GEORGES BANK BENTHIC INFAUNA MONITORING PROGRAM

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16. Abstract Concerns about the potential effects of oil and gas exploration activities on the highly productive Georges Bank off the coast of Massachusetts led to the initiation of an intensive monitoring program in July, 1981. The program includes intensive sampling of the benthic communities, collected near, upcurrent and downcurrent of the drilling rigs, analysis of bottom photographs for epifauna and microtopography, dredge and trawl collections, CHN and sediment grain size analysis. Collections of six replicate infaunal samples at each of 46 stations are made on a seasonal basis. Samples are collected with a 0.04m^2 modified Van Veen grab sampler and are double live-sieved through 500 µm and 300 µm screens. Twenty-nine stations are positioned in a tight radial array around 1 rig at 80 m. A second group of 3 stations are near a rig site at 145 m. The remaining stations cover a broad expanse of the Bank and nearby areas of potential deposition of drilling materials. Use of the 300 µm screen has resulted in the retention of newly settled and juvenile forms, as well as small-bodied species which are normally undersampled by larger screens. The capability of identifying the earliest juvenile stages of several species has enabled us to provide accurate counts of each species and to predict times of settlement. Results from the first 4 biological collections indicate little heterogeneity within stations, with good replication between samples. A strong relationship between faunal composition and both sediment type and depth is indicated by cluster analysis. No biological impacts which could be attributed to drilling activities have been detected to date at any station, including the site-specific array in Block 312, the 3 stations near the drill rig in Block 410, or any regional station monitored in this program.

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1. CONCLUSIONS

• The Regional Stations analyzed for benthic infauna group consistently over all four sampling periods by depth and sediment type. Replicate samples at each station show an exceptionally high degree of homogeneity. Cluster analysis demonstrates that all of the replicates of any one regional station are more similar to each other than to replicates from any other station. When replicates at each station are summed, the samples from each of the four sampling periods fuse before any separation occurs between stations. This homogeneity should enable us to detect biological changes should they occur at these stations.

• Site-specific stations in the array around Station 5-1 have a homogeneous community structure, both spatially and temporally over most of the area. The species composition does change with the increase in the proportion of fine sand at stations located 4 and 6 km to the west of Station 5-1.

• At all stations sampled, the community structure (i.e., species composition) does not change very much with season. Although average densities of several species were observed to fluctuate seasonally, these changes probably reflect natural cycles in these populations and do not appear to be related to drilling activities.

• The only result of the chemical analyses that provides a basis for an hypothesis of an impact due to drilling activities is the gradient of barium concentrations (as a marker of accumulation of drilling muds) near the Block 410 Stations 16, 17 and 18, and Site-Specific Station 5-1.

• Drilling began in Block 410 in July, 1981 and continued until March, 1982. With the methods of analysis used thus far, no biological impacts which could be attributed to drilling activities were detected. Differences between stations were always greater than temporal differences at any one of the three stations.

• Drilling began in Block 312 on December 8, 1981 and continued until June, 1982. At the site-specific array of stations in this block, the separation of February (M3) and May (M4) samples into discrete clusters may be a result of the decline in total densities at many of the stations in February (M3), followed by a recovery in May (M4).

The density declines in February (M3) may be related to changes in sediment composition or to normal seasonal population cycles. An analysis of the change in densities over time of 24 infaunal species revealed that at Stations 5-1, 5-2 and 5-8, where the greatest increment in barium concentration between July (M1) and May (M4) occurred, the densities of many species declined in November (M2) before drilling began and increased in February (M3).

- In general, no significant changes in benthic community structure which can be related to drilling activities have been detected with the methods of analysis used thus far.

2. RECOMMENDATIONS

- Sampling should continue at all long-term Regional Stations in order to establish normal seasonal patterns of population fluctuations. This will allow us to better interpret population fluctuations seen at drilling areas. The most important stations include the deeper water and canyon Stations 3, 6, 7A, 8, 9 and 12 adjacent to the proposed Lease Sale 52 area, and stations in major depositional areas (Stations 13 and 13A).

- Sampling should be continued at three stations in Block 410 (Stations 16, 17, 18). This will provide information on long-term effects at a deeper drilling site, which may be useful for predicting impacts of drilling in the Lease Sale 52 area.

- Biological and chemical sampling should continue at those stations in the Site-Specific array at which elevated concentrations of barium (a marker of drilling mud accumulation) were detected in the fine fraction of sediment on Cruise M4. First priority should be given to stations of this type two or more kilometers from the drill site. Analysis of sediment barium concentrations at an additional radial array of four to sixteen stations located about 8 and/or 10 km from the rig site would be useful for better defining the pattern and extent of movement of drilling muds away from the rig site.

- Barium should be analyzed in the fine fraction of sediments from the Secondary Site-Specific Stations for Cruises M1 through M4 to better establish the distribution of drilling muds in sediments around the rig site. If elevated concentrations

of barium are detected in sediments from the Secondary Site-Specific Stations or the new far-field stations, a subset of these, including Stations 5-23, 5-24, 5-26 and 5-27 should be analyzed for benthic infauna and sediment grain size.

• Additional effort should be made to obtain more samples of Arctica islandica or other suitable macroinfaunal animals at Site-Specific Stations having elevated sediment barium concentrations, for metals and petroleum hydrocarbon analysis. This will help answer the critical question of whether materials from drilling discharges accumulating on the bottom are bioavailable.

• Because of the problems with the wet-weight biomass technique, as discussed in the final report, the method for determining biomass should be re-evaluated. For at least one set of samples, another technique, such as decalcified wet weights or ash-free dry weights, should be used in order to establish a better estimate of secondary productivity.

3. BACKGROUND

The Georges Bank, a large plateau lying under 3 to 200 meters of water 80 to 325 km east-southeast of the Massachusetts coast, is one of the most productive commercial fishery areas in the world. Many species of finfish and shellfish, including codfish, haddock, flounder, ocean scallops, and lobster, with a market value in excess of 165 million dollars are harvested from Georges Bank each year.

As known domestic reserves for oil and gas have dwindled and dependence on foreign sources of these fossil fuels has increased, there has been a growing interest in exploring new oil and gas reserves in the coastal and Outer Continental Shelf waters of the United States, including the Georges Bank. The first offering of lease tracts for exploratory drilling on Georges Bank (Lease Sale #42) took place in December, 1979. In this offering, a total of 63 blocks, each 3 x 3 miles (23.3 km^2), on Georges Bank were leased by major oil companies or consortia. Two additional lease offerings are scheduled for the North Atlantic Outer Continental Shelf, including portions of Georges Bank (Figure 1). All lease blocks in Lease Area 42 and those blocks in the proposed Lease Area 52 that actually are on Georges Bank are located along the south-central and southwest portion of the Bank. The area of geologic potential for the proposed North Atlantic Lease Offering (February, 1984) includes much of the remainder of Georges Bank, as well as areas in deeper water (exceeding 2,000 m).

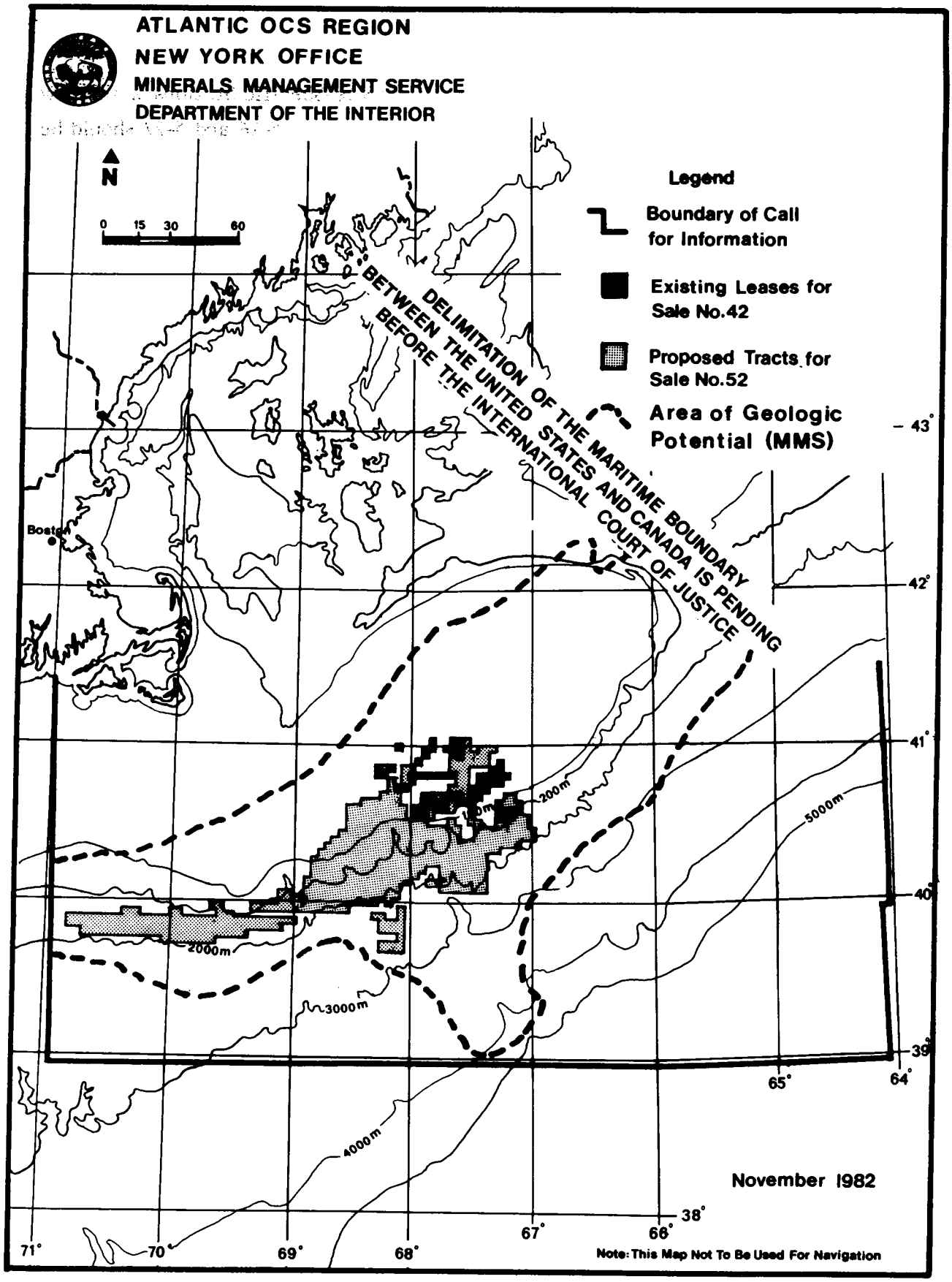

FIGURE 1. PROPOSED NO. ATLANTIC LEASE OFFERING (FEBRUARY 1984) .

Substantial concern has been expressed by environmentalists and the commercial fishing industry that oil and gas exploration and possible later fossil fuel development and production on Georges Bank would seriously damage this complex and highly productive ecosystem and the commercial fisheries dependent on it. Because of these concerns, a Biological Task Force for Outer Continental Shelf Lease Sale 42 was established by the Federal Government to recommend to the U. S. Department of the Interior, Supervisor of Oil and Gas Operations in the North Atlantic, the design of environmental studies and surveys that would provide an early warning of adverse effects of oil exploration on the Georges Bank environment (Biological Task Force, 1981). The Bureau of Land Management (now Minerals Management Service) of the U. S. Department of the Interior has implemented the monitoring program recommended by the Biological Task Force, with some slight modifications.

4. PURPOSE AND SCOPE OF THE PROGRAM

The major environmental concerns resulting from exploration and development activities for oil and gas on Georges Bank are that intentional discharges of materials (mainly drilling fluids and cuttings) from oil platforms during normal exploratory and development activities may damage the Georges Bank environment, particularly animals living on or in the bottom sediments, upon which commercial fisheries species depend for food. If commercial quantities of oil or gas are found, a major concern during the development and production phases of the Georges Bank field is that accidental spills of crude oil and operational discharges of petroleum hydrocarbon-laden produced water will harm the marine biota, and particularly the floating or pelagic eggs and larvae of commercial fishery species. Other concerns relate to increased ship traffic over the Bank, disruption of the bottom by pipelines, anchors and rig structures, and disturbances of migrating and feeding whales by noise and surface pollution.

The Georges Bank Monitoring Program is designed to address the concerns related to the initial exploratory phase of Georges Bank development. Specifically, the objectives of the Program are to determine the fate of discharges (primarily drilling fluids and cuttings) from exploratory drilling platforms in Lease Area 42 and to assess the effects of these discharges on benthic species and communities of Georges Bank and potential depositional areas for drilling fluids and cuttings in submarine canyons and the Outer Continental Shelf south of eastern New England. The accumulation and distribution of drilling fluid-associated metals, in particular barium and chromium, in bottom

sediments in the vicinity of exploratory activities are being used to trace the patterns and quantities of drilling fluid deposition around and downcurrent from drilling rigs. This research is being performed by the U.S. Geological Survey, Woods Hole, Massachusetts (Bothner et al., 1982). Concentrations of several metals are being analyzed in selected species of bottom-living fish and shellfish and possible petroleum hydrocarbon contamination of bottom sediments and marine animals of Georges Bank is being investigated by Science Applications, Inc. (Payne et al., 1982) in a further effort to determine if drilling activities are resulting in contamination of the Georges Bank environment. The major portion of the Monitoring Program is being performed by Battelle New England Marine Research Laboratory and Woods Hole Oceanographic Institution and addresses the question of whether populations of animals living in the bottom sediments (benthic infauna) change in selected regions of the southern Georges Bank and southwestward (downcurrent) along the southern New England Outer Continental Shelf, including Lydonia and Oceanographer Canyons, during various stages of oil and gas exploratory activity in Lease Area 42, and whether these changes can be related to observed changes in the concentrations in the benthic environment of pollutant materials discharged from exploratory platforms.

5. PROGRAM DESIGN AND IMPLEMENTATION

The Benthic Infauna Monitoring Program was designed to determine both the near-field short-term and the regional long-term environmental impacts of oil exploration activities in Lease Area 42. A total of 46 stations were established on and adjacent to Georges Bank. These were of two types. A group of long-term regional stations was established to assess long-term and widespread impacts of drilling activities (Figure 2). Benthic infaunal distributions on the southern flank of the Bank are determined largely by water depth and sediment characteristics. Therefore, three transects of three stations each were established perpendicular to the local depth profiles, approximately in a north-south direction. The transects were located west of, east of, and directly through the Lease Area 42 blocks. The three stations on each transect were located at depths of approximately 60, 80, and 100 meters. Because the net movement of water currents over the southern flank of Georges Bank at all depths and seasons is toward the southwest, the eastern Transect I, lying upstream of the lease area, was considered a reference transect, unlikely to be influenced by drilling activities, with which to compare the other transects. The western Transect III lies downstream of the drilling activity where drilling discharges

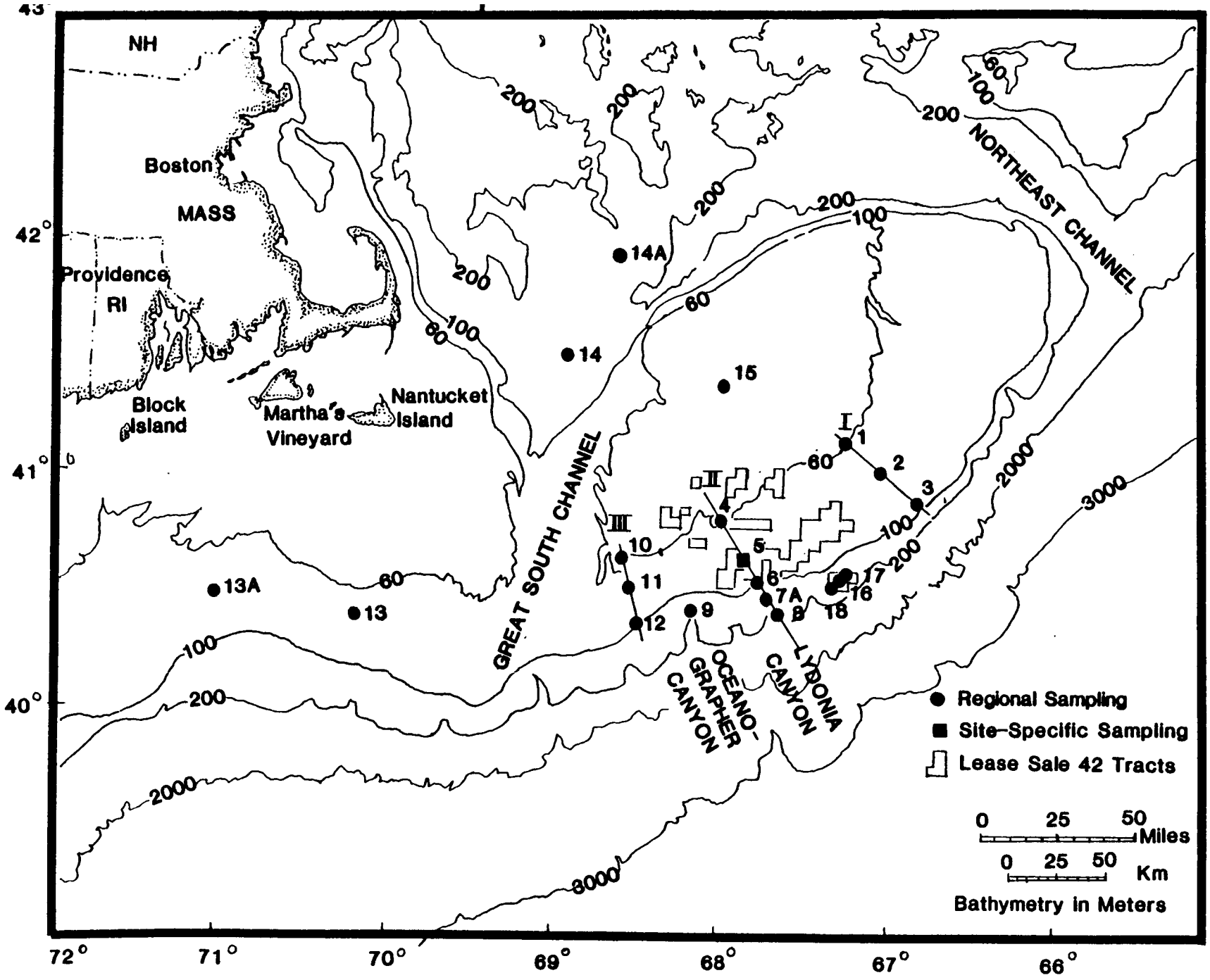

FIGURE 2. LONG-TERM REGIONAL STATIONS

could accumulate and long-term effects might occur. Additional regional stations were located at sites where drilling fluids and cuttings might accumulate over time. These include the heads of Lydonia and Oceanographer Canyons, the Mud Patch south of Cape Cod and Rhode Island, and just above the edge of the Continental Shelf south of the lease area. Another station was located in a high energy erosional area at the top of the Bank in about 35 meters of water.

In order to detect near-field impacts of drilling discharges on the benthic environment, two groups of sampling stations were established in close proximity to two exploratory drilling operations. A group of three stations was located within 200 meters, and approximately 2,000 meters upcurrent and downcurrent of the drilling site in Block 410 located in about 140 meters of water (Stations 16, 17 and 18 in Figure 2). A larger array of 29 stations was located in a radial pattern around the exploratory rig site in Block 312 in 80 meters of water (Figure 3). This rig site corresponds to Regional Station 5 in Figure 2. Stations were located within 200 meters and at distances of 0.5, 1, 2, 4 and 6 kilometers from the rig site. An over-sampling strategy was used here. Nineteen of the stations were designated as primary stations, and all samples from these stations were analyzed. The other ten stations were secondary stations, and samples from them will be analyzed, if needed, to aid in interpretation of impacts observed at the primary stations.

All stations were sampled four times per year on a seasonal basis. During the first year of the Program samples were collected in July and November, 1981 and February and May, 1982. At each station, six replicate biology samples and three replicate chemistry samples of undisturbed bottom sediments were collected with 0.04 m^2 and 0.1 m^2 Van Veen grab samplers, respectively. Subsamples of these were taken for analysis of carbon-hydrogen-nitrogen (CHN) and sediment grain size. Biology samples were sieved through 0.5 and 0.3 mm screens and preserved in buffered formalin. Chemistry samples were frozen.

Bottom photographs were taken at each station to document the presence of animals living on the sediment surface (epifauna) and bottom living (demersal) fish, and in an effort to detect evidence of accumulation of drilling mud and/or cuttings. Measurements of water column hydrography (salinity, temperature, dissolved oxygen) were taken at all regional stations. Dredge and trawl samples were collected at up to three regional and three site-specific stations to obtain fish and mollusc (ocean quahog Arctica islandica) samples for chemical analysis and to obtain representative specimens of epifauna and demersal fish for a voucher collection to be used in identifying species observed in bottom photographs.

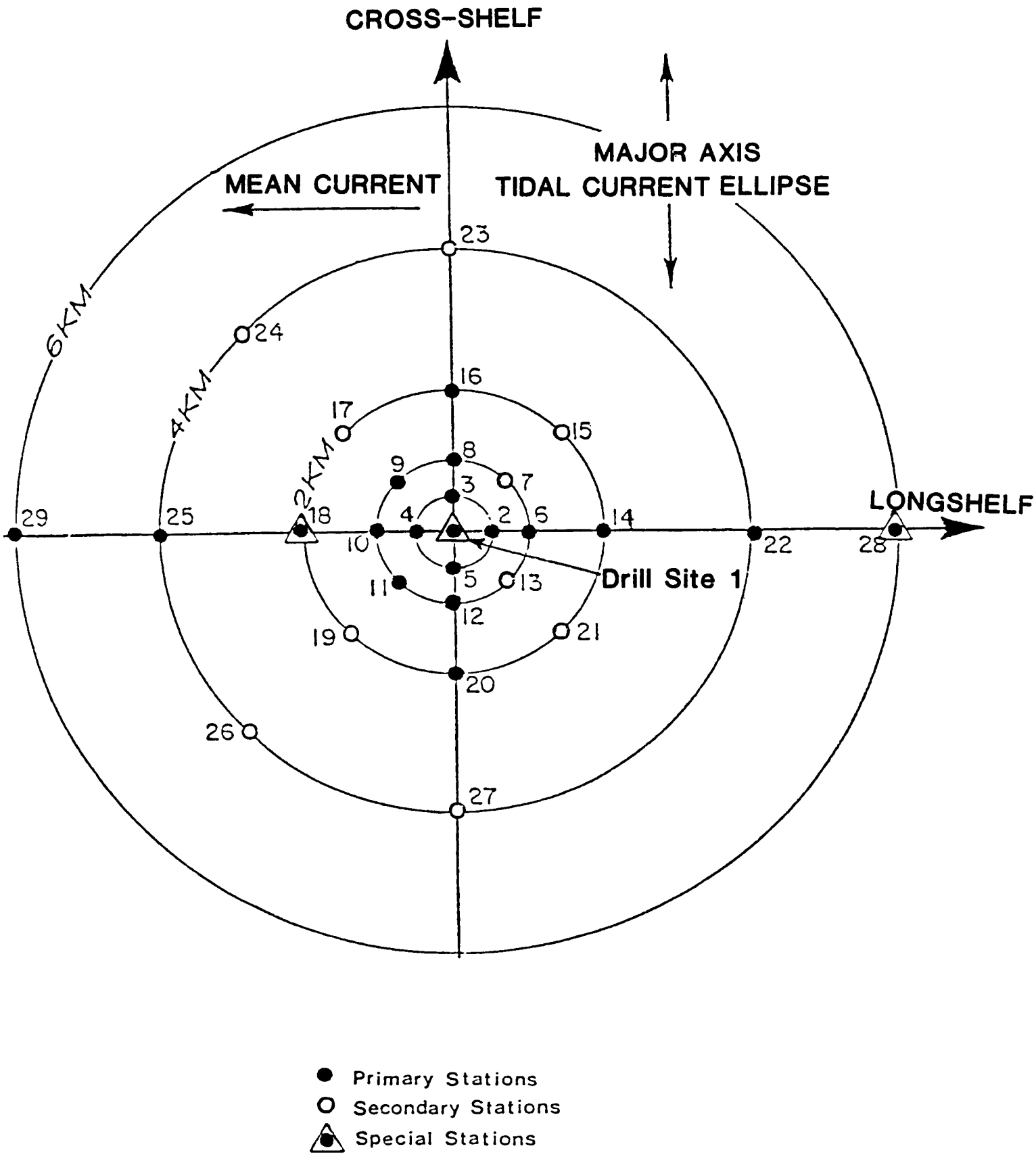

FIGURE 3. SITE-SPECIFIC STATIONS

In the laboratory, each benthic biology sample was transferred to 70 percent alcohol, stained with Rose Bengal and examined under a dissecting microscope. All organisms were sorted to basic taxonomic groups such as polychaete families, amphipods, isopods, other crustacea, molluscs, echinoderms, etc. Identifications then were made to the lowest possible taxon, usually species. Verification of the identity of voucher specimens and problematic species was performed by outside taxonomic experts. Wet-weight biomass was determined separately for each species.

All data from each sampling cruise were coded at Battelle and entered into the VAX 11/780 computer at Woods Hole Oceanographic Institution. Statistical treatment of the data set included an agglomerative clustering technique to determine similarity between samples. The similarity measure was NESS, the Normalized Expected Species Shared, where the comparison of expected species shared is between random samples of 50 or 200 individuals from the initial collection of individuals in each grab. NESS is more sensitive to the less common species than the other commonly used methods. The clustering strategy was flexible sorting with β set at the commonly used value of -0.25. We also have used the Bray-Curtis or percent similarity coefficient as a similarity measure with group average sorting. In addition, the Shannon-Wiener diversity (H') was calculated and Hurlbert's modification of the rarefaction method was used to predict the number of species in a random sample without replacement.

6. RESULTS FOR THE FIRST YEAR OF THE BENTHIC INFAUNA MONITORING PROGRAM

6.1 Sediments

Sediments at all regional stations except Station 13 consisted of greater than 95 percent sand. Sediments at Station 13 consisted of nearly equal parts very fine sand and silt/clay. At Stations 16, 17, and 18 near the rig site in Block 410, sediments were dominated by coarse to medium sands. However, Station 18 had a higher proportion of fine sand than Stations 16 and 17. There was no change in the percent of very fine sand or silt/clay between the first (predrilling) and fourth (postdrilling) cruises. The sediments at the 19 primary site-specific stations were very similar. However, sediments at Station 5-29, the station farthest west of the rig site, had a higher proportion of very fine sand and silt/clay than did the other stations. The percentage of fine sand at many site-specific stations was highest in February.

6.2 Taxonomy

The 0.3 mm screen was more efficient than the conventional 0.5 mm screen in sampling several species of benthic invertebrates. Very small species such as the polychaete Paradoneis new sp. A were retained almost exclusively on the 0.3 mm screen, while efficiency of sampling of long, thin, smooth species like the amphipod Erichthonius rubricornis was much greater with the 0.3 mm than the 0.5 mm screen. Recently settled early life stages of many species of polychaetes and crustaceans also were sampled more efficiently on the 0.3 mm screen.

A total of 783 taxa of benthic invertebrates have been identified in the samples analyzed to date. Seventy-four of these were epifaunal invertebrates or demersal fish. The remainder were infaunal invertebrates. Polychaetes, represented by 306 species, were the most abundant group, and accounted for 39.1 percent of all taxa identified. The polychaetes included at least 8 undescribed genera and 30 undescribed species. Arthropods, represented by 159 species, accounted for 20.3 percent of all taxa identified. Half of these were amphipods. There were at least two undescribed species. Molluscs accounted for 16.6 percent of the fauna with 132 species, at least one of which was a new species. The remaining 23.7 percent of the fauna included cnidarians, echinoderms, oligochaetes, ectoprocts, etc.

6.3 Abundance and Diversity

The number of individuals per 0.04 m^2 was high at most stations and varied seasonally. Densities were highest at Stations 5, 12, and 13, averaging approximately 1,020, 870 and 1,200 individuals per 0.04 m^2, respectively. Lowest densities were at Stations 11 and 17, averaging between 100 and 200 individuals per 0.04 m^2.

Shannon-Wiener diversity was lowest at the shallow Stations 4 and 10 and highest at the deeper Stations 3, 16, and 17. The number of species per 1,000 individuals was highest at regional stations at or below the 100 meter depth (mean 83-121 species per 1,000 individuals) and lowest at the shallow stations.

6.4 Population Patterns: Regional Stations

The most remarkable feature of the cluster analysis of the regional stations was that all of the replicate samples of one station clustered with each other before

joining with those of another station. This occurred for each of the four sampling seasons. The excellent comparability of replicate samples from the same station allows us to detect small changes in benthic community characteristics.

If the data from the six replicates for each station for each sampling period are summed, it is possible to perform a cluster analysis on all the data at once. With one exception the samples for the four seasons at each station cluster together before any separation occurred between stations. The exception was the closely-spaced Stations 16 and 17 which had particularly similar community characteristics in February (M3).

The species composition of the benthic infauna on the southern flank of Georges Bank changed very little over the year and differences between sampling dates were always less than differences between stations. If drilling activities had had a short-term regional impact on the Bank, we might have expected to have seen some changes in community characteristics at some regional stations between the first (predrilling) and subsequent seasonal sampling periods. This was not the case.

The stations tended to cluster together according to water depth, and to a lesser extent according to sediment type (Figure 4). Station 15 at the top of the Bank and Station 13 in the Mud Patch were the only two stations that were distinct from all the others. The remaining stations sorted into five groups: the eastern deep (140-150 m) Stations 8, 16, 17, and 18; a western deep (100-250 m) grouping of Stations 6, 7, 9, and 12; a low similarity fusion of the 80 m Station 11 with the 100 m Station 3; a 70-80 m grouping of Stations 2 and 5; and a 60 m group of stations 1, 4, and 10.

In Block 410, Station 18 to the west of the rig site clearly was different from Stations 16 and 17. For example, the amphipod Ampelisca agassizi was dominant at Station 18 and rare at Stations 16 and 17. This can be attributed to the finer sediments at the former station compared to the latter stations.

Exploratory drilling began in Block 410 in July 1981, shortly after Cruise M1, and continued until the end of March, 1982. During this time, approximately 1,000 metric tons of drill cuttings and 600-800 metric tons of drilling fluid solids were discharged. Bothner et al. (1982) reported that concentrations of barium (presumably from drilling fluids) in unfractionated surficial sediments at Station 16, 200 m from the rig site, increased by a factor of 3.5 between July, 1981 and May, 1982. Smaller increments in sediment barium concentration were observed at Stations 17 and 18. Some evidence of drill cuttings was observed in the gravel fraction of sediments at Station 16. The clay size fraction of sediments from this station showed increases in concentrations of barium, chromium, aluminum, copper, and mercury between pre- and postdrilling samples.

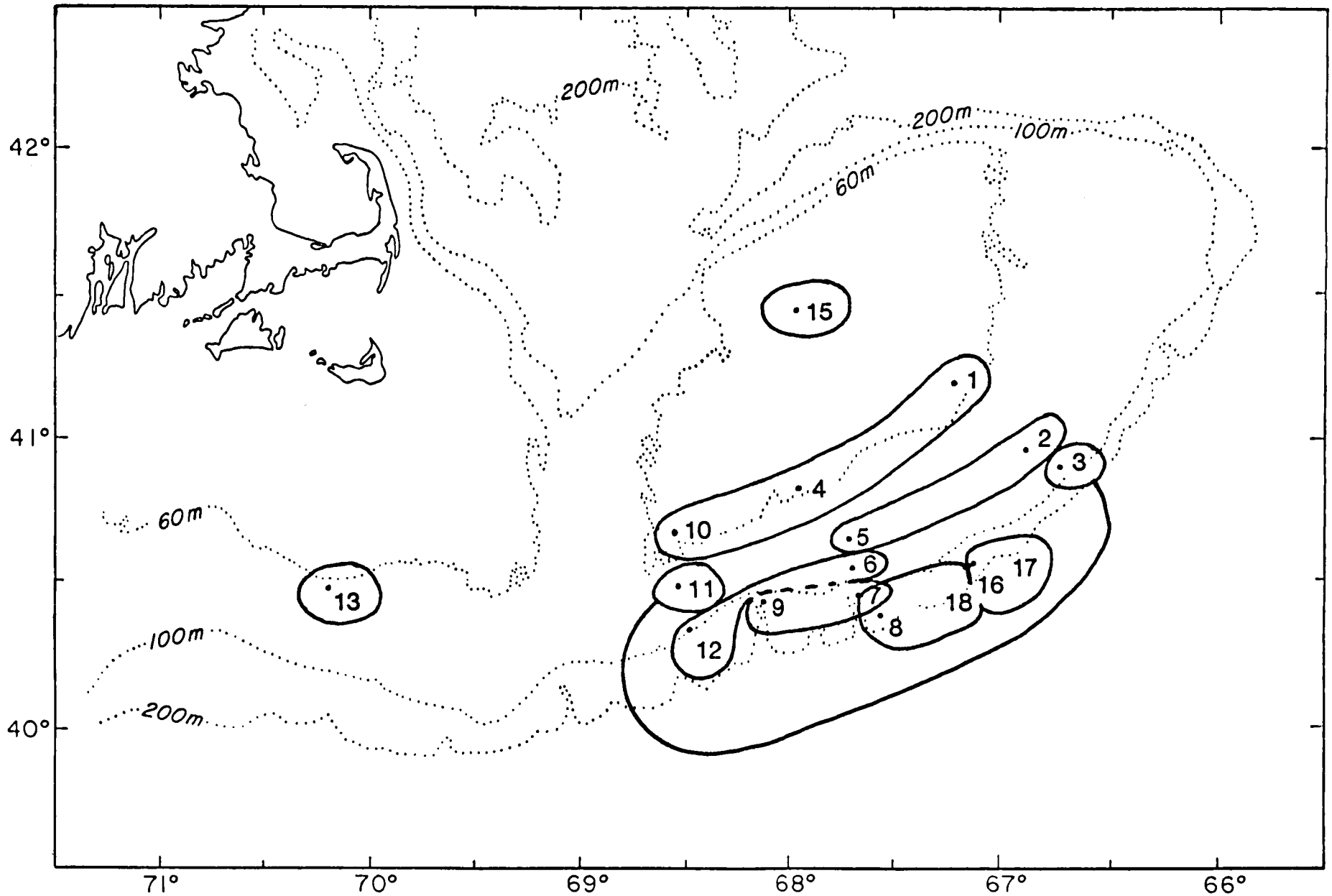

FIGURE 4. MAJOR CLUSTERS OF SUMMED REGIONAL STATIONS AS DELIMITED BY NESS AT 200 INDIVIDUALS AND FLEXIBLE SORTING.

There was no evidence of a biological impact that could be attributed to the accumulation of drilling fluids and cuttings in sediments around the rig site in Block 410. Some species of polychaetes and amphipods showed increases in abundance in November and February followed by a decline in May. Others showed declines in November followed by a large increase in February. Gravid females and recently hatched young of Ampelisca agassizi were abundant in February at Station 18.

Seasonal densities of several species at Station 13, the Mud Patch, showed an increase from July to November or February, followed by a sharp decline in May. These population fluctuations probably represent a sequence of normal seasonal settlement and mortality patterns.

6.5 Population Patterns: Site-Specific Stations

All site-specific stations and sampling dates could be clustered at once using NESS at 200 individuals. The clearest separation occurred between Station 5-29 and the rest of the site-specific stations. This was due in part to the fact that at Station 5-29, where sediments were finer-grained, the amphipod Ampelisca agassizi was more abundant and the amphipods Erichthonius rubricornis and Unciola inermis were less abundant than at the other site-specific stations, regardless of season. With the exception of Station 5-28, the station farthest east or upstream of the drill site, all site-specific stations showed some seasonal changes in community characteristics.

Bothner et al. (1982) reported increases in barium concentrations in bulk sediment samples from several site-specific stations between the first and fourth cruises. Drilling actually started in Block 312 on December 8, 1981, shortly after Cruise M2 and continued to June 1982, shortly after Cruise M4. As much as 900 metric tons of drilling fluids and 1,000 tons of drill cutting may have been discharged during this time. The major increase in sediment barium concentration occurred between the February and May cruises. Drill cuttings were observed in the gravel fraction of sediments at Station 5-1.

In an effort to determine if these accumulations had a biological impact, abundances of several species were compared over the four seasons at those near-field stations showing the largest increment in sediment barium concentration (Stations 5-8, 5-2 and 5-1), those downcurrent stations showing moderate increments in barium (Stations 5-10 and 5-25), and upcurrent stations where there was no evidence of drilling fluid or cuttings accumulation (Stations 5-28 and Regional Station 2). At stations near the rig site, there was a decrease in the number of individuals per sample from July to November,

with good recovery in February, continuing through May. The downcurrent stations did not experience a decline until February and there was substantial recovery by May. The upcurrent reference stations did not show declines in density in either November or February, but exhibited gradual increases in density through the four seasons.

Several species showed this or a slightly different pattern of seasonal change in abundance. The most dramatic population decline was experienced by the corophiid amphipod Erichthonius rubricornis, an epifaunal suspension feeder. Most of the population changes observed near the rig site can be correlated with changes in sediment grain size characteristics. This probably was due primarily to the scouring action of winter storms, particularly between November, 1981 and February, 1982. It also is possible that accumulation of drill cuttings near the rig between November and February could have contributed to the population changes observed. Evidence of drilling fluid accumulation did not occur until May, by which time most species had shown substantial recovery. Thus, no short-term adverse changes in the benthic infaunal community have been identified to date which can be related to accumulation of materials from drilling discharges in sediments near exploratory rigs.

6.6 Bottom Still Photographs

Bottom still photographs taken at regional and site-specific stations provided visual evidence of seasonal changes in the surface texture and color of the bottom, and patchiness of epifaunal invertebrates and demersal fish. No evidence of drill cuttings or drilling fluid accumulation on the bottom was found in any photograph. This is not surprising, because the chemical evidence provided by Bothner et al., (1982) indicates that only very small amounts of these materials accumulated per unit area of bottom near the rig sites.

Several regional stations, particularly those at the same depth interval, showed similarities in surface topography, amount of detritus or biological cover, and sediment type. Biological cover was most dense in July and May. There was evidence of bottom scour, including pronounced ripple marks, in November and particularly February at many stations. Bottom scour was most evident at the shallower stations.

7. KEY PARTICIPANTS IN THE PROGRAM

The Georges Bank Benthic Infauna Monitoring Program has been a collaborative effort of nearly 100 scientists and technicians. The program leaders are:

Jerry M. Neff, Program Manager, Nancy Maciolek-Blake and James A. Blake from Battelle New England Marine Research Laboratory, and J. Frederick Grassle and Howard L. Sanders from Woods Hole Oceanographic Institution. George R. Hampson (W.H.O.I.) is First Scientist on sampling cruises and Rose Petrecca (W.H.O.I.) is Cruise Coordinator.

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