I = Integral value.
X = Unspecified numeric entry.

* Larval codes: 1 = zoca;
2 = post zoca;
3 = megalops;
4 = juvenal;
5 = fragment of live or recently alive organism;
6 = adult.

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SCIENTIFIC DATA FILE

FILE 725 TAXONOMY NEUSTON - NUMBER OF SPECIMENS PER TAXON (RELATIVE ABUNDANCE DATA)

COLUMNS	ENTRY	DESCRIPTION
1- 3	725	File code.
4-15	XXX...XXX	Taxonomic I.D. number.
17-29	XXX...XXX	Sample number.
32-37	IIIISE	Eggs, number of specimens.
39	1	Larval code 1.
40-45	IIIISE	Number of specimens.
47	2	Larval code 2.
48-53	IIIISE	Number of specimens.
55	3	Larval code 3.
56-61	IIIISE	Number of specimens.
64-69	IIIISE	Females, number of specimens.
72-77	IIIISE	Adults, number of specimens.
80	I	Special code.*
81-175	AAA...AAA	Taxonomic name and larval code names.

Notes:

A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

* Special code: (a) b̸ = sampled from upper near surface net at depth of 10 cm; (b) 2 = sampled from lower near surface net (1976 data only); (c) 3 = organisms with lengths 2.5 cm.

FILE 725 TAXONOMY NEUSTON - NUMBER OF SPECIMENS PER TAXON (RELATIVE ABUNDANCE DATA) (cont'd)

NEUSTON LARVAL CODES

TAXA	TAXONOMIC I.D.	LARVAL CODE/NAME
Polychaeta	5001	1 = Trochopra 2 = Nectochate 3 = Unidentified
Molluscs	51,53-56	1 = Veligers
Copepoda	6117-6127	1 = Nauplii 2 = Copepodids
Barnacles	6130-6142	1 = Nauplii 2 = Cypris
Mysids	6151-6153	1 = Mysis
Isopoda and Amphopoda	6158-6172	1 = Juvenile
Euphausiids	6174	1 = Calyptopsis 2 = Fureilla
Natontia	6176-6179	1 = Zoea 2 = Post larval 3 = Subadult
Reptantia	6183-6189	1 = Zoea 2 = Megalopa 3 = Post larval
Stomatopoda	6190	1 = Antizoea 2 = Pseudozoea
Echinodermata	81	1 = Bipinnaria 2 = Juvenile
All others	---	1 = Larvae

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SCIENTIFIC DATA FILE

FILE 733 TAXONOMY MACROINFAUNA - BIOMASS DATA

COLUMNS	ENTRY	DESCRIPTION
1- 3	733	File code.
4-16	XXX...XXX	Sample number.
19-27	IIIIIIIFF	Molluscan biomass (mg wet weight).
30-38	IIIIIIIFF	Polychaete biomass (mg wet weight).
41-49	IIIIIIIFF	Anthropod biomass (mg wet weight).
52-60	IIIIIIIFF	Echinodern biomass (mg wet weight).
63-71	IIIIIIIFF	Misc. biomass (mg wet weight).

Notes:
I = Integral value, F = Fractional value; thus, IIFF = XX.XX.
X = Unspecified numeric entry.

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SCIENTIFIC DATA FILE

FILE 735 TAXONOMY NEUSTON - BIOMASS DATA

COLUMNS	ENTRY	DESCRIPTION
1- 3	735	File code.
4-16	XXX...XXX	Sample number.
19-24	IIIISE	Number of neuston sampled per minute tow.
36-41	IIIISE	Display volume biota 2.5 cm(ml).
46-51	IIIISE	Display volume sargassumm (ml).
56-61	IIIISE	Weight of tar balls (g).

Notes:
X = Unspecified numeric entry.
I = Integral value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 736 TAXONOMY ZOOPLANKTON - BIOMASS DATA

COLUMNS	ENTRY	DESCRIPTION
1- 3	736	File code.
4-16	XXX...XXX	Sample number.
21-26	IIIISE	Volume of water sampled (m^3).
30-32	FFF	Fractional part of sampled analyzed for biomass analysis.
36-41	IIIISE	Dry weight biomass (mg).
46-51	IIIISE	Ash-free dry weight biomass (mg).
56-61	IIIISE	Normalized dry weight biomass (mg/m^3).
66-71	IIIISE	Normalized ash-free dry weight biomass (mg/m^3).

Notes:

X = Unspecified numeric entry.
I = Integral value; F = Fractional value.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 737 TAXONOMY DEMERSAL FISH - MERISTIC AND MISCELLANEOUS DATA

COLUMNS	ENTRY	DESCRIPTION
1- 3	737	File code.
4-16	XXX...XXX	Sample number.
17-28	XXX...XXX	Taxonomic I.D. number.
30-33	IIII	Length (mm).*
36-40	IIIIF	Weight (g).*
42-43	XX	Pathologic condition code (ƀ = none observed; 1 = condition observed).
45	X	Sex code.**
47-50	IIII	Length (mm).*
53-57	IIIIF	Weight (g).*
59-60	XX	Pathologic condition code (ƀ = none observed; 1 = condition observed).
62	X	Sex code.**
64-67	IIII	Length (mm).*
70-74	IIIIF	Weight (g).*

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value, F = Functional value; thus, IIFF = XX.XX.

* 9999 = Entire specimen unavailable for length measurement and weighing.
** Sex codes: (a) 1 = male; (b) 2 = female; (c) 3 = functional amorphidite;
(d) 4 = not determined.

FILE 737 TAXONOMY DEMERSAL FISH - MERISTIC AND MISCELLANEOUS DATA (cont'd)

COLUMNS	ENTRY	DESCRIPTION
76-77	XX	Pathologic condition code (b̸ = none observed; 1 = condition observed).
78	X	Sex code.**
81-130	AAA...AAA	Taxonomic name.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 745 TAXONOMY NEUSTON - JUVENILE AND ADULT FISH LENGTH DATA BY CLASS INTERVAL

COLUMNS	ENTRY	DESCRIPTION	
1- 3	745	File code.	
4-16	XXX...XXX	Sample number.	
18-29	XXX...XXX	Taxonomic I.D. number.	
32-36	IIIII	<5 mm.	Neuston Length Class Intervals
39-43	IIIII	5 - 10 mm.	
46-50	IIIII	10 - 15 mm.	
53-57	IIIII	15 - 20 mm.	
60-64	IIIII	20 - 25 mm.	
67-71	IIIII	>25 mm.	
80-130	AAA...AAA	Taxonomic name.	

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 810 MARINE GEOLOGY - BOTTOM SEDIMENT GRAIN SIZE PARAMETERS

COLUMNS	ENTRY	DESCRIPTION	
1- 3	910	File code.	
4-16	XXX...XXX	Sample number.	
19-22	IIFF	<-1 phi.	Weight Percent by Phi Size Class
25-28	IIFF	-1 to 0 phi.	
31-34	IIFF	0 to 1 phi.	
37-40	IIFF	1 to 2 phi.	
43-46	IIFF	2 to 3 phi.	
49-52	IIFF	3 to 4 phi.	
55-58	IIFF	>4 phi.	
61-64	IIFF	4 to 8 phi.	
67-70	IIFF	≥8 phi.	
73-76	IIFF	$CaCO_3$, percent by weight.	

Notes:
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.

Phi. = $-\log_2(d)$, where d is the grain diameter in mm.
>-1ϕ = Gravel
-1 to 0ϕ = Very coarse sand
0 to 1ϕ = Coarse
1 to 2ϕ = Medium sand
2 to 3ϕ = Fine sand
3-4ϕ = Very fine sand
>4ϕ = Silt + clay size
4 to 8ϕ = Silt
≥8ϕ = Clay size

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 820 MARINE GEOLOGY - BOTTOM SEDIMENT CLAY MINERALOGY

COLUMNS	ENTRY	DESCRIPTION
1- 3	820	File code.
4-16	XXX...XXX	Sample number.
19-22	IIFF	Percent (%) Smectite.
26-29	IIFF	Percent (%) Chlorite.
33-36	IIFF	Percent (%) Vermiculite.
40-43	IIFF	Percent (%) Mixed Layer Minerals.
47-50	IIFF	Percent (%) Illite.
54-57	IIFF	Percent (%) Kaolinite.

Notes:
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = XX.XX.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 825 MARINE GEOLOGY - SUSPENDED SEDIMENT CLAY MINERALOGY

COLUMNS	ENTRY	DESCRIPTION
1- 3	825	File code.
4-16	XXX...XXX	Sample number.
17	I	1 = TOP.* 2 = BOTTOM.*
19-22	IIFF	Percent (%) Smectite.
26-29	IIFF	Percent (%) Chlorite.
33-36	IIFF	Percent (%) Verniculite.
40-43	IIFF	Percent (%) Mixed Layer Minerals.
47-50	IIFF	Percent (%) Illite.
54-57	IIFF	Percent (%) Kaolinite.

Notes:

X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = XX.XX.

* Top = Near surface sample (about 1 m depth).
Bottom = Near bottom sample.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 951 NEAR SURFACE AND BOTTOM WATER TEMPERATURE, SALINITY, AND DENSITY DATA - BENTHIC CRUISES

COLUMNS	ENTRY	DESCRIPTION
1- 3	951	File code.
4-16	XXX...XXX	Sample number.
21-25	IIFFF	Near surface salinity (ppt).
28-31	IIFF	Near surface temperature (°C).
34-36	III	Depth of near bottom sample (m).
39-43	IIFFF	Near bottom salinity (ppt).
46-49	IIFF	Near bottom temperature (°C).
52-55	IIFF	Near surface Sigma-T.
58-61	IIFF	Near bottom Sigma-T.

Notes:

X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = XX.XX.
Sigma-T = $(\rho-1) \times 10^3$ g/cm^3, where ρ is the density of sea water based on temperatures and salinity relations.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 952 NEAR SURFACE AND BOTTOM WATER TEMPERATURE, SALINITY, AND DENSITY DATA - WATER COLUMN CRUISES

COLUMNS	ENTRY	DESCRIPTION
1- 3	952	File code.
4-16	XXX...XXX	Sample number.
21-25	IIFFF	Near surface salinity (ppt).
28-31	IIFF	Near surface temperature (°C).
34-36	III	Depth of near bottom sample (m).
39-43	IIFFF	Near bottom salinity (ppt).
46-49	IIFF	Near bottom temperature (°C).
52-55	IIFF	Near surface Sigma-T.
58-61	IIFF	Near bottom Sigma-T.

Notes:
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = XX.XX.
Sigma-T = $(\rho-1) \times 10^3$ g/cm^3, where ρ is the density of sea water based on temperature and salinity relations.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 953 STD AND SIGMA-T DATA - BENTHIC CRUISES

COLUMNS	ENTRY	DESCRIPTION
1- 3	953	File code.
5-17	XXX...XXX	Sample number.
19-22	IIII	Time of profile (EST).
24-25	II	Card number.
26-27	II	Total number of cards for profile.
29-31	III	Depth of reading (m).
33-36	IIFF	Temperature (°C).
38-42	IIFFF	Salinity (ppt).
44-47	IIFF	Sigma-T for above temperature - salinity pair.

Notes:
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = XX.XX.
Sigma-T = $(\rho-1) \times 10^3$ g/cm^3, where ρ is the density of sea water based on temperatures and salinity relations.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 954 STD AND SIGMA-T DATA - WATER COLUMN CRUISES

COLUMNS	ENTRY	DESCRIPTION
1- 3	954	File code.
5-17	XXX...XXX	Sample number.
19-22	IIII	Time of profile (EST).
24-25	II	Card number.
26-27	II	Total number of cards for profile.
29-31	III	Depth of reading (m).
33-36	IIFF	Temperature (^{o}C).
38-42	IIFFF	Salinity (ppt).
44-47	IIFF	Sigma-T for above temperature - salinity pair.

Notes:
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = XX.XX.
Sigma-T = $(\rho-1) \times 10^3$ g/cm^3, where ρ is the density of sea water based on temperature and salinity relations.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 961 WATER COLUMN - TRANSMISSOMETER PROFILES

COLUMNS	ENTRY	DESCRIPTION
1- 3	961	File code.
4-16	XXX...XXX	Sample number.
17-20	HHMM	Time of observation (HH = hours; mm = minutes).
21-23	III	Depth of reading (m).
24-26	III	Percent transmission.
27-29	III	Depth of reading (m).
30-32	III	Percent transmission.
33-35	III	Depth of reading (m).
36-38	III	Percent transmission.
39-41	III	Depth of reading (m).
42-44	III	Percent transmission.
45-47	III	Depth of reading (m).
48-50	III	Percent transmission.
51-53	III	Depth of reading (m).
54-56	III	Percent transmission.
57-59	III	Depth of reading (m).
60-62	III	Percent transmission.
63-65	III	Depth of reading (m).
66-68	III	Percent transmission.
69-71	III	Depth of reading (m).
72-74	III	Percent transmission.

FILE 961 WATER COLUMN - TRANSMISSOMETER PROFILES (cont'd)

COLUMNS	ENTRY	DESCRIPTION
75-77	III	Depth of reading (m).
78-80	III	Percent transmission.

Notes:
X = Unspecified numeric entry.
I = Integral value.

This card may be repeated as often as required in order to describe the transmissometer profile.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 962 MET-OCEAN - PHYSICAL DATA, WATER COLUMN CRUISE LIGHT PENETRATION VALUES

COLUMNS	ENTRY	DESCRIPTION
1- 3	962	File code.
4-16	XXX...XXX	Sample number.
19-25	IIIIISE	On-deck light value (foot candles).
28-30	IIF	Depth in meters at 99% penetration.
33-35	IIF	Depth in meters at 50% penetration.
38-40	IIF	Depth in meters at 1% penetration.
44-56	XXX...XXX	Sample number.
59-65	IIIIISE	On-deck light value (foot candles).
68-70	IIF	Depth in meters at 99% penetration.
73-75	IIF	Depth in meters at 50% penetration.
78-80	IIF	Depth in meters at 1% penetration.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.
S = Sign of exponent, E = Exponent value; thus, IIISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE 963 MET-OCEAN - PHYSICAL DATA, METEOLOGICAL AND OCEANOGRAPHIC OBSERVATIONS

COLUMNS	ENTRY	DESCRIPTION
1- 3	963	File code.
4-16	XXX...XXX	Sample number.
		Observation time (EST):
19-20	II	Hours
22-23	II	Minutes
26-27	II	Fishing time (min).
35-36	II	Secchi disk depth (m).
39-40	II	Forel color code.
42-46	IIISE	On-deck light (foot candles).
58	I	SS.
60-61	IF	Wave height (M).
63-67	IIII	Quarter^{o} moon.

Notes:
X = Unspecified numeric entry.
I = Integral value, F = Fractional value; thus, IIFF = xx.xx.
S = Sign of exponent, E = Exponent value; thus, IISE = (III) x 10^{SE}.

MAFLA AA550-CT7-34
SCIENTIFIC DATA FILE

FILE TAXA GENERAL TAXONOMIC I.E. - NAME CORRESPONDENCE TABLE

COLUMNS	ENTRY	DESCRIPTION
1- 4	TAXA	Taxonomic file number.
6-17	XXX...XXX	Taxonomic I.D. number.
21-70	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

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SCIENTIFIC DATA FILE

FILE TNEUS NEUSTON TAXONOMIC I.D. - NAME CORRESPONDENCE TABLE

COLUMNS	ENTRY	DESCRIPTION
1- 5	TNEUS	File code.
6-17	XXX...XXX	Taxonomic I.D. number.
21-70	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

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SCIENTIFIC DATA FILE

FILE TZOO ZOOPLANKTON I.D. - NAME CORRESPONDENCE TABLE

COLUMNS	ENTRY	DESCRIPTION
1- 5	TZOO	File code.
6-17	XXX...XXX	Taxonomic I.D. number.
21-70	AAA...AAA	Taxonomic name.

Notes:
A = Alpha-Numeric entry.
X = Unspecified numeric entry.

VOLUME II

CHAPTER 30

ARCHIVED SAMPLES

DAMES & MOORE
CONTRACT NO. AA550-CT7-34

The disposition of the Archived Samples has not been determined by BLM at time of this submission.

VOLUME II

CHAPTER 31

QUALITY CONTROL

DR. HAL PALMER
DAMES & MOORE
CONTRACT NO. AA550-CT7-34

CHAPTER 31

QUALITY CONTROL

by

Harold D. Palmer
Technical Committee Chairman
Dames & Moore

BUREAU OF LAND MANAGEMENT

Contract AA550-CT7-16

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ABSTRACT

Quality Control (QC) measures were implemented by means of a Technical Committee established at the initiation of the MAFLA Program. Site visits, interviews and laboratory inspection at each Principal Investigator's (PI) facility led to a program of testing and monitoring which ensured the highest quality of analytical performance. Although analytical QC was established by each PI (calibrations, spiking, blanks, etc.) various standards were exchanged between laboratories conducting trace metals sediment and high molecular weight hydrocarbon analyses to ensure analytical precision.

An independent QC laboratory received 45 samples from the three benthic cruises and from archived materials. Seven analyses were performed, and reported to the BLM under separate contract. Contaminant samples from on-board ship were collected and stored for possible anlayses should contamination of actual samples be suspected. Such analyses were not required.

For program of this magnitude, the Committee approach to QC provides adequate surveillance and control over complex analytical tasks in numerous laboratories nationwide.

INTRODUCTION

PURPOSE OF QUALITY CONTROL (QC)

In industry, the purpose of Quality Control (QC) practice is to assure that a product meets certain prescribed standards before it reaches the customer. QC is thus an integral function which is exercised during the various phases of production. Within the Benchmark surveys conducted for the Bureau of Land Management (BLM), the product is the final report containing rhe results and interpretations of numerous Principal Investigators (PI's), and QC during the execution of all aspects of the Benchmark studies must be no less rigorous than that exercised in the manufacturing of a product marketed to the public. Indeed, the complexity inherent in a program conducted at the scale of Benchmark surveys demands careful attention to analytical detail as well as precautions in sample collection, storage and handling.

For this purpose, Dames & Moore established QC practices in all aspects of sample flow, from the moment of collection to the time of analyses or archiving. The methods of sample collection, and the precautions taken by each PI in their treatment of materials both on-board ship and in the laboratory, have been described in the preceding chapters. The purpose of this chapter is to summarize those aspects of QC for which Dames & Moore assumed specific responsibility under overall Program Management.

METHODS

COORDINATION IN MOBILIZATION

Upon award of the contract, the Program Manager, Dr. Thomas B. Scanland and the Technical Committee Chairman, Dr. Harold D. Palmer, conducted site visits at all PI facilities. The purpose of these visits was to establish coordination between Dames & Moore and the PI's and their staffs, to establish delivery schedules, to inspect the various facilities, and to review various aspects of record keeping to be initiated for accounting purposes. In addition, Dr. Palmer visited the Corpus Christi offices of the U.S. Geological Survey where he arranged for the transmittal of "standard" materials from the custody of the USGS to both Dr. Doyle (Sediments, University of South Florida) and Dr. Trefrey (Trace Metals in sediment, TerEco). These materials were designated by the BLM for interlaboratory calibration analyses, and are described in that section.

SAMPLE ACCOUNTABILITY

Each PI was made responsible for samples in his or her custody, and each shipment was logged in or out of each facility as the materials were transferred for analyses. Sample designations were by code, such that each sample had a unique number (see Feldhausen copy).

TECHNICAL COMMITTEE

The Technical Committee established by Dames & Moore was designed to function as a review and advisory group whose responsibilities included the periodic inspection of analytical laboratories and a review of the data which they produced. These data include the QC analyses of reagents, solvents, an glassware as well as the procedural blanks and interlaboratory calibration materials circulated between the appropriate laboratories. The Technical Committee consisted of the following individuals:

Dr. Harold D. Palmer, Chairman, Dames & Moore
Dr. David L. Johnson, Chemistry, The State University of New York
Dr. Donald J. Reish, Biology, California State University, Long Beach
Dr. James I. Marlowe, Geology, Dames & Moore
Dr. Thomas f. McKinney, Ships and Logistics, Dames & Moore

Drs. Reish and Johnson were present at all Quarterly meetings, ensuring continuity in their association with the PI's. Drs. Marlowe and McKinney were represented by Dr. Palmer.

LABORATORY INSPECTIONS

Within three weeks of the contract award, members of Dames & Moore's Technical Committee visited each laboratory assigned a task within either the Chemistry or Biology disciplines. Dr. Reish, an expert in benthic biology, inspected the facilities at Dauphin Island (University of Alabama) and in St. Petersburg (University of South Florida). Dr. Johnson visited both Science Applications Incorporated (SAI) and Analytical Research Laboratories, Incorporated (ARLI) in California, the laboratories of the University of South Florida, and those of TerEco and Texas A&M University in College Station Texas. During the early phases of this program, we were assisted by Dr. C.S. Giam, Texas A&M in the formulation of analytical tasks. In this capacity, he also visited SAI and ARLI in September 1978. Laboratories assigned tasks of zooplankton (Uniersity of Florida), demersal fish and neuston (University of West Florida) and foraminifera and ATP (University of Miami) were visited by Dr. Scanland. Dr. Marlowe inspected the geology laboratory at the University of South Florida.

With only a few reservations, the Committee Chairmen endorsed the techniques and facilities of the PI's. Perhaps the greatest concern dealt with the unpartitioned laboratory space in ARLI. The real possibility of sample cotamination through airborne particulate fall-out prompted both the construction of a fully enclosed clean bench and the performance of an exposure test in which plates (test surfaces) were exposed for various periods to a variety of environments within ARLI and subsequently analyzed for metals fall-out. The results proved that contamination was minimal with newly installed enclosure for clean bench operation and that all plates displayed levels of the trace metals within the acceptable range of analytical standard deviation. A full report of this test appears in the Appendix to this chapter. Other aspects of concern to the Technical Committee were minor points such as dedication of space and equipment, overall cleanliness and similar points which were resolved during or shortly after their visits.

MODIFICATIONS TO THE WORK SCOPE

In the course of establishing analytical procedures and sampling techniques at the onset of the program, several departures from the specific contract work scope were deemed desirable from the standpoint of efficiency and/or cost effectiveness. Examples included modifications to the sample treatment for ATP on-board ship, changing the size of trawl boards, changing the normality of HNO_3 in the treatment of sediment samples for trace metal analyses, extending the time for digestion of zooplankton samples in trace metal extractions, and other minor modifications which were considered as improvements over the contract instructions. In every case, a letter requesting such a change, and documentation from the PI to explain why the modification was desirable, were submitted by the Program Manager to the BLM Contracting Officer (Mr. Peter Niebauer, later Mr. Jerry Rourke) and his authorized representative (COAR, Dr. Ed Wood) prior to any change in technique or approach. Upon written authorization from BLM, the appropriate changes were initiated.

SELECTION OF SAMPLES FOR COMBINED GAS CHROMATOGRAPHY/MASS SPECTROSCOPIC ANALYSIS

The contract stipulates that 10% of the total number of samples designated for High Molecular Weight Hydrocarbon analyses (HMWHC) - approximately 79 samples in all - would be subjected to combined gas chromatographic/mass spectroscopic (GM/MS) analyses. The intent was to provide further definition of substances which appeared as anomalous and/or interesting peaks on chromatograms which could not be identified by conventional GC techniques employing Kovat's Indices and integration of the area under defined peaks. These "unresolved" peaks may be identified by the more definitive MS analysis.

As a result of a conference between Program Management and the Technical Committee, it was determined that the selection criteria for choosing samples for GC/MS could be two-fold:

1) Five percent of the samples which showed anomalous and/or ineresting peaks would be identified for combined GC/MS analyses, thus providing new insights into the nature of the "unresolved" substances.

2) The remaining five percent would be selected at random to provide confirmation of identications established through the routine GC analyses.

The results of these analyses are contained in the appropriate chapters dealing with HMWHC determinations.

INTERLABORATORY CALIBRATIONS AND COMPARISONS

Because it was ultimately necessary to combine the various data from numerous laboratories participating in the program, the Technical Committee Chairman, Dr. Palmer, established a policy of exchange of materials between appropriate laboratories performing similar or identical analyses. The exchange of materials employed as "standards" in other BLM programs, the analyses of aliquots of MAFLA PI's materials by other laboratories, and the analysis of "official" National Bureau of Standards (NBS) or USGS standards ensured a sound basis for comparison for both method efficiency and quantitative precision. In this regard, various laboratories performed analyses according to the following:

Sediment Trace Metals

As a result of the South Texas Outer Continental Shelf (STOCS) program of the USGS, Corpus Christi, bulk sediment samples are maintained by that laboratory for purposes of calibration. Two aliquots of these materials, cited as MAG-1 and COMP I/III, were forwarded by Dr. Charles Holmes, USGS, to Dr. Trefry of TerEco. The outcome of these analyses are presented in the Appendix to this chapter. The methods employed by Dr. Trefry were identical to those used for MAFLA materials.

NBS Standards for TM

Samples of Bovine Liver, NBS catalog number 1577, were forwarded by that agency to ARLI in March, 1978. Upon completion of their analyses, ARLI forwarded sealed portions of the same standard to Dr. Betzer. Results of their analyses are presented in their respective chapters, and ARLI's reproduced under Results, to follow.

Sediment Grain Size

The USGS Corpus Christi office also maintains a suite of STOCS sediment samples for which they have grain size analyses data. Dr. Gerald Shideler, sedimentologist with that office, kindly forwarded aliquots of six samples to Dr. Doyle for interlaboratory comparison. As shown in the Results section, there is some disagreement between the two analyses. This was anticipated before the analyses were undertaken, since Dr. Doyle uses sieves and pipette techniques for obtaining grain size data for sand and silt-clay, respectively, whereas Dr. Shideler employes a settling tube and Coulter Counter in obtaining the same information. BLM was informed of the certainty of non-comparability prior to the analyses. The discrepancy arises due to the method by which sediment particles are "measured." Dr. Doyle's technique employes mechanical separation through nested sieves, with the "fine fraction" consisting of silt and clay particles (diameters less than 62 microns) then being suspended in water and sized by settling rates over a period of 24 hours. Dr. Shideler uses settling velocities to measure the size of sand-sized materials, and an electronic particle counter to determine the size of fine fractions by displacement of a volume of electrolyte.

We feel that the size analyses performed by Dr. Doyle are satisfactory, and certainly fulfill the requirements of the contract. Numerous studies on the theory of sediment size analyses have been published, and a review of the subject in this report is neither necessary nor desirable. Several of the more recent references are cited at the close of this chapter.

HMWHC Standards

Two materials were circulated as reference standards for HMWHC analyses. The first was prepared by ARLI from five replicate samples of Kuwait Crude Oil (American Petroleum Institute Reference Oil) by fractionation into aliphatic and aromatic fractions. These were run by ARLI, and aliquots were provided to Dr. Jeffrey at Texas A&M for similar analyses. The test format appears in a subsequent portion of this chapter, and it is discussed in both ARLI's and Dr. Jeffrey's chapters. In addition, a standard hydrocarbon material used in other programs by ARLI (their standard HC STD 7-13-77) was used by both ARLI and Dr. Jeffrey in GC calibrations. This material contains the following carbon compounds used as standards:

Solvent: Benzene

Constituents	Concentration, mg/ml
n-C17	1.326
n-C18	0.869
n-C24	0.888
n-C32	0.830
Pristane	1.136
Phytane	0.688

The interlaboratory calibration program is described in detail in the Appendix to this chapter.

A second hydrocarbon standard was prepared at BLM's direction by Supelco with the intention of providing a synthetic reference mixture for the use of all BLM HC PI's. Although some Program PI's received ampoules of the materials, (ARLI received 3) they were instructed to refrain from analyzing these standards until notified by BLM. To date they have not been examined.

During the course of this program, two memoranda were received from the BLM Branch of Environmental Studies regarding precaustions in the analyses of HMWHC. The first, dated 15 August, 1977 from the Branch Chief Dr. Monastero, included precaustions in the use of GC electronic integrators which led to errors of integration over broad peaks of clustered unresolved materials. The second, from Mr. Cimato of the same office, included a description of the "dead space" problem in Hewlett-Packard glass capillary GC inlet systems. Where appropriate, the precautions and/or applications described in these two memoranda were implemented within the MAFLA program.

INDEPENDENT QC LABORATORY

The BLM has selected the Center for Bio-Organic Studies of the University of New Orleans as their HMWHC QC laboratory for the MAFLA (and other) benchmark surveys. At the initiation of this program, it was intended that a similar laboratory be identified for trace metals. No such selection was made by the BLM, and no TM external QC was implemented.

A total of 45 samples from the three benthic cruises were submitted to the QC laboratory. Of these, 16 were bottom sediments, 10 were macroepifauna and 19 were the demersal fish dusky flounder (Syacium papillosum). Of this number, 12 sediment samples and 5 epifaunal samples (4 being dusky flounder) were analyzed at the time of this report. Two of the sediment samples were archived materials from the previous MAFLA Program (summer 1976 cruise). The results of these analyses have been provided to the BLM under a separate contract in a report by Drs. J.L. Laseter and E.B. Overton. A copy of this report was received by Dames & Moore on 14 June, 1978. Inspection of the results and a comparison with those data from ARLI's analyses will be found in the Chapters on HMWHC. It is clear that no major discrepancies between data sets exists, and that minor differences may be attributed to experimental and procedural error inherent in analyses conducted by different laboratories.

CONAMINANT SAMPLES

Sample recovery and handling aboard ship always exposes the materials to potential contamination from a variety of sources. Special precautions were taken during all operations at sea, and a suite of substances which could conceivably contaminate samples was recovered from the vessel at the time of sampling operations. The following samples are stored frozen at ARLI.

ARLI ID# 97046-N	Sample Description	Status*
-1	Grease	A
-2	Hydraulic Fluid & Absorbant	A
-3	Hydraulic Fluid	A
-4	Industrial Detergent	A
-5	Grease	A
-6	Diesel Fuel	A
-7	Sediment Exposed to Exhaust	A
-8	Paint Chips	A
ARLI ID# 117103-N	Sample Identification	Status
-43	2960 01 4971117 Algal slick	A
-44	2960 02 4971117 Algal slick	A
-45	Ship's paint	A
-46	Anchor rust	A
ARLI ID# 28073-N	Sample Description	Status
-108	2101 9745 80220 Bearing Seal	A
-109	2101 9745 80220 Lube Oil	A
-110	2101 9745 80218 Hydraulic Fluid	A
-111	2101 9744 80220 Fuel Oil	A
-112	2101 9746 80220 Bilge Water	A

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*A = freezer storage

Inasmuch as these materials are considered "contingency" samples, that is, they would be run only if contamination was suspected, they have been retained until all analyses are complete. To date we do not consider any analyses to indicate contamination and no analyses of the ship's samples have been performed.

LABORATORY ANALYSES

Within each laboratory, certain QC functions were performed as a matter of routine. For example, in the HMWHC analyses spiking of samples and procedural blanks were run during the analyses of all materials. Dr. Betzer performed several experiments for trace metals in zooplankton to evaluate statistical aspects of different sample preparation schemes (grinding, centrifugation, etc.). Dr. Ivester used aliquot counting in comparison with whole counting techniques to test the repeatability of sorting and classifying. These, and similar internal QC efforts were proposed to and authorized by the Program Manager after approval of the BLM officers for this program. A more detailed description of these activities will be found in various chapters of this report.

One significant QC problem was identified in the anlyses of suspended particulates by Dr. Betzer. In extracting the more refractory portions of samples, the materials are routinely stored in linear polyethylene volumetric flasks. High procedural blanks suggested a source of zinc contamination and testing of the flasks revealed them as the source of zinc. For this reason no zinc data were reported. A discussion of this problem is contained in Dr. Betzer's Chapter.

RESULTS

Establishing Quality Control was recognized as a vital function of the MAFLA Benchmark Survey and from the first site visits by the Technical Committee through the entire study, Program Management stressed adherence to QC standards within each PI's laboratory. Inasmuch as it is difficult to quantify the results of the QC program, the reader is referred to descriptions of precautions, standards, and other aspects of an analytical nature which appear in the PI's contributions. The results of the independent QC laboratory are not included in this report, but are available through the BLM.

Because the greatest discrepancy in interlaboratory comparisons lies in the area of sediment grain size, those results are presented below. A description of the differing techniques is included under Methods, and will not be repeated here. The reader may wish to consult references treating the theory of grain-size analyses which are cited at the end of this chapter.

SEDIMENT GRAIN SIZE INTERLABORATORY COMPARISON

USGS Sample No.		% Sand	% Silt	% Clay
018G	USF	19.14	34.42	46.44
	USGS	30.72	52.21	17.07
052G	USF	1.81	35.63	62.56
	USGS	1.57	60.62	37.82
062G	USF	5.49	40.37	54.14
	USGS	3.72	75.05	21.23
140G	USF	0.96	38.20	60.95
	USGS	0.48	57.22	42.30
208G	USF	52.32	12.32	35.36
	USGS	66.73	19.50	13.77
220G	USF	63.10	9.18	27.72
	USGS	66.73	19.50	13.77

Results of the analyses of NBS standard 1577, Bovine Liver, by ARLI are presented below. Agreement is excellent, lending confidence to the trace metals analyses performed by the PI. Dr. Betzer's results of similar analyses are presented in his chapter.

RESULTS OF TRACE METALS ANALYSIS OF NBS BOVINE LIVER STANDARD

Element	Bovine Liver (NBS), ppm	Bovine Liver (ARLI)*, ppm
Cd	0.27 ± 0.04	0.34 ±0.03
Cr	0.088 ± 0.012	0.06 ±0.02
Cu	193.0 ±10.0	184.0 ±2.0
Fe	268.0 ± 8.0	263.0 ±5.0
Ni	---	0.39 ±0.07
Pb	0.34 ± 0.08	0.4 ±0.1
Zn	130.0 ±13.0	131.0 ±2.0

---

*Average of 3 determinations ± standard deviation

DISCUSSION

As a result of the rigorous QC program, Dames & Moore feels confident that the data supporting the conclusions for this third year of MAFLA surveys are as accurate as is possible under the analytical techniques required by the BLM. The formation of a Technical Committee, and its early involvement with the PI's through laboratory inspections and interviews, is credited with the implementation and continued supervision of laboratory activities.

An example of the utility of such a Committee is provided by the requirement of an airborne particulate fall-out test in the ARLI laboratory. The possibility of contamination was recognized, and appropriate remedial measures were taken such that quality assurance was guaranteed in the trace metals work performed by that PI. That report appears in the Appendix to this chapter.

An aspect of the overall QC program for this Benchmark study which could be improved is that of coordination with the independent QC laboratory. At the outset, it appeared reasonable to have a representative from that laboratory present at Quarterly Meetings, and to establish contact between that laboratory and PI's involved in HMWHC analyses. Such proposals were rejected by the BLM, and the Center for Bio-Organic Studies remained autonomous for the duration of the study.

A second aspect of QC which was not exercised was that of including a BLM representative on-board the survey vessel during sample collection activities. It is felt that such an observer would provide the BLM with valuable first-hand experience in the methods and techniques of sample recovery and handling. We would recommend that, whenever possible, a BLM scientist become part of the crew for at least one leg of each cruise performed under similar contracts.

CONCLUSIONS

The effectiveness of applying QC procedures to a complex program involving numerous facilities and individuals has been demonstrated. In such a program, adherence to analytical practices required by the BLM must be maintained, and frequent calibration, comparison and data exchange are necessary. At the scale of this survey, control of such activities is best maintained by an individual, with appropriate assistance, whose prime responsibility is QC. This was achieved by the formation of a Technical Committee charged with the responsibility for monitoring performance and reviewing data. Given the magnitude of the MAFLA (and other) Benchmark Surveys, and the geographic separation of the PI's, the Committee concept offered the most efficient QC approach, and it is suggested that future studies of this scale establish a similar body to ensure adequate QC.

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APPENDICIES

A. Correspondence and data relating to the interlaboratory comparisons of sediment samples for Trace Metals. The letter from Dr. Holmes is included in order to provide background data on the USGS Standards run under the previous contract. Analytical comparisons between Dr. Trefry's laboratory and Dr. Chow, Scripps Institution of Oceanography and Dr. Patterson of the California Institute of Technology are included.

B. Proposed interlaboratory calibration program for HMWHC analyses by ARLI.

C. ARLI Report on the results of airborne fall-out tests.

APPENDIX A

Trace Metals in Sediments

Interlaboratory Comparisons

March 3, 1849

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

Office of Marine Geology
P. O. Box 6732
Corpus Christi, Texas 78411

August 16, 1977

Dr. Harold D. Palmer
Dames & Moore
7101 Wisconsin Avenue, Suite 700
Washington, D.C. 20014

Dear Dr. Palmer:

Enclosed is a letter from Paul Boothe at Texas A&M University documenting the exchange of standards in July and a copy of the results completed in the fall, 1976. We feel that there is excellent agreement between the two sets of data and this information serves as a satisfactory fulfillment of the BLM requirement for interlaboratory standardization.

Yours truly,

Charles W. Holmes

TEXAS A&M UNIVERSITY
COLLEGE OF GEOSCIENCES
COLLEGE STATION, TEXAS 77843

Reply to
Department of
OCEANOGRAPHY
Telephone (713) 845-7211

1359

July 23, 1976

Dr. Charles Holmes
U. S. Geological Survey
P.O. Box 6732
Corpus Christi, Texas 78411

Dear Chuck,

Enclosed are our five samples for the intercalibration exercise. The sample numbers and description are as follows:

1. Zooplankton dated May 13, 1976
2. 4517 TE5 shrimp
3. 4924 TE5 shrimp
4. 4922 TE9 starfish
5. Orchard Leaves NBS #1571

Also I would appreciate your analyzing Bovine Liver NBS #1577 as we discussed. You said that you had a supply of the Bovine Liver so I did not include any.

Thank you very much for your assistance and cooperation.

Sincerely,

Paul N. Boothe

Paul N. Boothe

PNB:lmm

Table 6. Intercalibration samples

Lab	Ba	Cd	Cr	Cu	Fe	Mn	Ni	Pb	V	Zn
					MAG I					
USGS, Corpus Christi	540±1	0.27±.07	108±3	29.0±5	51200±300	666±20	64.5±10	19.7±2	128±8	139±8
Texas A&M	-	-	120±5	30.3±0.6	49300±200	762±24	61.5±3	28.8±2.2	-	140±3
Prof. Paper 841	493	-	121±20	48.8	52400	-	50.7	20.4	132	102
					G-2					
USGS, Corpus Christi	1434	0.11	10.3	7.5	-	-	4.3	25.8	-	87.1
Prof. Paper 841	1532	-	8.0	9.7	24400	410	2.4	31.3	44.6	68.2
					STOCS I/III					
USGS, Corpus Christi	528±80	0.24±.04	64±1	16.4±3	32800	404	35.4±6	16.4±8	99±8	92±2
Texas A&M	-	-	71±5	17.5±.2	32100±200	468±1	30.9±1	25±1	-	87±2
					#4922 Starfish					
USGS, Corpus Christi	-	0.34±.08	4.4±1.0	7.3±1.0	223±20	189±70	1.8±0.2	0.74	-	41.8
Texas A&M	-	0.40	0.6	14	273	-	-	0.9	-	-
					#4517 Shrimp					
USGS, Corpus Christi	-	0.02±.01	3.6±0.5	17.3±18	104±13	0.8±0.03	2.0±.3	0.1±.03	-	47.7
Texas A&M	-	0.04	-	20	-	-	-	0.1	-	-
					#4924 Shrimp					
USGS, Corpus Christi	-	0.05±0.01	3.6±0.2	12.6±0.7	60±8	1.0±.08	2.4±0.3	.29±.16	-	45.4
Texas A&M	-	0.05	-	15	-	-	-	.2	-	-
					Zooplankton					
USGS, Corpus Christi	-	0.32±.02	7.8±1.0	28±0.3	170±36	5.50±0.55	3.1±1.1	0.36±14	-	61.2±5
Texas A&M	-	0.40	-	35	-	-	-	0.3		49

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WATER QUALITY CONSULTANTS
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GLOBAL OCEANOGRAPHIC STUDIES
Coastal Zone to the Abyss

July 22, 1977

Dr. Harold D. Palmer
Dames and Moore
Suite 700, 7101 Wisconsin Avenue
Washington, DC 20014

Dear Dr. Palmer:

Intercalibration is certainly fundamental to attaining reliable data for environmental samples. During our previous work on MAFLA sediments, we intercalibrated with Drs. Peter Betzer (Univ. So. Fla.) and Douglas Segar (NOAA, Miami) using one U.S.G.S. standard rock (AGV-1) and two MAFLA samples. We also compared results on four of the MAFLA sediment samples with Dave Robertson (Batelle NW). The results of these intercalibrations were generally acceptable and were reported as parts of the first and second years' final reports (MAFLA CY 1974 and 1975).

In preparation for the upcomming MAFLA work and as part of the STOCS-BLM study, we recently intercalibrated with Dr. Charles W. Holmes (U.S.G.S., Corpus Christi) using a new U.S.G.S. standard (MAG-1) and one STOCS sediment sample (COMP 1/III). Our results for these samples and a description of the analytical methods used are enclosed and may be interfaced with the data you have received from Chuck Holmes.

Cursory inspection of the data showed the comparative results to be quite good. We are now processing two additional STOCS sediment samples (COMP 4/IV and COMP 6/IV) and will continue to intercalibrate with the U.S.G.S., Corpus Christi, particularly with respect to leachable metal concentrations.

We also recently began an intercalibration program with Drs. C.C. Patterson and T.J. Chow of the Southern California BLM program. Some initial results on Standardized Sample 727 are presented on an attached enclosure. We will be analyzing additional elements on Sample 727 and also plan to analyze Standardized Sample 565 and the California Bight Marine Sediment Standard which we have received in our laboratory.

Intercalibration is an integral part of our MAFLA-BLM program, and we will keep you informed of new comparisons or problems pertinent to these studies.

Sincerely,

John H. Trefry

John H. Trefry, Ph.D.

JHT:ikh
Enclosures

Analytical Techniques

Total sediment metal concentrations were determined by atomic absorption spectrophotometry (AAS) following dissolutin with HF and $HClO_4$. Each sample was analyzed in triplicate. The powered samples (0.3 -0.5 g) were ashed at 375°C for 6-8 hours and then transferred to teflon beakers to which 3 ml HF and 1 ml $HClO_4$ were added. The beakers were covered with teflon watch glasses and heated for 4-5 hours. The watch glasses were then removed and the samples were brought to dryness. The acid treatment was repeated and the dried residue was redissolved with 1 ml 16N HNO_3 to which aliquots of deionized water were gradually added and heated strongly. After sufficient heating, the residue-free solution was diluted to 25 ml for analysis by AAS.

During AAS analysis, background absorbance, due to molecular absorption, was monitored by simultaneously measuring the abosrbance of the analytical wavelength and that of a nearby non-resonance line. This technique has been shown to correct for absorbance due to a variety of matrices such as that of 10,000 ppm Ca.

TerEco (MAFLA) Results in U.S.G.S. (STOCS) and TerEco (MAFLA) Sediment Intercalibration Program.

Sample	Fe (%)	Mn (ppm)	Cu (ppm)	Ni (ppm)	Pb (ppm)	Co (ppm)	Zn (ppm)	Cr (ppm)
COMP 1/III	3.23	468	17.7	30.3	24.1	12.6	86	71
	3.19	469	17.5	32.0	25.4	13.9	86	67
	3.22	468	17.4	30.4	25.7	14.5	90	76
COMP 1/III mean	3.21	468	17.5	30.9	25.1	13.7	87	71
std. dev.	(±0.02)	(±1)	(±0.2)	(±1.0)	(±0.9)	(±1.0)	(±2)	(±5)
MAG - 1	4.93	789	29.7	60.2	31.2	24.4	143	117
	4.96	752	30.6	59.4	27.1	26.3	140	-
	4.95	745	30.7	65.0	28.0	25.3	137	124
MAG - 1 mean	4.95	762	30.3	61.5	28.8	25.3	140	120
std. dev.	(±0.02)	(±24)	(±0.6)	(±3.0)	(±2.2)	(±1.0)	(±3)	(±5)

Initial Results of Sediment Intercalibration Program with So. California BLM Investigators

Investigator	Cu (ppm)	Pb (ppm)	Zn (ppm)	Ni (ppm)
Trefry (TerEco)	23.3	15.6	73	26.3
	22.5	16.5	79	27.0
	23.5	15.2	73	6.7
	23.1 ± 0.5	15.7 ± 0.7	75 ± 4	26.6 ± 0.4
Chow (SIO)	24	23	69	18
Patterson (Cal.Tech.)	-	14.9	-	-
		15.1		

APPENDIX B

Proposed Interlaboratory Calibration Program for High Molecular Weight Hydrocarbon Analyses

PROPOSED INTERLABORATORY CALIBRATION PROGRAM FOR HIGH MOLECULAR WEIGHT HYDROCARBON ANALYSES

Laboratories Involved:

1) Analytical Research Laboratories, Inc.
   Monrovia, California
   Co-P.I. - G. F. Gould - M. L. Moberg

2) Dept. of Oceanography
   Texas A&M University
   College Station, Texas
   P.I. - L. M. Jeffrey

Phase I: To be completed prior to analysis of any samples

A. Calibration of Gas Chromatographs

Gravimetrically-prepared hydrocarbon standards will be used to establish response factors for GC instruments in each laboratory. An aliphatic hydrocarbon standard (HC STD 7-13-77) has been prepared at ARLI for this purpose (Attachment). Two sealed ampoules containing this standard have been sent to the laboratory at Texas A&M University.

B. Interlaboratory Calibration

1. Five (5) replicate samples of Kuwait Crude Oil (API Reference Oil) will be fractionated into aliphatic and aromatic fractions.
2. Inject each sample into a gas chromatograph.
3. Report
   a. Gravimetric yields of aliphatic and aromatic fractions
   b. Weight-fractions (mg/g of crude oil) for each resolved peak in the aliphatic fraction. Data to include retention times, Kovats Indices and constituent assignments.

c. Weight-fractions (mg/g of crude oil) of total aliphatic material identified and quantified by GC.

d. Weight-fraction (mg/g of crude oil) of total GC unresolved aliphatic material.

e. Total weight-fraction (mg/g of crude oil) of aliphatic material recovered by GC (sum of items 3 & 4).

f. Odd/even ratio of n-alkanes.

g. Weight-% of n-alkanes and weight-% of isoprenoid alkanes (pristane and phytane) in GC recovered aliphatics.

h. Pristane/phytane, pristane/n-C_{17}, phytane/n-C_{18} ratios and GC resolution of last two pairs.

i. Normal/branched alkane ratio.

j. Data for aromatic LC fraction per items b, c, d, and e above.

k. Averages and standard deviation will be reported for above items. Selected major peaks only will be reported for item b.

Phase II: To be completed prior to analysis of samples from Cruise III.

Details for this phase will be determined at a later date. It may involve an exchange of sample extracts prepared in the early stages of the program. On it might be simple a repeat of Phase I.

Alkane Hydrocarbon Standard

Prepared by Analytical Research Laboratories, Inc.
Monrovia, CA

Date: July 13, 1977

Composition:

Solvent: Benzene

Constituents:

	Concentration, mg/ml
n-C17	1.326
n-C18	0.869
n-C24	0.888
n-C32	0.830
Pristane	1.136
Phytane	0.688

APPENDIX C

Trace Metal Contamination of Tissue Samples by Particulate Fall-Out From the Laboratory Atmosphere

ANALYTICAL RESEARCH LABORATORIES, INC.

COMPLETE ANALYTICAL SERVICE
arli

160 TAYLOR STREET, P.O. BOX 369, MONROVIA, CALIFORNIA 91016 • (213) 357-3247

13 September 1977

Dr. Harold Palmer
Dames & Moore
7101 Wisconsin Avenue
Suite 700
Washington, DC 20014

Dear Hal:

Enclosed please find a copy of the report on Trace Metal Contamination of Tissue Samples by Particulate Fall-Out from the Laboratory Atmosphere. This study was recently completed in our laboratory and we find the results quite encouraging. By preparing the MAFLA tissue samples in the clean bench and exposing them to the atmosphere for a minimum period of time, the risk of contamination due to trace metals in atmospheric particles can be kept to insignificant levels.

Since the study was completed, an extension made of wood and polyethylene film has been constructed around the front of the clean bench (see attached photo). With this addition, the clean bench filtering system provides a supply of clean air to the bench and excess air is allowed to escape at flow level beneath the flexible walls of the extension. The bench is now even more isolated from the general laboratory atmosphere. We believe it will provide a sample preparation area quite free of sample contamination hazards approaching that of a clean room.

A copy of the report and a photo of the modified clean bench has also been sent to Dave Johnson at Syracuse. Please let me know if you have questions regarding the report or if you feel that additional tests are needed.

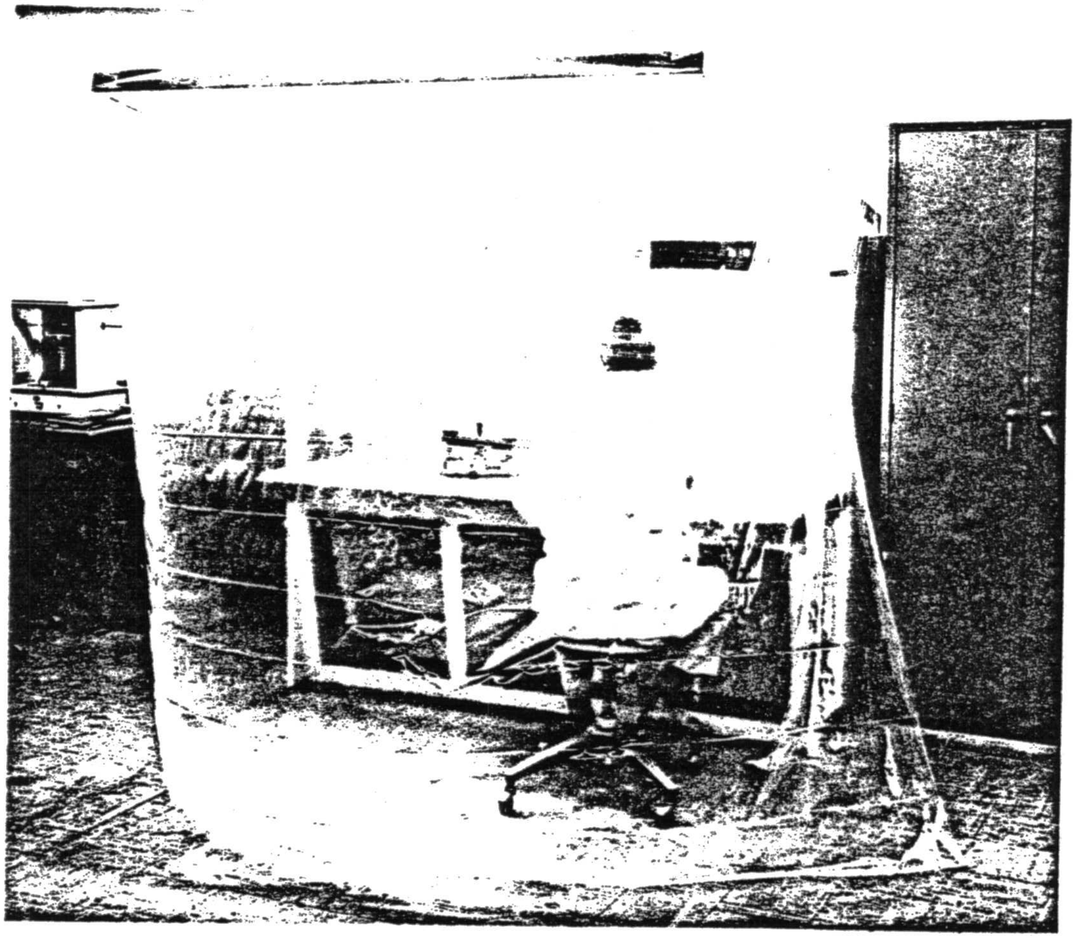
Sincerely yours,

George F. Gould

George F. Gould

4175:GFG:cjw

cc: Dr. David L. Johnson



Modified Clean Bench at ARLI

TRACE METAL CONTAMINATION OF TISSUE SAMPLES BY PARTICULATE FALL-OUT FROM LABORATORY ATMOSPHERE

September 1977

Prepared by

G. F. Gould

Analytical Research Laboratories, Inc.
160 Taylor Street, Monrovia, CA 91016

Prepared for

Dames & Moore
New Orleans, Louisiana

Third Year MAFLA Project
Bureau of Land Management Contract AA550-CT7-34

I. INTRODUCTION

The trace metal content of fish and macroepifauna collected on the MAFLA program heretofore has been reported to be at the sub part-per-million levels. For this reason a reasonably thorough evaluation was made of laboratory atmospheric particulate contamination that might contribute adversely to the collected samples. Recognizing that particulate fall-out is a discontinuous process, the particle collection times have been extended well beyond the time the average sample would be exposed to the laboratory atmosphere. In addition, the area exposed for particle collecting is much larger than that of an average sample. As a result, the tests are designed to be quite rigorous, thus providing a margin of safety of one or two orders of magnitude.

II. EXPERIMENTAL PROCEDURE

Twenty-five clean, covered, plastic petri dishes, each containing 25 milliliters of 1:10 nitric acid (Ultrex grade) solution, were divided among three different locations. One set of dishes was placed on the open laboratory bench. Another set was placed in a Farr Clean Bench where the organisms are to be prepared for digestion. The third set was placed in the fume hood where the tissues are to be digested. Some dishes were left covered throughout the tests to serve as blanks. At each location, individual dishes were uncovered for either a one- or a four-hour period as indicated in Table 1. At each location, three one-hour samples and three four-hour samples were collected. Three additional four-hour samples were collected in the clean bench to confirm the values measured in that location. Each set of three samples was collected consecutively rather than simultaneously in order to evaluate possible variations during the course of the day. The surface area of each petri dish was 61 cm^2.

Zinc was analyzed by flame AA. All other metals were analyzed by Hallow Graphite Atomizer.

Solvent and reagent blanks are given in Table 2. Deionized water and Ultrex grade nitric acid were used in these tests.

TABLE 1. Results of Tests for Trace Metal Contamination by Particulate Fall-Out from Laboratory Atmosphere

Zinc Analyzed by Flame AA; All Other Elements Determined by HGA

Location	Date	Time of Day	Duration, Hours	Pb $\mu g/10\ cm^2$	Cr $\mu g/10\ cm^2$	Cu $\mu g/10\ cm^2$	Cd $\mu g/10\ cm^2$	Ni $\mu g/10\ cm^2$	Fe $\mu g/10\ cm^2$	Zn $\mu g/10\ cm^2$
Procedural Blank	8/ 1/77			0.0014	0.0026	0.019	0.0009	0.015	0.020	0.082
Procedural Blank*	8/24/77			0.0020 ± 0.0005	0.0031 ± 0.0004	0.032 ± 0.008	0.0006 ± 0.0005	0.042 ± 0.022	0.020 ± 0.002	0.126 ± 0.012
Open Lab Bench	8/ 1/77	9-10 AM	1	0.0031	0.0030	0.18	0.0027	0.015	0.049	1.19
		11-12 M	1	0.0056	< 0.0026	0.046	0.0011	0.026	0.034	0.25
		2- 3 PM	1	< 0.0014	< 0.0026	< 0.019	< 0.0009	< 0.015	0.062	< 0.082
		9- 1 PM	4	< 0.0014	< 0.0026	< 0.019	< 0.0009	0.017	0.025	0.23
		1- 5 PM	4	0.0026	< 0.0026	0.19	< 0.0009	0.088	0.042	0.37
	8/ 2/77	9- 1 PM	4	0.0027	< 0.0026	< 0.019	0.0009	< 0.015	0.031	< 0.082
Fume Hood	8/ 1/77	9-10 AM	1	0.0053	< 0.0026	< 0.019	< 0.0009	< 0.015	< 0.020	< 0.082
		11-12 M	1	0.0044	< 0.0026	< 0.019	< 0.0009	< 0.015	< 0.020	0.099
		2- 3 PM	1	0.024	< 0.0026	< 0.019	< 0.0009	0.044	< 0.020	< 0.082
		9- 1 PM	4	0.0027	0.0026	< 0.019	< 0.0009	< 0.015	0.066	< 0.082
		1- 5 PM	4	0.0031	< 0.0026	< 0.019	< 0.0009	< 0.015	0.029	< 0.082
	8/ 2/77	9- 1 PM	4	0.0049	< 0.0026	0.051	< 0.0009	< 0.015	< 0.020	0.14

* Procedural blank listed as average of 3 blanks ± standard deviation

TABLE 1. Results of Tests for Trace Metal Contamination by Particulate Fall-Out from Laboratory Atmosphere

Zinc Analyzed by Flame AA; All Other Elements Determined by HGA

Location	Date	Time of Day	Duration, Hours	Pb μg/10 cm^2	Cr μg/10 cm^2	Cu μg/10 cm^2	Cd μg/10 cm^2	Ni μg/10 cm^2	Fe μg/10 cm^2	Zn μg/10 cm^2
Clean Bench	8/ 1/77	9-10 AM	1	0.0014	< 0.0026	< 0.019	< 0.0009	< 0.015	< 0.020	< 0.082
		11-12 M	1	< 0.0013	< 0.0026	< 0.019	< 0.0009	< 0.015	< 0.020	< 0.082
		2- 3 PM	1	< 0.0013	< 0.0026	< 0.019	< 0.0009	< 0.015	< 0.020	0.32
		9- 1 PM	4	0.0033	< 0.0026	0.022	< 0.0009	< 0.015	0.036	0.57
		1- 5 PM	4	0.0014	< 0.0026	< 0.019	< 0.0009	< 0.015	0.036	0.27
	8/ 2/77	9- 1 PM	4	< 0.0013	< 0.0026	0.036	< 0.0009	0.047	< 0.020	0.43
	8/24/77	9- 1 PM	4			< 0.032		< 0.042	< 0.020	< 0.13
		11- 3 PM	4			< 0.032		< 0.042	< 0.020	< 0.13
		1- 5 PM	4			< 0.032		< 0.042	< 0.020	< 0.13

TABLE 2. Solvent and Reagent Blanks

Solvent or Reagent Injected Directly Into HGA (Zinc Analysis by Flame)

	Pb, ppb	Cr, ppb	Cu, ppb	Ni, ppb	Cd, ppb	Fe, ppb	Zn, ppb
Deionized Water	0.7	0.09	4.5	1.7	0.7	1.5	0.00 (assigned)
Distilled Deionized Water	1.0	0.6	11.	2.5	1.5	0.2	15.
Nitric Acid, Ultrex	2.3	10.	2.8	14.	0.09	22.7	ND*
Nitric Acid, Reagent	2.0	11.	6.3	13.	1.1	41.5	ND*
Nitric Acid, Electronic Grade	0.4	7.6	2.1	3.6	0.9	11.5	ND*

*ND - Zinc concentrations of nitric acids could not be determined due to inability of instrument to correct for background.

III. DISCUSSION OF RESULTS

In evaluating these results, it is useful to make several assumptions regarding the size of the sample, metal ion concentrations in the sample, other sources of metal ions, volume of reagents used, and final volume of solution analyzed on the AA spectrophotometer. These assumptions are based in part on preliminary testing done here at ARLI and in part on results reported from earlier MAFLA investigations. With regard to the sample, we will assume:

A. That a one gram sample is used;

B. That the sample has a surface area of 10 cm^2;

C. That the sample is exposed to the laboratory atmosphere for one hour;

D. That the trace metals concentration in the sample will be on the order of those listed below:

1. Cu: 5. ppm
2. Cd: 0.5 ppm
3. Cr: < 1. ppm
4. Pb: 0.5 ppm
5. Fe: 25. ppm
6. Ni: < 1. ppm
7. Zn: 35. ppm

Additional assumptions include that:

A. Ten (10) ml of Ultrex grade nitric acid will be used in each analysis

B. The volume of the solution analyzed is ten (10) milliliters

C. The trace metal content of the sulfuric acid and hydrogen peroxide used is neglected for these calculations

TABLE 3a. Estimated Contributions to Metal Content of AA Analysis Solution by Tissue Sample, Nitric Acid, and Particulates (Average Value)

	Weight of Element Contributed by								
				Particulates (Average Value)					
				Clean Bench		Fume Hood		Open Bench	
	Sample, µg	Acid, µg	Total, µg	µg	%	µg	%	µg	%
Column #	I	II	III	IV		V		VI	
Pb	0.5	0.023	0.523	< 0.0013	< 0.25	0.0113	2.12	0.0034	0.65
Cr	< 1.	0.10	1.10	< 0.0026	< 0.24	< 0.0026	< 0.24	< 0.0027	< 0.25
Cu	5.	0.028	5.028	< 0.019	< 0.38	< 0.019	< 0.38	< 0.083	< 1.62
Cd	0.5	0.0009	0.5009	< 0.0009	< 0.18	< 0.0009	< 0.18	< 0.0016	< 0.31
Ni	< 1.	0.14	1.14	< 0.015	1.29	< 0.0247	< 2.13	< 0.019	< 1.61
Fe	25.	0.227	25.227	< 0.020	< 0.08	< 0.020	< 0.08	0.048	0.19
Zn	35.	N.A.*	35.	< 0.162	< 0.46	0.0877	0.24	< 0.510	< 1.44

*NA - Not Available

Column I - weight of metal found in a 1 g sample of tissue (see assumption above)

II - weight of metal found in 10 ml nitric acid (Ultrex grade) (See Table 2)

III - total of column I & II - weight of metal in the 10 ml solution used for AA analysis

IV - weight of metal collected during 1 hour on 10 cm^2 in clean bench. Average value from Table 1 is used. Expressed as micrograms and as a percentage of column III & IV

V - similar to column IV, except for fume hood location

VI - similar to column IV except for open lab bench location

TABLE 3b. Estimated Contributions to Metal Content of AA Analysis Solution by Tissue Sample, Nitric Acid, & Particulates (Maximum Value)

	Weight of Element Contributed by						
		Particulates (Maximum Value)					
		Clean Bench		Fume Hood		Open Bench	
	Sample & Acid, μg	μg	%	μg	%	μg	%
Column #	III	VII		VIII		IX	
Pb	0.523	0.0014	0.27	0.0242	4.42	0.0056	1.06
Cr	1.10	< 0.0026	< 0.24	< 0.0026	< 0.24	0.0030	0.27
Cu	5.028	< 0.019	< 0.38	< 0.019	< 0.38	0.185	3.59
Cd	0.5009	< 0.0009	< 0.18	< 0.0009	< 0.18	0.0027	0.54
Ni	1.14	< 0.015	1.29	0.044	3.73	0.025	2.22
Fe	25.227	< 0.020	< 0.08	< 0.020	< 0.08	0.002	0.25
Zn	35.	0.322	0.92	0.099	0.28	1.197	3.3

Column VII - weight of metal collected during 1 hour on 10 cm^2 in clean bench. Highest value from Table 1 is used. Expressed as micrograms of metal and as a percentage of Column III & VII.

VIII - similar to Column VII, except for fume hood location

IX - similar to Column VII, except for open lab bench location

MARCH 3, 1849

The Department of the Interior Mission

As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering sound use of our land and water resources; protecting our fish, wildlife, and biological diversity; preserving the environmental and cultural values of our national parks and historical places; and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to ensure that their development is in the best interests of all our people by encouraging stewardship and citizen participation in their care. The Department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

The Minerals Management Service Mission

As a bureau of the Department of the Interior, the Minerals Management Service's (MMS) primary responsibilities are to manage the mineral resources located on the Nation's Outer Continental Shelf (OCS), collect revenue from the Federal OCS and onshore Federal and Indian lands, and distribute those revenues.

Moreover, in working to meet its responsibilities, the **Offshore Minerals Management Program** administers the OCS competitive leasing program and oversees the safe and environmentally sound exploration and production of our Nation's offshore natural gas, oil and other mineral resources. The MMS **Minerals Revenue Management** meets its responsibilities by ensuring the efficient, timely and accurate collection and disbursement of revenue from mineral leasing and production due to Indian tribes and allottees, States and the U.S. Treasury.

The MMS strives to fulfill its responsibilities through the general guiding principles of: (1) being responsive to the public's concerns and interests by maintaining a dialogue with all potentially affected parties and (2) carrying out its programs with an emphasis on working to enhance the quality of life for all Americans by lending MMS assistance and expertise to economic development and environmental protection.