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Report on the Invertebrate Megafauna Sampled by Trawling in the Atlantic 3800 Meter Low-Level Radioactive Waste Disposal Site

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REPORT ON THE INVERTEBRATE MEGAFAUNA SAMPLED BY TRAWLING IN THE ATLANTIC 3800 METER LOW-LEVEL RADIOACTIVE WASTE DISPOSAL SITE

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FOREWORD

In response to the mandate of Public Law 92-532, The Marine Protection, Research, and Sanctuaries Act of 1972, as amended, the Environmental Protection Agency (EPA) has developed a program to promulgate regulations and criteria to control the ocean disposal of radioactive wastes. As part of that program, the EPA Office of Radiation Programs initiated feasibility studies in 1974 to learn whether present technologies could be used to determine the fate of radioactive wastes dumped in the past.

In 1978, the Research Vessel ADVANCE II conducted four bottom trawls at the deepest of the previously-used, United States low-level radioactive waste disposal sites. That site, located approximately 320 kilometers (200 miles) offshore in the Atlantic at a depth of approximately 3800 meters (12,500 feet), is situated in the axis of the Hudson Canyon channel. Two of the trawls were slightly south and east of the 3800-meter dumpsite, and the other two trawls were near the Block Canyon channel north and east of the 3800-meter dumpsite.

The present report provides a detailed description of the invertebrate megafauna collected from the four trawls. Megafauna are defined here as those benthic organisms larger than one centimeter in diameter. The most abundant species are identified and compared with the results of historical and contemporary studies. Differences between the Block and Hudson channel trawl catches are noted and discussed. The feeding behavior of the most numerous invertebrates, the brittle stars (ophiuroids), is presented as it relates to bioturbation of the sediment. The report makes tentative conclusions regarding design of dumpsite-related biological monitoring programs, and notes the need to differentiate between natural spatial variation of organisms and variations resulting from man's activities.

The Agency invites all readers of this report to send any comments or suggestions to Mr. David E. Janes, Director, Analysis and Support Division, Office of Radiation Programs (ANR-461), Environmental Protection Agency, Washington, D.C. 20460.

Glen L. Sjoblom

Glen L. Sjoblom, Director
Office of Radiation Programs

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INTRODUCTION

Biomass for radionuclide analysis and information on deep-sea faunal composition were successfully collected from four otter trawl samples taken from the R/V ADVANCE II. The samples were collected at four stations during June 24-27, 1978, in the general location of the 3800m radioactive waste disposal site centered at 37°50'N, 70°35'W. While the small number of samples allows for neither a comprehensive characterization of the megafauna nor an assessment of any ecological impact, it does serve two very useful purposes. First, even a rudimentary comparison with existing information on deep-sea ecology serves to identify those data and concepts that may be useful in future site-specific or generic ecology studies. Second, the relative abundance of the captured species can be used when designing cost-effective sampling programs.

The megafauna in the vicinity of the dumpsite can be described as an ophiuroid-pagurid (brittle starfish and hermit crab) dominated, soft-bottom abyssal assemblage. It resembles assemblages collected at similar depths, with similar equipment, off the coast of New England in a series of studies conducted by R. Haedrich and G. Rowe (Haedrich et al., 1980; and Carney, Haedrich and Rowe, 1983). This similarity suggests that germane research could be conducted outside of the actual dumpsite. Additionally, the preponderance of ophiuroids and pagurids suggests that these animals would provide a cost-effective focus for any radionuclide accumulation or biological effects studies requiring large sample sizes.

EQUIPMENT AND METHODS

John Musick, of the Virginia Institute of Marine Science, conducted the trawl sampling using a 13.7 meter, semi-balloon otter trawl with a 4.45 centimeter stretch mesh in wings and body, and 1.27 centimeter stretch mesh lines in the cod end. The nature of the equipment is fully discussed in his report (Musick and Sulak, 1979). Tow duration was approximately three hours of bottom time for each of the four samples.

RESULTS

T fauna collected in all four trawl samples can be characterized as an ophiuroid-pagurid dominated assemblage. As such, it is typical of western north Atlantic abyssal megafaunal communities at these depths (3900m) (Carney, Haedrich and Rowe, 1983). While there are too few samples for any meaningful statistical analysis, the composition suggests that there is considerable faunal variation, which may be related to topography. There is an apparent difference in trawl contents corresponding to station location (Figure 1). Samples 70 and 7014 were in close proximity to the Block Canyon axis, whereas 7011 and 7013 were taken between the Hudson and Block Canyon channel axes at a slightly greater depth. In the 7009-7014 sample pair, ophiuroids were abundant, with Ophiomusium armigerum being more abundant than Amphiophiura bullata (Table 1). The small ascidian Mugula sp. was numerous, as was the pagurid Parapagurus pilosomanus. In the 7011-7013 pair of samples, the dominance of ophiuroids was reversed; there were no Mugula sp., and the overall abundance of ophiuroids and pagurids was reduced (Table 1).

PREVIOUS STUDIES OF THE ABYSSAL FAUNA NEAR THE SITE

The disposal site lies between areas that have been relatively well studied when compared with most abyssal environments. The Gay Head-Bermuda transect (Sanders, Hessler, and Hampson, 1965), lying east of the site, is one of the most comprehensively studied parts of the deep-sea. The fish fauna of the deep-sea mid-Atlantic region to the south has been well studied by Musick (1976). Although the National Oceanic and Atmospheric Administration (NOAA) conducted studies in Deepwater Dumpsite 106 (NOAA, 1975), a report on the megafauna was never produced due to the death of the principal investigator, Dr. Robert Menzies of Florida State University.

The trawl-based data of Haedrich and Rowe (Haedrich and Rowe, 1977; Carney, Haedrich, and Rowe, 1983) and Musick (Musick, 1976; and Musick and Sulak, 1979) afford the greatest potential for comparison with the disposal site. Unfortunately, the limited data reported herein cannot support rigorous

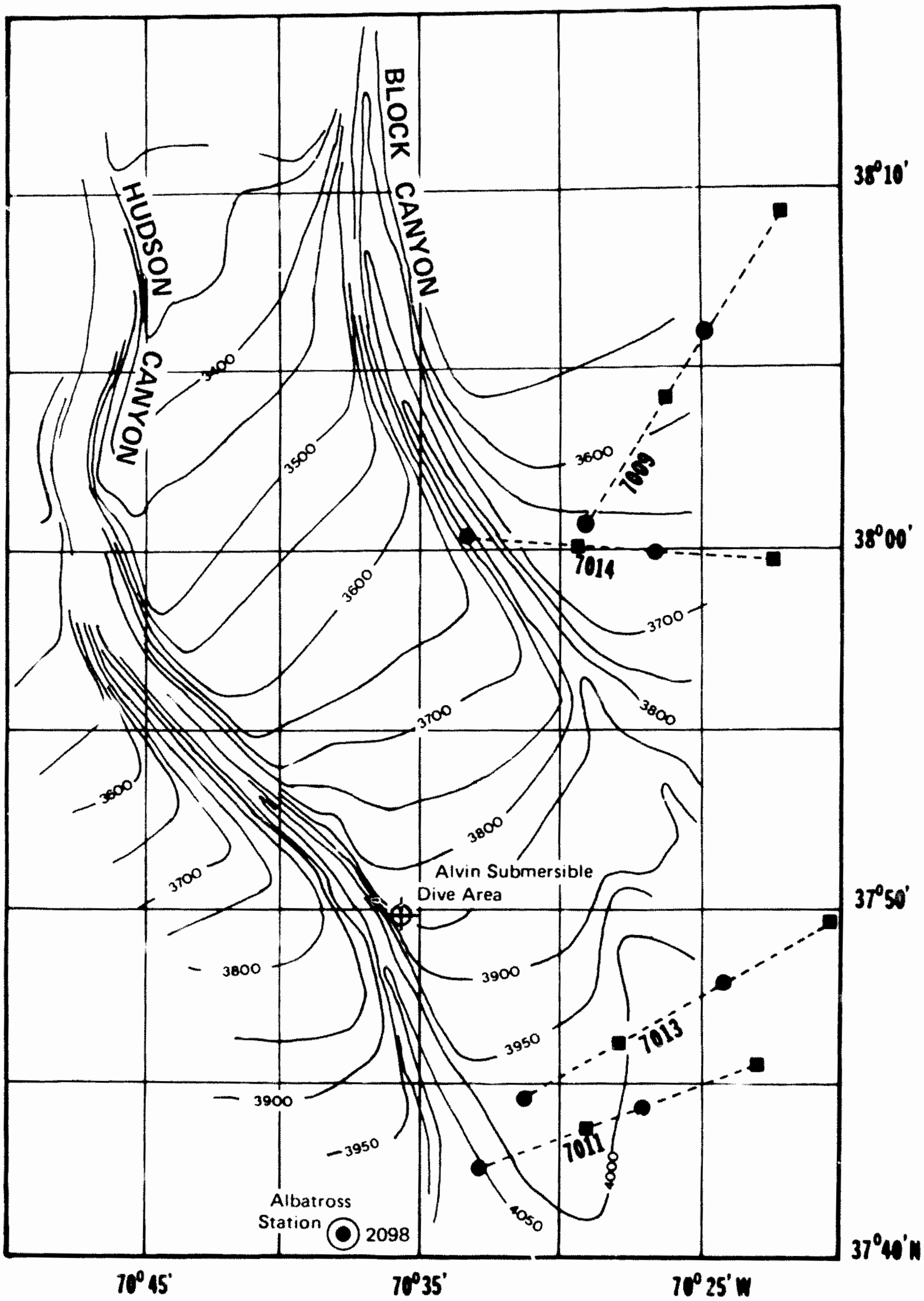

Figure 1. Otter trawl locations in the vicinity of the Atlantic 3800 meter radioactive waste disposal site (Musick et al., 1979)

■- - - -■ indicates ship's track as determined by LORAN-C

●- - - -● indicates probable net positions behind ship from Set to Haul

TABLE 1

MEGAFAUNAL INVERTEBRATES COLLECTED BY TRAWLING

	. . . . EPA STATIONS				
	7009	7014	7011	7013	H&R**
	3560-3655m*	3975-4000m	3670-3750m	4025-4050m	3244-3740m
ECHINODERMS					
Ophiuroids					
Ophiomusium armigerum	1543	1921	42	22	P
Amphiophiura bullata	992	797	205	157	P
Asteroids					
Dytaster grandis	3	7	1	1	P
Benthopecten spinosus	3	0	1	0	P
Pseudarchaster parelii	0	1	3	0	P
Solaster sp.	0	1	0	0	A
Echinoids					
Aeropsis sp.	0	1	0	0	P
Holothuroids					
Molpadia blakei	1	1	10	0	P
Molpadia musculus	0	0	2	0	P
Benthodytes typica	0	3	0	0	P
Protankyra sp.	0	2	0	0	P
Myriotrochus sp.	10	6	6	7	P
ASCIDIANS					
Mugula sp.	405	75	0	0	A
COELENTERATES					
Flabellula goodei	0	0	5	2	P
CRUSTACEA (dominants only, see Musick and Sulak (1979) appendix 1)					
Parapagurus pilosomanus	64	240	39	23	P
Ethusina abyssicola	6	13	3	0	P
Pontophilus abyssi	6	2	0	6	P
Pleisiopenaeus armatus	2	2	1	8	P
Acanthephyra purpurea	1	2	0	4	A

TABLE 1 (Continued)

	EPA STATIONS				
	7009	7014	7011	7013	H&R**
	3560-3655m*	3975-4000m	3670-3750m	4025-4050m	3244-3740m
MOLLUSCA (smaller than trawl mesh, retained fortuitously)					
Pelecypoda (mixed)	23	10	16	0	
Gastropoda					
Pleurotomella jeffreysii	5	2	4	1	
Mangelia bandella	42	0	5	0	
Colus profundicola	3	2	8	0	
Pleurotoma emertoni	4	8	1	1	
Pleurotoma sp.	0	0	1	0	
Pleurotoma circumcinctum	2	6	0	1	
Clionella brychia	1	1	0	0	
Lacuna sp.	3	0	0	1	
Turbonilla sp.	0	0	3	0	
Aceton sp. (megafaunal)	0	0	0	1	
Aceton sp. (megafaunal)	0	0	0	2	
Aceton sp. (megafaunal)	1	0	0	2	
Limpet	1	0	0	1	

*Sampling depth range.

**Due to the differences in sampling, only the presence (P) or absence (A) of a species in the results of Haedrich and Rowe are considered. These comparisons are based upon Haedrich and Rowe (1977) and unpublished data provided by them. The absence of the ascidian, *Mugula* sp., from Haedrich and Rowe's data may be a sampling artifact. Since most of the listed molluscs are below the megafauna size class, comparisons with the data of Haedrich and Rowe are not justified.

comparisons. Even with the required comprehensive sampling program, comparison of trawling results collected with a variety of equipment by different investigators must be made with extreme caution. The techniques are nonquantitative and are subject to unknown sources of error (Rice et al., 1982), which could reduce the reliability of even qualitative analyses.

Should future investigations include a more comprehensive faunal survey, then the extensive taxonomic literature produced from Howard Sanders' sampling program could prove to be of great value (Allen and Sanders, 1973; Clark, 1977; Cook, 1970; Cutler, 1973; Cutler and Duffy, 1972; Gardiner, 1975; Hartman, 1955; Hartman and Fauchald, 1971; Hessler, 1970; Jones, 1973; Laubitz and Mills, 1972; Mills, 1971; Monniot and Monniot, 1968, 1970a, 1970b; Sanders and Allen, 1973, 1977; Southward, 1971; and Zezina, 1975). However, the trawl samples of the present study cannot be compared with the core and epibenthic sledge samples on which the just referenced literature is based.

REVIEW OF HISTORICAL MUSEUM MATERIAL

The deep-sea off New England and the mid-Atlantic states has been sampled at various times for over a century, raising the possibility that some of the historical data might be of value in establishing species identities and assemblage compositions. A review of specimens in the collections of the U.S. National Museum of Natural History and the Museum of Comparative Zoology at Harvard University confirmed that adequate reference material exists to allow for identification, to the generic or species level, of most of the megafaunal organisms that can be collected in the disposal site. In addition, these collections demonstrate that the dominant echinoderm species in the present study have been present near the 3800m Atlantic dumpsite for almost 100 years. Unfortunately, museum collections cannot be used to determine the quantitative composition of historical samples since entire samples were seldom preserved and detailed records were not kept.

In spite of relatively intense sampling over the last two decades, many of the easily accessible museum specimens are still those collected by the

Fisheries Vessel (F/V) ALBATROSS in the 1880's, which are housed primarily at the U.S. National Museum of Natural History. The lack of more recent material is due to three main factors. First, historical expeditions were undertaken specifically to build national collections, while collection-building is only an ancillary part of modern deep-sea ecology. Second, collections have been largely built to serve as taxonomic resources; thus there is little use for recently collected duplicates. Finally, even when recent material has been donated to museums, the cataloguing and identification may be deferred for decades.

Three F/V ALBATROSS stations occupied in the 1880's, for which data are available, were near the Atlantic 3800m disposal site (Figure 1).

Station Number	Depth	Location
2097	3506m	37°56'20"N, 70°57'30"W
2098	4062m	37°40'30"N, 70°37'30"W
2223	4060m	37°48'30"N, 69°43'30"W

Since the ALBATROSS expeditions were undertaken for the primary purpose of collecting samples, no comprehensive scientific account of the ALBATROSS cruises was ever produced, and faunal lists by station were not compiled following taxonomic studies. Because no records were kept as to how much of a particular trawl sample was preserved, attempts to recreate faunal lists from museum catalogues are useless.

In an attempt to partially reconstruct the faunal assemblages of the 1800's, the echinoderms from stations 2097, 2098, and 2223 were reexamined. This effort was restricted to the echinoderms due to their abundance and relative taxonomic stability. The two common ophiuroids at the Atlantic 3800m site, Amphiophiura bullata and Ophiomusium armigerum, were also collected at ALBATROSS stations 2097 and 2098. In addition, the starfish, Dytaster grandis and Benthopectin spinosus, collected at the 3800m dumpsite, were also taken at station 2097. As pointed out in the above paragraph, the lack of records on ALBATROSS sample processing and disposition makes negative information (the lack of a particular species from a particular station in a museum collection) uninterpretable. We can only conclude that the four species listed above have been collected from the general area around the disposal site for about 100 years. There is no historical data on their distribution among stations.

COMPARISON WITH THE RESULTS OF HAEDRICH AND ROWE

As has been stressed in this report, it is not possible to conduct a rigorous statistical comparison between the results of this study (Table 1) and the data of Haedrich and Rowe. Sampling techniques were not strictly comparable, and sampling designs differed markedly. Haedrich and Rowe sampled extensively in order to establish vertical trends, whereas the present study took only four samples in a smaller area. Likewise, it is not possible to compare the present results with earlier work by Musick, since his studies have been restricted to a few taxa, primarily the fishes. A few simple comparisons are, however, informative and suggest that the disposal site fauna is appreciably similar to that encountered at similar depths elsewhere on the U.S. Atlantic coast.

A comparison of the presence or absence of invertebrate species collected from the disposal area with the data collected to the north and east by Haedrich and Rowe (1977) shows similar composition (Table 1). Furthermore, the three most abundant invertebrates are the same. Between 3244m and 3740m Haedrich and Rowe (Haedrich *et al.*, 1980) found *Ophiomusium armigerum* most abundant, followed by *Amphiophiura bullata* and *Parapagurus pilosomanus*. When all the 3800m disposal site samples are pooled, the same sequence of rank abundance is found. The absence of the ascidian, *Mugula* sp., from Haedrich and Rowe's data may reflect either real ecological differences or a sampling artifact arising from the organism's small size.

In spite of the overall similarity between disposal site fauna and that found relatively nearby, there is some indication of variation within the site. The samples in or near the Hudson Canyon (7011 and 7013) had large numbers of *Amphiophiura bullata* relative to *Ophiomusium armigerum*, and *Mugula* was absent. The Block Canyon samples (7009 and 7014) showed a reversed order of ophiuroid abundance, and *Mugula* was present. This apparent faunal-topographic correspondence may be a sampling artifact or a real difference due to some unmeasured substrate parameter.

NATURAL HISTORIES OF PREDOMINANT LARGE INVERTEBRATES

In general, little is known about the biology of deep-sea organisms. The submersible ALVIN was employed during the June 1978 survey at the 3800m disposal site for observation of the condition of radioactive waste containers and surrounding topographic features (Figure 1). However, schedule limitations precluded its use in the present study of megafaunal invertebrates. But published information and unpublished observations from the submersible ALVIN at Woods Hole Permanent Deep Station 2 at a depth of 3659m to the northeast of the disposal site provide some detail (Rowe *et al.*, 1982).

Ophiomusium armigerum

The biology of the various species of echinoderms is particularly interesting, especially the ophiuroids (brittle starfish). Representatives of the phylum are common at abyssal depths, comprising a reliable portion of the deep-sea samples. In addition, a considerable amount of information on deep-sea echinoderm biology is being collected in a comprehensive deep-sea study in the Rockall Trough in the northeast Atlantic (see Gage, 1982).

Ophiomusium armigerum and its related species, *O. lymani* (common at shallower depths and studied by Gage (1982)), appear to be relatively sedentary deposit feeders and scavengers. Observed *in situ*, they appear to be immobile. The arms protrude into the sediment, and the disk is held a centimeter or two above the sediment-water interface. Of 200 specimens examined for stomach contents, only two had any ingested material, and that was a nondescript mucoid-fibrose, grey-green mass. In time-lapse films, these animals have been observed to move slowly over the sediment (Rowe *et al.*, 1975). Because they dig with their arms, *O. armigerum* can be expected to contribute to bioturbation (see Carney, 1981, for a general discussion) to a depth of approximately 4 centimeters.

Only a few incidental aspects of the species' ecology are known. It is host to an external parasitic gastropod, which is a previously undescribed genus and species (Waren and Carney, 1981), and the ophiuroid's early post-larval stages have been identified (Schoener, 1966 and 1967). This latter point is especially important because it makes detailed life history studies feasible.

Amphiophiura bullata

The shorter arms of A. bullata and the more numerous tube feet suggest a natural history different than that of O. armigerum. The species has been observed to crawl rapidly for short distances when disturbed. Litvinova and Sokolova (1971) published a survey of the stomach contents of several species of Amphiophiura that suggested a predatory/scavenging habit. Amphiophiura convexa has also been reported from similar depths in the western Atlantic, but the two species appear to be identical upon direct comparison.

Molpadid Holothurians

Holothuroids of the genus Molpadia are found at all ocean depths. Since they are infaunal, trawl samples probably underestimate their abundance. Although the habits of the deep-sea forms are unknown, they resemble shallow-water forms so closely that similar ecologies are likely. If this is the case, then the deep-sea species M. blakei and related forms may be important agents of bioturbation, contributing to the maintenance of a mixed surface-sediment layer about 10 centimeters thick in the disposal area.

This suggestion is based upon extensive shallow-water work in Buzzard's Bay, Massachusetts, where M. oolitica has been found to be a major agent of bioturbation (Rhodes and Young, 1971). It is so common and so active a burrower that it may be the principal determinant of mixed layer thickness and turnover rates. M. oolitica and M. blakei share a common morphology.

ADDITIONAL FAUNAL GROUPS

In spite of the mesh size of the otter trawl used in the present study, numerous small benthic gastropods were retained in the net (Table 1). While not an intended part of the benthic sample, the relative ease with which many specimens can be collected suggests that they can be of value in future studies that seek to characterize the site fauna. In addition to abundance, their importance as a focus of investigation is increased because their taxonomic and functional classifications in the region of the dumpsite have been established (Rex, 1977 and 1981).

CONCLUSIONS

In spite of the limited data, the results point to three tentative conclusions. The first two can be rigorously tested if appropriate sampling and analytical designs are adopted.

1. The megafauna of the disposal site is quite similar in composition to that found at comparable depths at other locations in the northwestern Atlantic off the United States coast. This hypothesis, if confirmed, would greatly simplify the task of site selection and monitoring, because highly detailed investigations of the ecology and radioecology of target species would not need to be site-specific. Common organisms, such as Ophiomusium armigerum, could be collected in large numbers by trawling at 4000m at convenient locations. Similarly, in situ work by submersibles would not need to take place within a particular disposal site.

2. There appears to be substantial place-to-place variation in the numbers of species, even within the 3800m disposal site. Therefore, formally designed studies must avoid confusing this type of variation in future data with variations that might be due to some form of impact, such as changes which might arise from waste disposal operations.

3. The previous research on megafaunal zonation off New England by Haedrich and Rowe and that on the macrofauna by Sanders and his collaborators provides a context for precise description of most of the 3800m disposal site fauna when sufficient samples are available. These same studies, along with historical expeditions, have provided an extensive taxonomic base, which will greatly reduce the time and effort devoted to sample identification.

While verification of points one and two is amenable to sampling and analysis within an analysis-of-variance context, it cannot, in a strict sense, answer the two central questions that arise with the issue of deep-sea radioactive waste disposal. First, is there a significant threat to man via a biological pathway? Second, will there be a significant detrimental impact on the deep-sea fauna? Both questions require research into basic functional ecology of deep-sea organisms, which cannot be accomplished by simple survey sampling.

The identification of major links in the deep-sea food web is necessary in order to anticipate the spread of any pollutant through the biota and possibly to man. Such determinations are difficult under ideal conditions and are impossible on the basis of the limited data presented herein. However, it is possible to narrow the approaches that might be valuable in the future. For example, two dominant taxa, brittle starfish and hermit crabs, masticate their food to the point at which traditional gut analyses are useless. However, the immunoassay techniques developed by Feller (1981) may be of value in future studies of pollutant transfer.

The only demonstrated feeding connection on the basis of the present data is that between the rattail fish, Coryphaenoides sp., and the infaunal holothuroid Molpadia. One specimen of Molpadia blakei was found in the stomach of a rattail. Since the molpadids are infaunal detritus feeders, they could serve as a vector for introducing buried contaminants into the food web.

An assessment of bioturbation in the 3800m site, which was part of the original intent of this study, was precluded due to the lack of submersible time. As noted, both the brittle starfish and the holothuroid Molpadia blakei can be expected to be important in the process of bioturbation.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT Four otter trawls were carried out in 1978 near the Atlantic deepsea low-level radioactive waste dumpsite located at a depth of 3800 meters, approximately 320 kilometers offshore, centered at 37°50'N, 70°35'W, and situated in the axis of the Hudson Canyon Channel. Two of the trawls were slightly south and east of the 3800-meter dumpsite, while the other two trawls were made near the Block Canyon Channel north and east of the 3800-meter dumpsite.

The megafauna collected in the vicinity of the dumpsite can be described as an ophiuroid-pagurid (brittle starfish-hermit crab) dominated, soft-bottom abyssal assemblage. It is typical of western north Atlantic abyssal megafaunal communities. The ophiuroids were most abundant at all four trawl stations. However, differences in distribution of individual species were noted between the trawls made southeast and northeast of the dumpsite. In particular, an ascidian, Mugula sp., and a pagurid crab, Parapagurus pilosomanus were numerous only at the trawl area northeast of the dumpsite. This may be related to topographic differences between the two trawl areas.

Available information on the life histories of the predominant large invertebrates is presented and discussed. The report makes particular note of the need to differentiate between natural spatial variation of organisms and spatial variations resulting from man's activities, when designing dumpsite-related biological monitoring programs.

17. KEY WORDS AND DOCUMENT ANALYSIS

a. DESCRIPTORS	b.	c. COSATI Field/Group
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