Distribution of Bottom Habitats on the Continental Shelf off South Carolina and Georgia

submitted by

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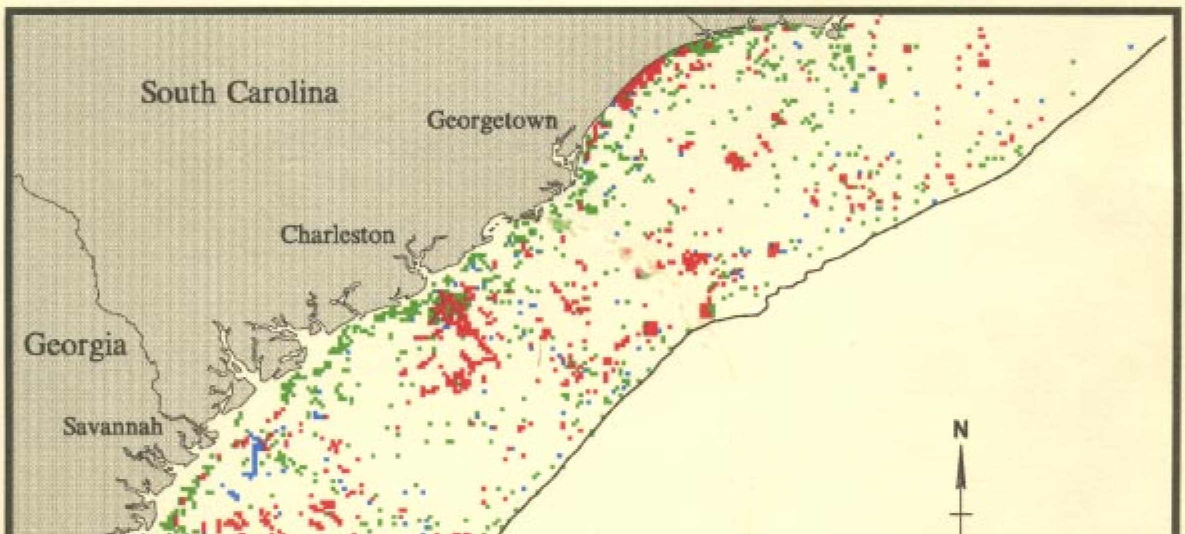

FINAL REPORT

submitted to

Southeast Area Monitoring and Assessment Program

South Atlantic Committee

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EXECUTIVE SUMMARY

Marine resource managers, scientists, and user groups in the southeastern United States have identified the need for accurate information of the location and extent of various bottom types on the continental shelf, especially hard-bottom reef habitats. In order to meet these needs, a Bottom Mapping Workgroup was formed by the SEAMAP Committee in 1985 to develop a plan for establishing a regional database that would describe the location and characteristics of hard-bottom resources in the South Atlantic Bight. The study described in this report represents the first major phase of a continuing effort to create the full database for the South Atlantic Bight. Specific objectives of this phase were to:

1. develop a flexible, easy to use database in a format that provides users with pertinent information concerning the location and extent of hard-bottom areas, types of data used in determining bottom type, and source of the data;
2. conduct an extensive evaluation of existing databases having information on bottom type (i.e., reef versus non-reef habitat) on the continental shelf off South Carolina and Georgia; and
3. evaluate PC-based software programs that will allow database users to easily obtain graphic outputs of the database.

The database format developed by the Workgroup was based upon results of a previous survey of regional resource manager needs, combined with input from regional scientists who participated in several workshops. The database format consists of three related files. The primary file provides information on the specific location and date of each record, type of gear used, bottom type, and source of the data. The second file provides additional information on how to locate the original data source. The third file provides summary information for grid cells which divide the entire survey area into cells measuring one minute of latitude by one minute of longitude in size. A total of 40,941 grid cells were established for the survey area, which extends from the shoreline out to a depth of 200 m between the 28.0 N and 36.5 N latitudes.

Historic data records incorporated into the database included those from: television (2094) and diver observations (311), which were considered the most reliable; bottom fish trawls

(3077) and traps (3908); and side scan sonar records (1861). Data sources included most of the long term fishery-independent and geological surveys conducted within the South Carolina and Georgia shelf areas since the early 1970's.

To date, the number of records within the database by state are: NC, 672; SC, 7729; GA, 2805; and FL, 857. The numbers of records will increase greatly through subsequent study phases that will target remaining data sources off North Carolina and Florida.

Graphical summaries of the bottom-type data off SC and GA are presented. A review of four desktop mapping software packages (ArcView 1.0/2.0, Atlas GIS, IDRISI 4.0 and MapInfo for Windows) that could provide similar graphical output indicated that all packages should be suitable for use with the database, although each has unique characteristics and capabilities.

INTRODUCTION

Hard-bottom reef habitats represent an important biological resource in the South Atlantic Bight (SAB). Struhsaker (1969) was one of the first to categorize bottom types in this region, and document that some hard or "live" bottom reef habitats supported large populations of commercially and recreationally important fishes. Additional classifications have been made to characterize reef habitat based on relief, morphology and location within the shelf zone (Henry & Giles, 1979; Miller & Richards, 1980). Hard-bottom reefs can include a variety of bottom types, ranging from areas with little or no vertical relief which support patchy communities of sponges and corals to areas of high-relief rocky-outcroppings and abundant invertebrate growth.

Knowledge of reef habitats and their biological communities in the southeast region has expanded considerably in recent years. Biological studies have evaluated the distribution and abundance of invertebrate and fish faunas associated with live-bottom and rocky outcrops (Powles & Barans, 1980; Grimes et al., 1982; SCWMRD, 1981, 1982, Wenner et al., 1983, 1984; Chester et. al., 1984; Sedberry & Van Dolah, 1984; Barans & Henry, 1984; Lindquist et. al., 1989; Parker, 1990). Location and size estimations of reef habitats have included studies which have looked at species composition in historical trawl data (Miller & Richards, 1980), and studies utilizing modern techniques such as underwater visual census using television and SCUBA, side scan sonar, and submersibles (Continental Shelf Associates, 1979; Henry & Giles, 1979; Parker et al., 1983; Barans & Henry, 1984; Sedberry & Van Dolah, 1984; Van Dolah & and Knott, 1984; Parker & Ross, 1986; Stender et al., 1991; Maier et al., 1992).

Recent interest in the distribution of reef sites has expanded because of concerns regarding the ability of the shelf to support populations of reef fish in the face of increasing fishing efforts (South Atlantic Fisheries Management Council, 1990). A first step in assessing the size of reef fish populations is to quantify the amount of habitat available for those species of concern. Determining locations of reef habitats also is of concern to a variety of other users of marine resources, including petroleum companies; private, state and federal entities interested in dredging marine habitats for sand and other minerals, or using marine areas as disposal sites;

researchers; and management staff of state and federal agencies charged with protecting and preserving reef habitats.

In 1981, scientists involved in studies of hard-bottom habitats throughout the SAB met during a workshop sponsored by the Bureau of Land Management to discuss research priorities and data needs related to hard-bottom areas. A priority goal identified at that workshop was to produce a map and accompanying descriptive material that summarized the occurrence and distribution of reefs and hardgrounds on the shelf between Cape Hatteras, NC and Jacksonville, FL (Henry, 1981).

In 1985, the NOAA South Atlantic SEAMAP program established a Bottom Mapping Workgroup to develop a plan for establishing a regional database that would describe the location and characteristics of hard-bottom resources in the SAB. By 1986, a plan had been developed and a small-scale evaluation of the methods for defining and characterizing hard-bottom areas in the region had been completed for a test area off North Carolina (Ross et al., 1986). That study also included an extensive survey of state and federal agencies to identify their information needs related to reef habitats.

Beginning in 1992, the first phase of a multi-year effort to establish the full-scale database for all four coastal states in the SAB was initiated. Specific objectives for this first phase were to:

1. develop a flexible, easy-to-use database in a format that provides users with pertinent information concerning the location and extent of hard-bottom areas, types of data used in determining bottom type, and source of the data.
2. conduct an extensive search of existing databases having information on bottom type (i.e. reef versus non-reef habitat) on the continental shelf off South Carolina and Georgia, and
3. evaluate PC-based software programs that will allow database users to easily obtain graphic outputs of the database

This report summarizes activities related to the above objectives, and provides both a printed copy and graphical summaries of the database completed to date. These data will also be available in digital form through the SEAMAP Data Management System.

METHODS

Development of Database Format:

The format of the database was developed by the SEAMAP Bottom Mapping Workgroup, which includes representatives from the four coastal states, the National Marine Fisheries Service (NMFS), and the South Atlantic Fisheries Management Council (SAFMC). Table 1 provides a listing of the members currently serving on the Workgroup.

Table 1. Representatives currently serving on the SEAMAP Bottom Mapping Work Group.

Name	Affiliation
Robert Van Dolah, Chair	South Carolina Department of Natural Resources
Charles Barans	South Carolina Department of Natural Resources
Fred Rhode	North Carolina Department of Environment, Health and Natural Resources
James Henry	Georgia Southern University
Ken Haddad	Florida Department of Natural Resources
William Lyons	Florida Department of Natural Resources
Richard Parker	National Marine Fisheries Service, Southeast Fisheries Science Center
Roger Pugliese	South Atlantic Fishery Management Council

Since the formation of the Workgroup in 1985, several meetings were held to discuss and refine an appropriate database format. The database approved by the workgroup contains three relational files. A primary file provides information on the location and type of each data record, with codes for the source of information and bottom type indicated (Table 2.). A secondary database file provides more detailed information on the source of each record, with information necessary to obtain the original report or contact the agency which maintains the original data (Table 3). Another secondary file provides summary information on the number of records for each grid cell of the survey area included in the database (Table 4).

Table 2. Structure of Primary file for the SEAMAP Bottom Mapping Database.

Field	Description
Block	contains unique number for each 1' grid cell established for the survey area; code represents latitude and longitude of southeastern corner of grid cell
Date	YYMMDD (year/month/day) of the collection or date of report publication if the collection date was unavailable
Agency - Pro	four character code that provides information on agency (first 2) and project (last 2 characters) that provided the data
Origicoll	lists original collection number if available; last 6 characters of code if >6 digits or letters
Start/End/Lat/Long	data collection start coordinates in latitude/longitude, LORAN data were converted to latitude/longitude when necessary. End coordinates were included when available.
Posmethod	code describing positioning system used
Corrfactor	describes any corrections made to the LORAN position coordinates during conversion to latitude/longitude by the original researcher
Geartype	describes the gear and method used to collect the data
Depth	water depth recorded to nearest meter; data records in fathoms were converted to the nearest 2 meters.
Bottomtype	code for bottom type as one of following categories: hard bottom (HB), possible or probable hard bottom (PH), no evidence of hard bottom (NH), artificial reef (AR)
Relief	maximum bottom relief, if documented: low (<.5m), medium (.5 -.2m), or high (>2m)

Table 3. Structure of Project file.

Field	Description
Agency_Pro	provides agency_project code for relation to primary database
Pos_Prec	recorded data precision
sourc_code	provides SEAMAP with a source code to identify the state that data source was obtained from
Proj_Title	100 character allotted for title, can be expanded if necessary
Fund_Agen	source of original funding
Grant_Num	original grant number, if indicated
Prin_Inves	name of principal investigator(s)
Company	name of agency or company which performed the study
Street City State Zip Phone Fax	company information

Table 4. Structure of Summary file on Grid Cells

Field	Description
Block	provides grid cell code for relation to the primary database, code represents latitude and longitude of southeastern corner
N_Obs	total number of observations within a grid cell
HB	number of records indicating the presence of hard bottom within the grid cell
PH	number of records indicating the possible presence of hard bottom within the grid cell
NH	number of records indicating no evidence of hard bottom within the grid cell
AR	number of records indicating presence of artificial reef structure within grid cell
HA	number of records indicating presence of hard bottom and artificial reef within grid cell

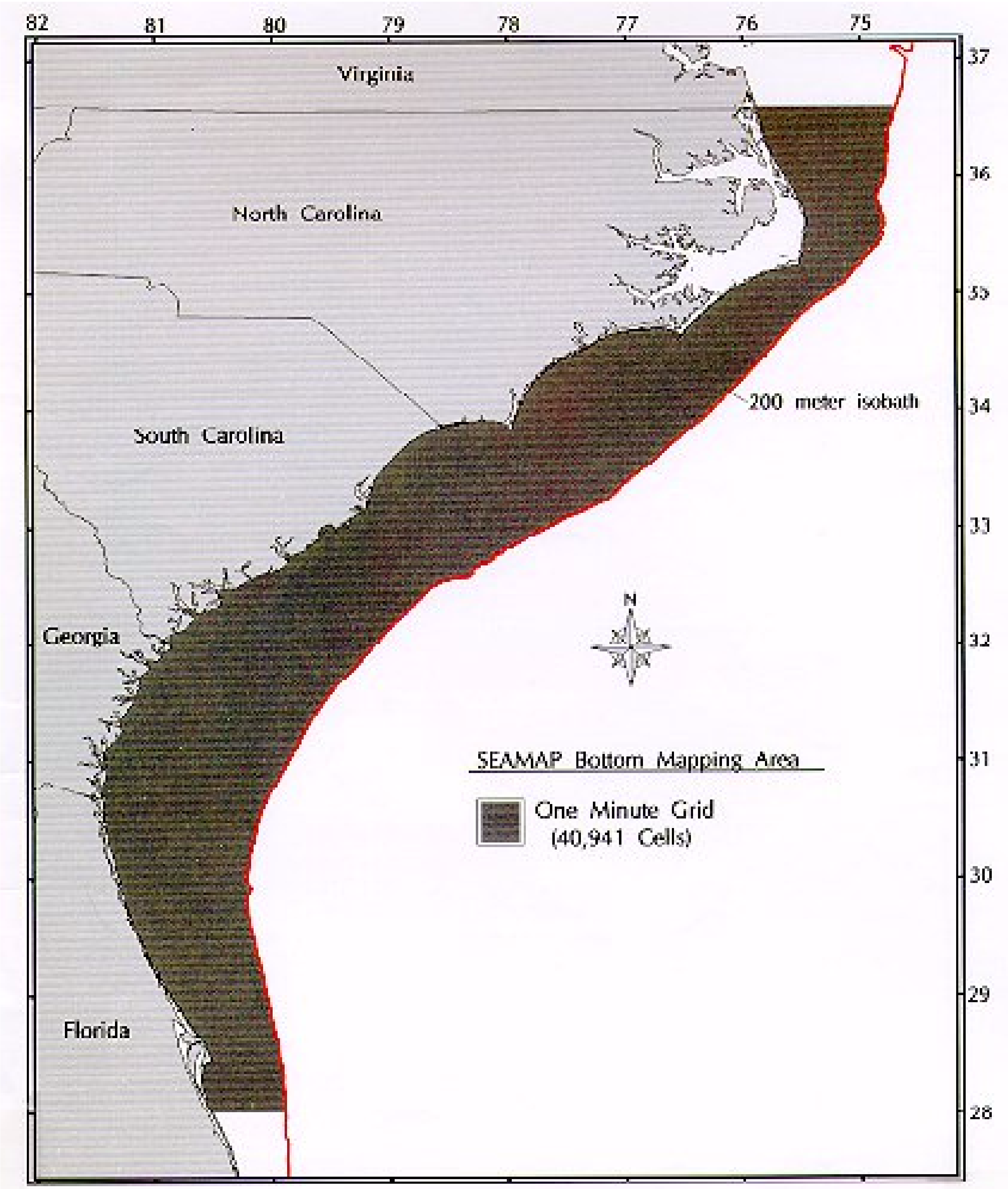
All data records evaluated for the bottom mapping database were associated by position with a grid which divides the entire survey area into cells that are one minute of latitude by one minute of longitude in size.   There are a total of 40,941 grid cells for the entire survey area (Figure 1). The grid cell system was developed primarily as a mechanism to evaluate the continuous data records, such as side scan sonar or underwater television transects, to code bottom type for discrete segments of those records.   Point data were also coded by grid cell. Point data located on a boundary line between two grid cells resulted in coding the cell to the north if latitude was in question and coding the grid cell to the east if longitude was in question. Specific protocols for the evaluation of each gear type are provided in the following sections.

Types of Records Evaluated:

Television Data:

Television records were from closed-circuit underwater television systems that were either towed or suspended in a manner to observe the bottom and/or fauna. These records were considered to be one of the most reliable types of records for detecting the presence of hard bottom habitat since they provided visual confirmation of bottom type. Television records evaluated in this study phase included both point and continuous data. Point data consisted of records that contained only a start coordinate, and the TV camera was on the bottom for only a short time period. Continuous data consisted of extended transects over the bottom, with the start and end coordinates often several kilometers apart. Television records longer than one grid cell in length were re-evaluated to divide the transect into several discrete segments corresponding to the coordinates where the transect entered and left a grid cell. Presence or absence of hard bottom (or associated sessile growth) was coded for each segment and entered as a separate record in the SEAMAP database. No attempt was made to identify patches of sand bottom or hard bottom within a grid cell. When multiple bottom types were noted, priority was given to coding the segment as hard bottom.

Figure 1. **Extent of survey area included in the bottom-mapping database.**



82
81
80
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76
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37
36
35
34
33
32
31
30
29
28
Virginia
North Carolina
South Carolina
Georgia
Florida
200 meter isobath
N
SEAMAP Bottom Mapping Area
One Minute Grid
(40,941 Cells)

Diver Observations:

Only observations provided by divers associated with research projects or research and management agencies were considered in this database. For this reason, this type of record was also considered to be one of the most reliable sources of information on bottom type. Diver logs had to have reliable position coordinates and had to clearly indicate the presence of hard-bottom habitat based on outcroppings or sponge/coral growth, to be included in the database.

Trawl Data:

Trawl collections provided a less reliable indication of bottom type than visual methods, but there are numerous and extensive databases available in the South Atlantic Bight that were evaluated for bottom type based on the presence or absence of reef fish species. Bottom trawl collections were subjected to an analysis of species composition to determine whether they contained an adequate number of indicator reef species to be considered a collection from reef habitat. Indicator reef species were determined based on a review of species lists compiled by the Marine Resources Monitoring, Assessment and Prediction Program (MARMAP) using samples known to be collected from hard-bottom areas, and a review of the species list compiled by Ross et al. (1987) using similar criteria. This latter list was based, in part, on the list of reef fish species established by Miller and Richards (1980). Both species lists were reviewed and combined to derive an overall list of indicator species agreed upon by the Workgroup participants and Dr. Ross (Table 5). Only bottom trawls were considered in this analysis and tow times of the records evaluated generally ranged from 10-30 minutes.

Criteria for categorizing trawl collections as indicative of a particular bottom type were based on the occurrence of specific reef fish. Two methods were considered in this approach. The first, originally described by Ross et al., (1987), was based on a discriminant function analysis using a variety of input variables. Although useful in determining factors affecting fish distribution, this method was very time consuming, and unnecessary for confirming the presence of reef habitat from occurrence of indicator fish species. Furthermore, this method would require developing discriminant functions for each type of reef habitat, and for different zones of latitude and depth within the survey area. To avoid these complications, another method was developed that was based only on the number of obligate reef fish species present in the sample. The co-occurrence of more than one indicator species was considered a simpler, and effective method for assigning bottom type based on finfish collections. For the SEAMAP bottom-mapping database, samples were classified as reef habitat, possible reef habitat, or non-reef habitat based on the co-occurrence of three or more, two, or less than two indicator species, respectively.

A comparison was made between the two analysis methods to determine which was best for classifying stations for bottom type. For this comparison, 58 daytime trawl samples taken during a live-bottom trawl survey conducted from 1978-1987 were analyzed. Of the 58 samples, only four were classified differently by the two methods. Three of these collections were classified as reef habitat by the discriminant function analysis method and as non-reef habitat by the co-occurring indicator species method (Table 6). A classification of non-reef habitat appeared to be more appropriate for these samples based on the relative number and abundance of non-reef species in the samples. The fourth sample was classified as possible reef habitat using the co-occurring indicator species method (i.e. two indicator species present), and as non-reef habitat based on the discriminant function analysis (Table 6). This sample had two indicator reef species, each represented by one individual and 1,077 individuals of 11 non-reef species. Based on the comparison and general agreement among the two methods, the Bottom Mapping Workgroup selected the simpler, more conservative approach for classification of bottom type to apply to the large trawl data sets available within the survey area using the list of indicator species identified in Table 5.

Table 5. List of fish species considered to be reef species for use in categorizing trawl and trap data for bottom type.

- *Abudefduf saxatilis*
- *Acanthurus bahianus*
- *Acanthurus chirurgus*
- *Acanthurus coeruleus*
- *Adioryx bullisi*
- *Anarchias similis*
- *Anisotremus virginicus*
- *Antennarius ocellatus*
- *Antennarius scaber*
- *Antennarius radiosus*
- *Anthias nicholsi*
- *Apogon affinis*
- *Apogon aurolineatus*
- *Apogon maculatus*
- *Apogon pseudomaculatus*
- *Apogon quadrisquamatus*
- *Archosargus probatocephalus*
- *Astrapogon alutus*
- *Balistes capriscus*
- *Balistes vetula*
- *Bodianus pulchellus*
- *Bodianus rufus*
- *Calamus nodosus*
- *Calamus proridens*
- *Canthigaster rostrata*
- *Caulolatilus chrysops*
- *Caulolatilus cyanops*
- *Caulolatilus microps*
- *Centropristis ocyurus*
- *Centropristis striata*
- *Chaetodon aculeatus*
- *Chaetodon aya*
- *Chaetodon capistratus*
- *Chaetodon ocellatus*
- *Chaetodon sedentarius*
- *Chaetodon striatus*
- *Chromis cyanea*
- *Chromis enchrysurus*
- *Chromis insolatus*
- *Chromis scotti*
- *Clepticus parrai*
- *Conger oceanicus*
- *Corniger spinosus*
- *Coryphopterus punctipectophorus*
- *Decodon puellaris*
- *Diodon holocanthus*
- *Diodon hystrix*
- *Diplodus holbrooki*
- *Doratonotus megalepis*
- *Emblemaria atlantica*
- *Epinephelus adscensionis*
- *Epinephelus cruentatus*
- *Epinephelus drummondhayi*
- *Epinephelus fulvus*
- *Epinephelus guttatus*
- *Epinephelus inermis*
- *Epinephelus itajara*
- *Epinephelus morio*
- *Epinephelus mystacinus*
- *Epinephelus nigritus*
- *Epinephelus niveatus*
- *Epinephelus striatus*
- *Equetus acuminatus*
- *Equetus iwamotoi(=blackbar)*
- *Equetus lanceolatus*
- *Equetus punctatus*
- *Equetus umbrosus*
- *Evermannichthys spongicola*
- *Gnatholepis thompsoni*
- *Gobiosoma ginsburgi*
- *Gobiosoma xanthiprora*
- *Gymnothorax funebris*
- *Gymnothorax hubbsi*
- *Gymnothorax moringa*
- *Gymnothorax saxicola*
- *Gymnothorax vicinus*
- *Haemulon plumieri*
- *Haemulon sciurus*
- *Haemulon striatum*
- *Halichoeres bivittata*
- *Halichoeres caudalis*
- *Halichoeres cyanocephalus*
- *Halichoeres garnoti*
- *Halichoeres maculipinna*
- *Halichoeres poeyi*
- *Halichoeres radiatus*
- *Hemanthias aureorubens*
- *Hemanthias vivanus*
- *Holacanthus bermudensis*
- *Holacanthus ciliaris*
- *Holacanthus bermudensis x ciliaris*
- *Holacanthus tricolor*
- *Holanthias martinicensis*
- *Holocentrus ascensionis*
- *Holocentrus rufus*
- *Hypleurochilus geminatus*
- *Hypoplectrus aberrans*
- *Hypoplectrus indigo*
- *Hypoplectrus nigricans*
- *Hypoplectrus puella*
- *Hypoplectrus unicolor*
- *Lachnolaimus maximus*
- *Lactophrys polygonia*
- *Lactophrys trigonus*
- *Liopropoma eukrines*
- *Lutjanus analis*
- *Lutjanus apodus*
- *Lutjanus buccanella*
- *Lutjanus campechanus*
- *Lutjanus griseus*
- *Lutjanus jocu*
- *Lutjanus purpureus*
- *Lutjanus synagris*
- *Lutjanus vivanus*
- *Lythrypnus nesiotes*
- *Lythrypnus phorellus*
- *Lythrypnus spilus*
- *Microspathodon chrysurus*
- *Mulloidichthys martinicus*
- *Mullus auratus*
- *Muraena miliaris*
- *Muraena retifera*
- *Muraena robusta*
- *Mycteroperca bonaci*
- *Mycteroperca interstitialis*
- *Mycteroperca microlepis*
- *Mycteroperca phenax*
- *Mycteroperca sp.*
- *Mycteroperca venenosa*
- *Myripristis jacobus*
- *Nicholsina usta*
- *Ocyurus chrysurus*
- *Opsanus beta*
- *Opsanus pardus*
- *Opsanus sp.*
- *Opsanus tau*
- *Pagrus pagrus*
- *Parablennius marmoreus*
- *Paraconger caudilimbatus*
- *Paranthias furcifer*
- *Parophidion lagochila*
- *Phaeoptyx pigmentaria*
- *Pomacanthus arcuatus*
- *Pomacanthus paru*
- *Priacanthus arenatus*
- *Priacanthus cruentatus*
- *Prisigenys alta*
- *Pristipomoides aquilonaris*
- *Pseudupeneus maculatus*
- *Rhomboplites aurorubens*
- *Risor ruber*
- *Rypticus bistrispinus*
- *Rypticus maculatus*
- *Rypticus saponaceus*
- *Scarus croicensis (=iserti)*
- *Scorpaena agassizi*
- *Scorpaena brasiliensis*
- *Scorpaena calcarata*
- *Scorpaena dispar*
- *Scorpaena plumieri*
- *Serraniculus pumilio*
- *Serranus baldwini*
- *Serranus notospilus*
- *Serranus phoebe*
- *Serranus subligarius*
- *Serranus tigrinus*
- *Sparisoma radians*
- *Sphoeroides spengleri*
- *Starksia ocellata*
- *Stegastes (=Pomacentrus) leucostictus*
- *Stegastes (=Pomacentrus) partitus*
- *Stegastes (=Pomacentrus) planifrons*
- *Stegastes (=Pomacentrus) variabilis*
- *Tautoga onitis*
- *Thalassoma bifasciatum*

Table 6. Results of classification of trawl samples from a known reef area. Classification is by discriminant function (DF) analysis (Ross et al., 1987). Using the simpler classification scheme, collections would be designated as indicative of reef habitat if 3 or more reef species were present; possible reef habitat if only 2 reef species were collected, and non-reef habitat if fewer than two indicator species were present. *denotes samples where there was disagreement between two classification schemes.

Classification From DF Analysis	No. Reef Fish	No. Reef Species	No. Sand Fish	No. Sand Species
REEF	16	2	34	8
REEF	7	2	41	8
REEF	16	5	2876	7
REEF	13	3	2268	11
REEF	89	4	714	9
REEF	6	4	2227	10
REEF*	19	1	171	14
REEF	44	3	161	15
REEF	45	3	198	12
REEF	8	3	57	7
REEF	35	4	171	16
REEF	28	2	143	12
REEF	67	3	359	20
REEF	24	2	520	10
REEF	37	3	583	11
REEF	27	4	405	17
REEF	16	4	65	7
REEF	29	5	75	17
REEF	12	3	12	6
SAND	2	1	648	7
REEF	10	2	382	6
REEF	4	3	135	8
REEF	11	3	223	11
REEF	15	3	150	9
REEF	80	6	836	27
REEF	227	9	570	27
REEF	142	7	1042	27
SAND	3	1	1877	13
REEF	12	2	2331	11
SAND*	2	2	1077	11
REEF	16	4	905	7
SAND	.	.	2416	6
SAND	3	1	158	6
REEF	5	2	263	12

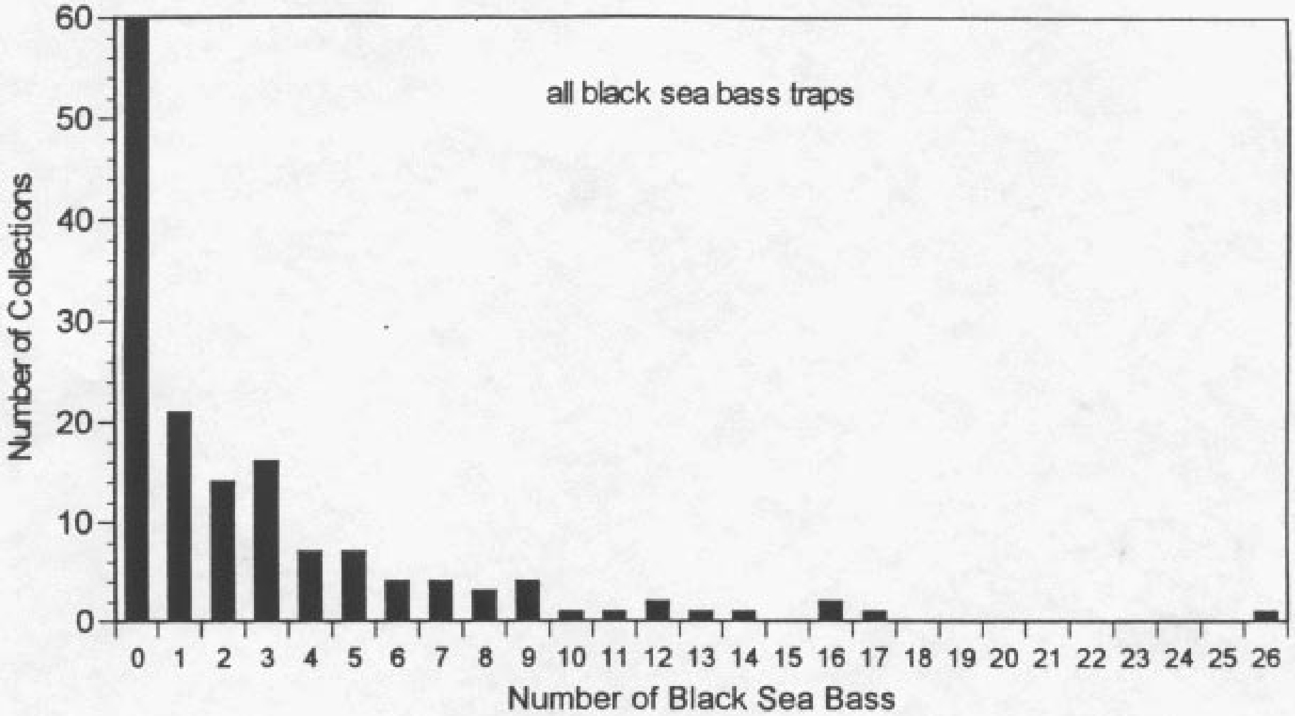
Table 6. Continued.

Classification From DF Analysis	No. Reef Fish	No. Reef Species	No. Sand Fish	No. Sand Species
REEF	9	2	141	11
REEF	6	2	140	11
SAND	.	.	1	1
SAND	3	1	462	9
SAND	1	1	220	6
REEF	10	2	2303	9
SAND	.	.	1808	6
SAND	1	1	969	9
SAND	1	1	294	5
SAND	3	1	780	10
SAND	.	.	90	6
SAND	.	.	88	3
REEF	6	4	1689	9
SAND	1	1	1836	8
REEF	8	4	1615	10
REEF	6	2	120	7
SAND	3	1	577	8
REEF	17	3	915	10
REEF*	6	1	777	10
SAND	2	1	357	5
REEF	11	4	331	5
REEF	6	2	35	7
REEF	7	2	30	3
REEF*	6	1	65	5

Trap Data:

Trap collections were also classified using the co-occurring indicator species method used for the trawl collections. Because black sea bass (BSB) traps often catch large numbers of a single reef species (i.e. black sea bass, Centropristis striata), an additional test was done on BSB trap collections to determine if the method was too conservative for black sea bass traps. We examined BSB trap data by determining the number of black sea bass caught in all BSB traps, and the number of black sea bass collections that would have been classified as positive or probable reef catches based on the presence of two or more reef fish in the trap (Figure 2). Many BSB trap samples that would have been classified as from positive or probable reef habitat

Figure 2. Catches of black sea bass in black sea bass traps.



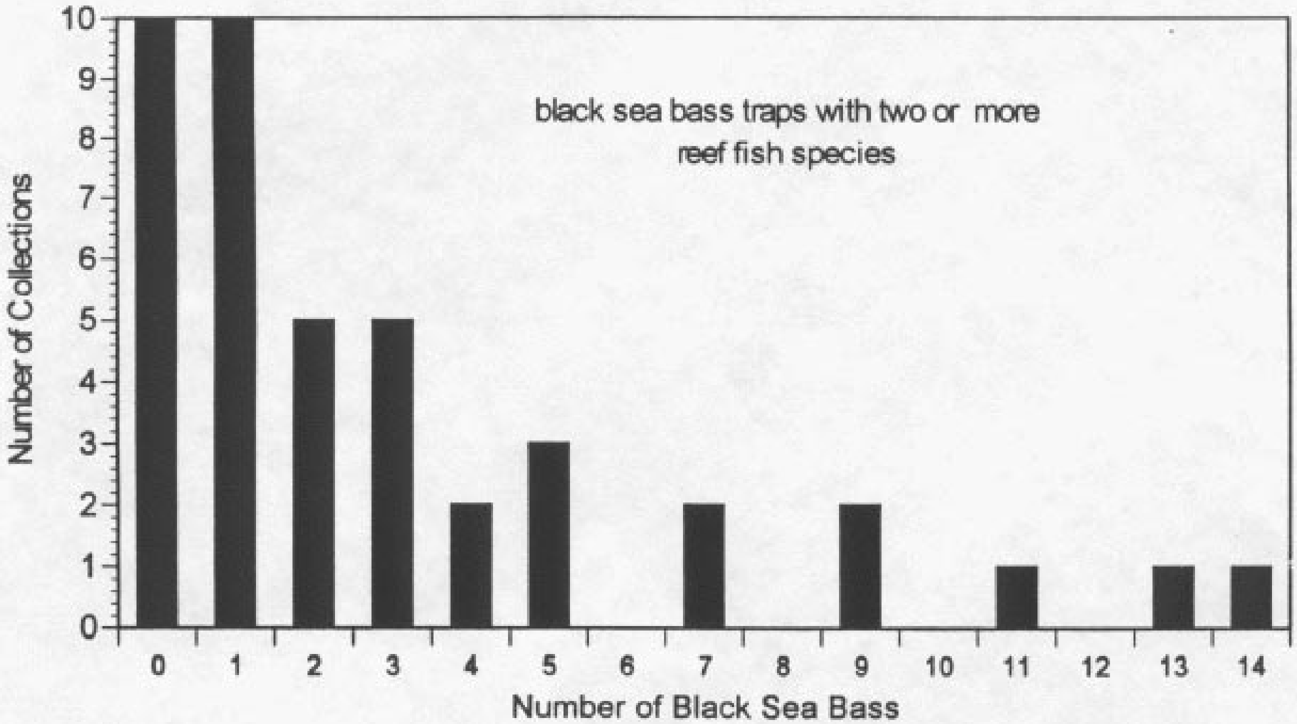


Figure 2. Catches of black sea bass in black sea bass traps.

caught only 0-2 individuals of black sea bass. Because many BSB traps caught no black sea bass, but often caught other reef fishes, we decided that BSB traps can be treated as any other trap sampler. Soak times for all traps considered in this analysis were less than two hours during daylight periods. Restrictions on trap soak time were intended to make the number and composition of fish within the traps reflective of the immediate fishing area and reduce the likelihood that species are being drawn from distant reef areas.

Side-Scan Data:

Information on bottom relief and hardness from side-scan records was treated in a manner similar to that described for the evaluation of television records. Many of the side-scan surveys considered in this report were done using television gear as well. Each side-scan transect was divided into segments corresponding to the points that the transect entered and left a grid cell. Segments were classified based on bottom type as reported by the original investigators. In some cases where bottom type could not be determined for each segment, it was possible to re-evaluate original printouts of the transects and code bottom type based on the expert opinion of project staff responsible for this data component. Many of the side-scan databases available for the continental shelf area off South Carolina and Georgia region were quite extensive and generally not available in a digitized form. Re-evaluation of these records proved quite time-consuming and, as a consequence, priority was placed on analyzing those segments that showed evidence of hard bottom.

Dredge Data:

Only a small number of dredge samples have been collected off South Carolina and Georgia. Therefore, the dredge data were not evaluated in this study phase. Analysis of dredge records would require the compilation of a listing of all known obligate reef species (sessile fauna requiring attachment to rock substratum, such as sponge, coral and algal species) that are typically found in the South Atlantic Bight. An analysis of dredge samples using procedures similar to that done for the trawl and trap databases could then be completed. The development of an acceptable method might best be accomplished using the extensive SEAMAP dredge collection from the east coast of Florida.

Sources of Data:

A large number of data sources were reviewed to compile the database on bottom type for the continental shelf off South Carolina and Georgia. Appendix 2 provides a listing of the studies and programs reviewed. Even though the scope of work for this study phase required analysis of data collected off South Carolina and Georgia only, project personnel included data available from the entire region if the data were already in a digitized format that could be easily incorporated into the database.

MARMAP Fishery-Independent Surveys:

One of the largest databases available for the South Atlantic Bight was developed by the Marine Resources Monitoring, Assessment, and Prediction Program (MARMAP) supported by NMFS/NOAA at the South Carolina Marine Resources Research Institute (MRRI). This program has conducted annual cruises involving removal sampling to describe the distribution, abundance and biomass of demersal fishes throughout the South Atlantic Bight (Cape Fear to Cape Canaveral). From 1973-1980, the SC MARMAP program conducted a trawl survey of sand bottom habitats annually throughout the region. (Wenner et al. (1979a, 1979b, 1979c, 1979d, 1980) and Sedberry et al. in prep.).

Beginning in 1978, the program concentrated on sampling hard-bottom reef habitat throughout the region, using a variety of gears, including trawls, fish traps and underwater television. Each station was surveyed and mapped with underwater television, fathometer and LORAN-C. Observations regarding bottom type (reef vs. non-reef) and the distribution and abundance of reef invertebrates and fishes were recorded. From these reconnaissance television transects, maps of reef areas were drawn. All subsequent sampling attempted to target known reef areas using a variety of gears, with sampling generally restricted to spring and summer months.

SEAMAP Shallow Water Trawl Survey:

This program represents another major database within the South Atlantic Bight that includes trawl samples collected at randomly selected stations within the inner shelf zone from 1986 to 1992. Most of the samples collected in this program were located on sand bottom habitat. Beatty et al. (1994) provides the most recent update on the sampling approach and results obtained from this survey program.

Surveys Related to Oil and Gas Lease Sales:

The Bureau of Land Management and, subsequently, the Minerals Management Service have required or funded numerous surveys of bottom areas in the South Atlantic Bight related to lease sales for oil and gas exploration. These studies include extensive regional surveys completed by University of Georgia, U.S.G.S, and private consulting firms. Much of the data obtained by the University of Georgia and the USGS is archived at the Georgia Southern University (GSU) Applied Coastal Research Laboratory (ACRL). These surveys include side scan sonar, high-resolution seismic and bathymetric data that provide information on bottom type. Many smaller scale and more detailed surveys have been completed on specific lease blocks of interest to oil companies (see Appendix 2 for listing). The South Carolina Department of Natural Resources (SCDNR) and the Georgia Department of Natural Resources (GADNR) also completed biological assessments on several representative hard-bottom areas located in different depth zones in the SAB under funding from the Bureau of Land Management and Minerals Management Service. These latter studies included extensive television surveys and trawl sampling, as well as other sampling efforts not included in the bottom mapping database.

Other State and Federal Agency Databases:

Both the SCDNR and the GADNR maintain information on natural and artificial reef habitats off their coastlines. Some of this information has been published (e.g. Georgia Offshore Fishing Guide, 1991; South Carolina's Artificial Fishing Reefs and Wrecks, 1992), but much of the data available is in the form of contract and technical reports conducted for other agencies such as the Corps of Engineers, the U.S. Fish and Wildlife Service and the U. S. Navy (e.g. Stender et al. 1991, Maier et al., 1992, SCWMRD unpublished surveys). Other unpublished survey data includes television surveys completed in and around the Charleston Ocean Disposal area by the Environmental Protection Agency and detailed side scan surveys completed by Henry (1985) within the Gray's Reef National Marine Sanctuary for NOAA. All data from the above sources were included in the database.

Data available from other studies conducted by state and federal agencies were not included in the database for South Carolina and Georgia if positioning was based on LORAN A due to problems in resolving the true position of those samples. LORAN A data may be acceptable for data collected in other portions of the region if the latitude/longitude coordinates are also provided in the record.

RESULTS AND DISCUSSION

Database Composition:

The database compiled for the continental shelf off South Carolina and Georgia contains a total of 10,534 records (Table 7, Appendix 1). An additional 1,529 records located off North Carolina and Florida were also added to the database as part of our review of the larger data sets that spanned the entire SAB, providing a total of 12,063 records for the entire SAB (Table 7). Most of the records located off South Carolina and Georgia were obtained using traps (35%), television (27%), or trawls (21%). Side scan sonar and diver observations represented 15% and 3% of the total records off these two states, respectively. The shelf area off South Carolina contained 73% of the records found off the two states (all gears combined). This roughly corresponds to the areal extent of total shelf habitat (sand plus reef) included in the survey area for South Carolina versus Georgia (i.e., 62% of the survey area was located off South Carolina versus 38% off Georgia).

A summary of the distribution of bottom types in the database is provided in Table 8. The percentage of records off South Carolina and Georgia which indicated the presence of hard bottom or possible hard bottom was 42% and 17%, respectively. Approximately 40% of the records showed no evidence of hard bottom and less than 2% of the records identified artificial reefs.

The proportion of records categorized as hard bottom should not be used to estimate the actual proportion of natural hard-bottom habitat on the shelf. Most of the records available from the largest source of data (MARMAP Program) represent sampling that was focused primarily on known hard-bottom habitats. This was also the case for many of the other data sources. Additionally, the review of extensive geophysical data complied by Georgia Southern University staff was restricted to mapping only those segments of survey lines that included hard-bottom habitat.

A graphical presentation of the grid cells coded by bottom type is provided for the entire SAB (Figure 3) and for the South Carolina-Georgia coastal zone (Figure 4). Approximately 11%

of the grid cells located off South Carolina and Georgia contained data records on bottom type. Grid cells which contain multiple records representing different bottom types were coded to give priority to indicating the presence of hard-bottom or possible hard bottom versus no evidence of hard bottom. Thus, these figures do not accurately represent the proportion of bottom types represented by the records in the database. However, they do provide information of the general distribution of hard bottom resources for the region.

Figure 5 provides an index map which separates the South Carolina-Georgia survey area into 12 subzones. A more detailed graphical summary of the actual distribution of point and line records within each of these subzones is provided in Figures 6-17. These figures were created using ArcInfo. Although the position of a data record within a block is indicated, users should note that the exact position is limited by the accuracy of the positioning system and correction factors used in the original study. This information is provided in the database (Appendices 1-3). It also should be noted that LORAN C positioning, which was used in most of the studies reviewed, is only accurate to within approximately 1/4 mile of the true location. Since many of the grid cells coded in Figures 2-3 are based on one record that was near the border of a cell, caution should be used in interpreting the true location of different bottom types depicted in those figures. Despite these limitations, the figures and database are useful for locating the general position of sites where bottom types have been coded based on the protocols described in this study. Artificial reef data are not shown graphically in the figures, but these data can be retrieved from the database listing. Users of the database will be able to sort records for selected variables and graphically view the data at any scale of resolution using one of the PC mapping software packages described in the following section. This software will also allow the user to select a specific record from the screen and display the record's attributes as shown in Figure 18. Users interested in obtaining more information on the record, such as the composition and abundance of species in a trawl or trap sample, can obtain the information necessary to contact the original data source recorded in the secondary file provided as part of the SEAMAP Bottom Mapping Database.

Table 7. Summary of data available in primary database file by gear type.

State	Total Records	TV[1]	Diver	Gear types Trawl	Trap	Sidescan Sonar[2]	Subbottom Profiler
North Carolina	672	54	0	379	239	0	0
South Carolina	7729	2429	124	1459	3235	482	0
Georgia	2805	402	181	739	424	1059	0
Florida	857	19	6	500	10	320	2
Totals	12063	2904	311	3077	3908	1861	2

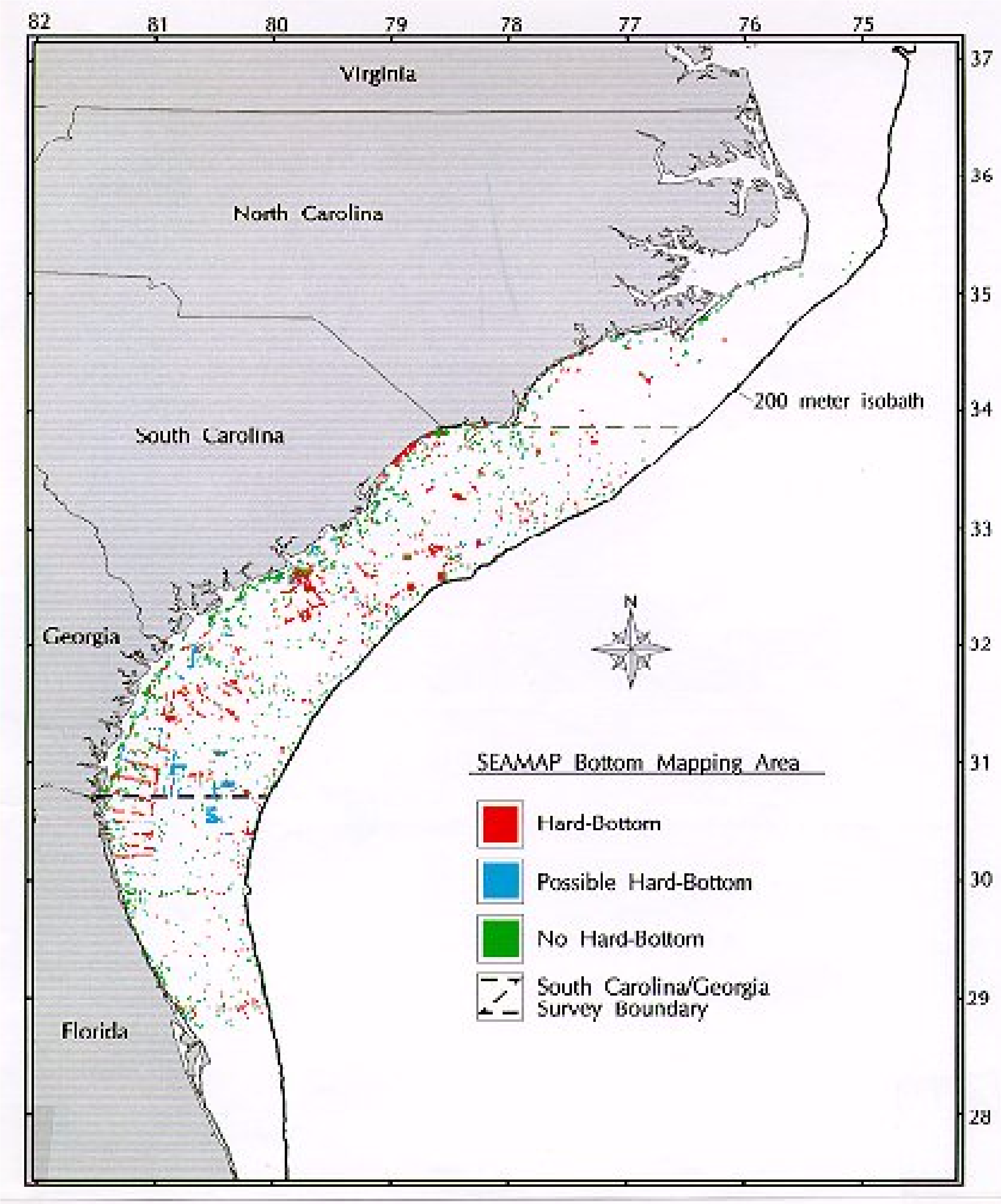
[1] Includes television alone or in combination with other gear types.
[2] Includes sidescan sonar alone or in combination with other gear types (excluding TV).

Table 8. Summary of data available in primary database file by bottom type.

State	Total Records	HB	PH	Bottom Types[1] NH	AR	HA
North Carolina	672	128	89	455	0	0
South Carolina	7729	3330	958	3271	158	12
Georgia	2805	1042	797	957	9	0
Florida	857	232	265	360	0	0
Totals	12063	4732	2109	5043	167	12

[1] HB = Hard Bottom PH = Probable Hard Bottom NH = No Hard Bottom AR = Artificial Reef
HA = Hard Bottom on Artificial Reef

Figure 3. **Distribution of grid cells throughout the SEAMAP bottom mapping area which contain information on bottom type.**



82
81
80
79
78
77
76
75
37
36
35
34
33
32
31
30
29
28
Virginia
North Carolina
South Carolina
Georgia
Florida
200 meter isobath
N
SEAMAP Bottom Mapping Area
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
South Carolina/Georgia
Survey Boundary

Figure 4. **Distribution of grid cells off South Carolina and Georgia which contain information on bottom type.**

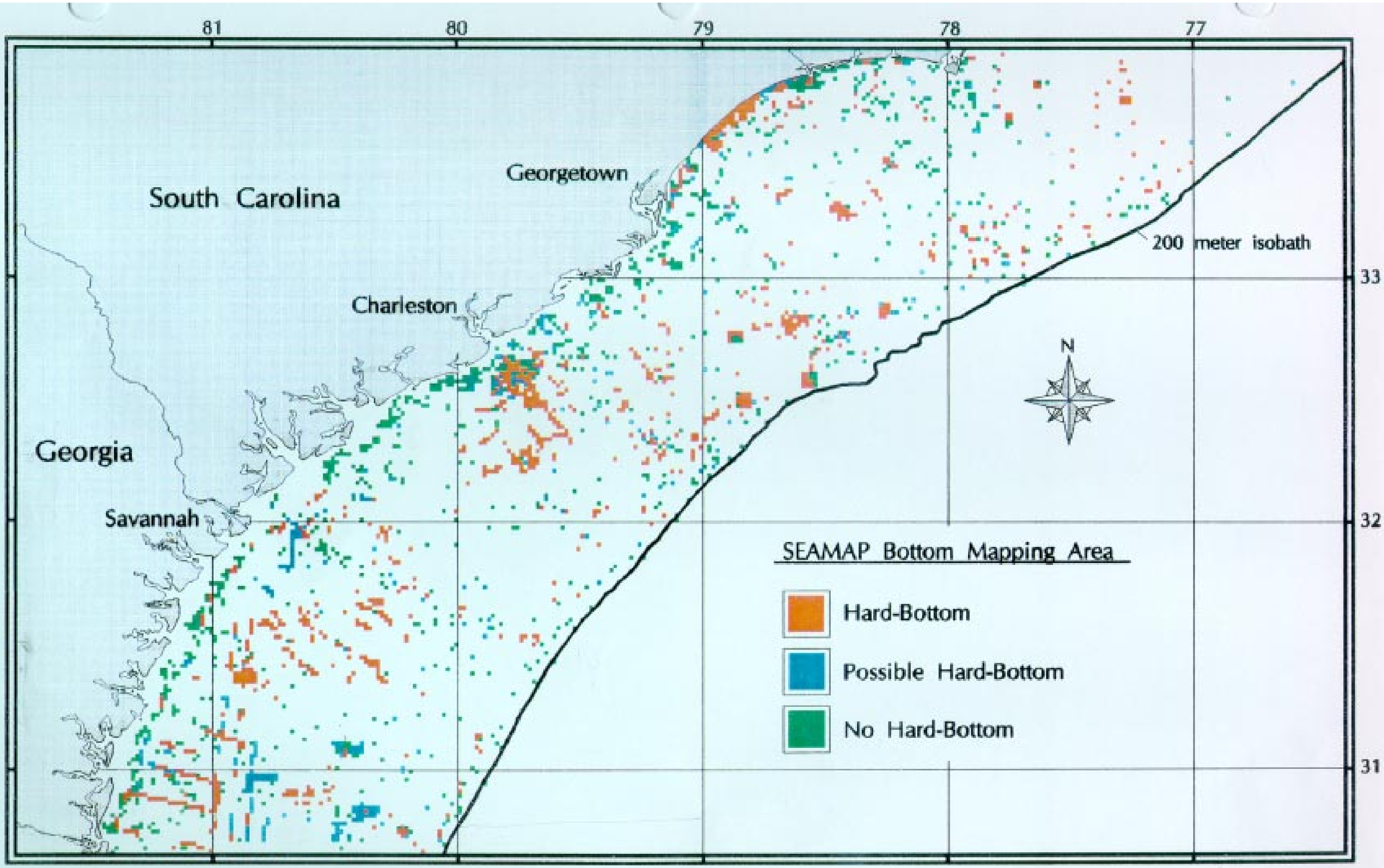
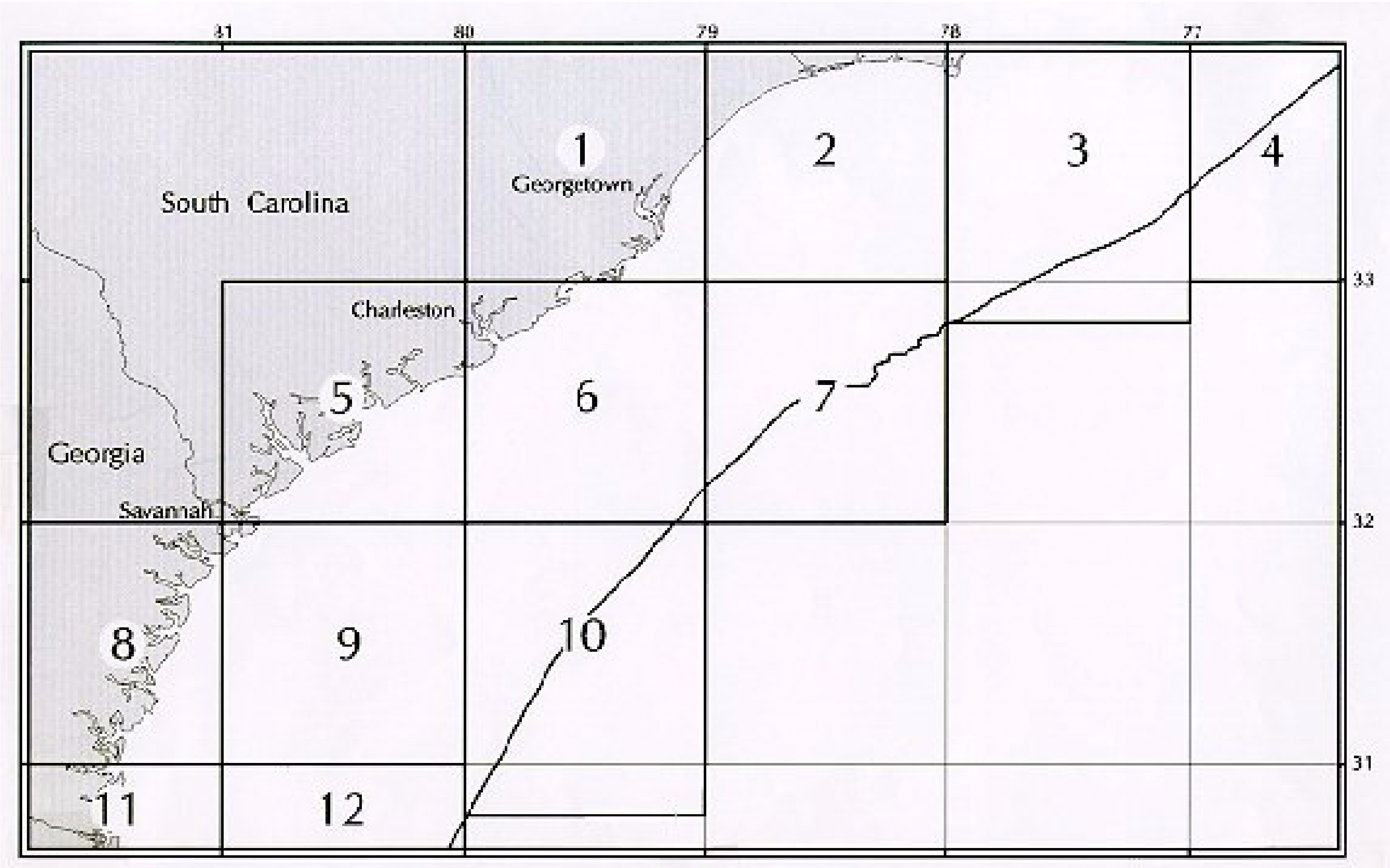


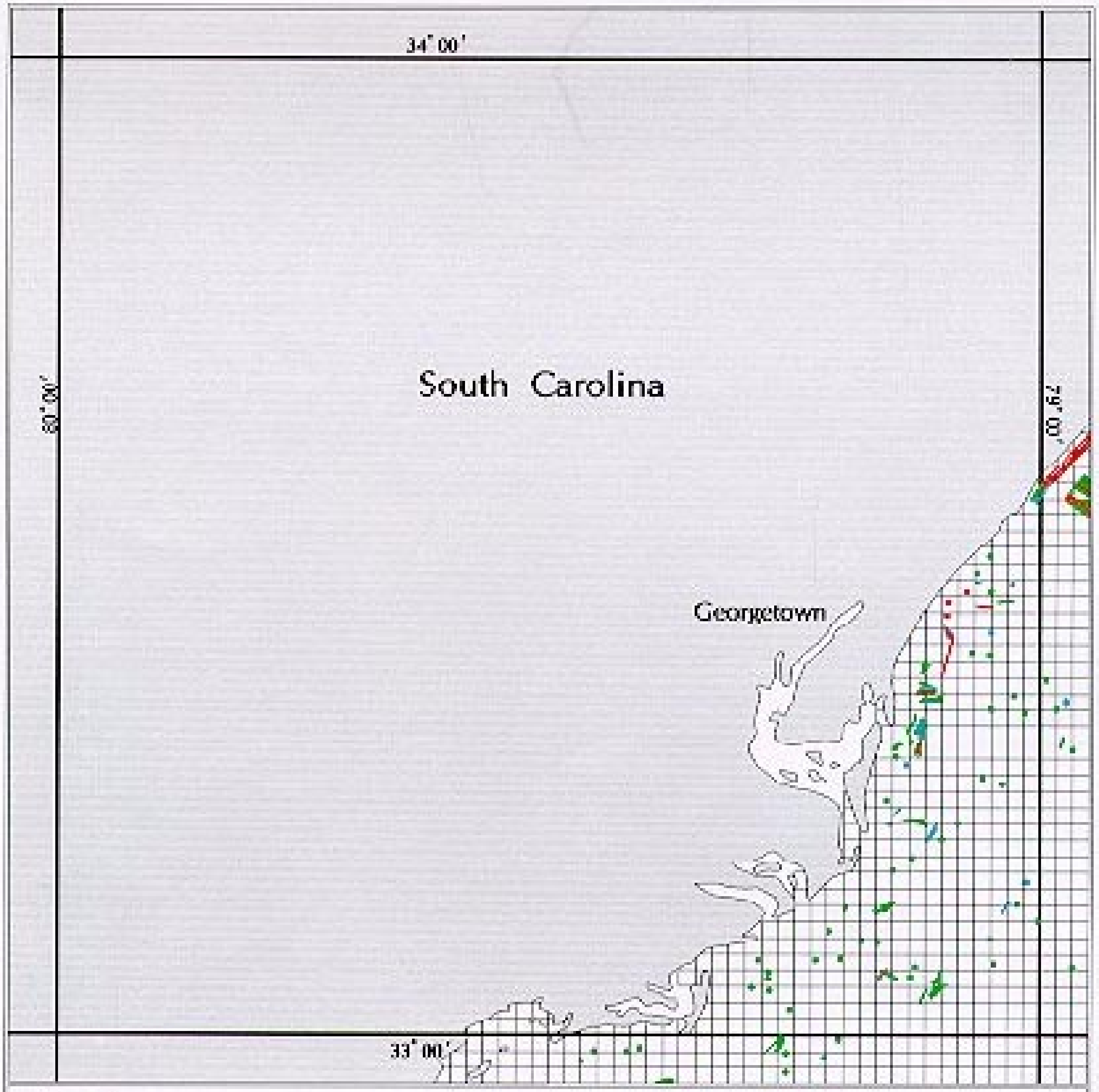
Figure 4. Distribution of grid cells off South Carolina and Georgia which contain information on bottom type.

Figure 5. **Index of survey area divided into blocks to provide expanded detail of data in Figures 6-17.**



81
80
79
78
77
33
32
31
1
2
3
4
5
6
7
8
9
10
11
12
South Carolina
Georgetown
Charleston
Georgia
Savannah

Figure 6. **Location of point and line data which provide information on bottom type in Area 1 of the South Carolina - Georgia survey area shown.**



Hard Bottom

Possible Hard-Bottom

No Hard-Bottom

SEAMAP
Bottom Mapping Project

AREA 1

Figure 7. **Location of point and line data which provide information on bottom type in Area 2 of the South Carolina - Georgia survey area shown.**

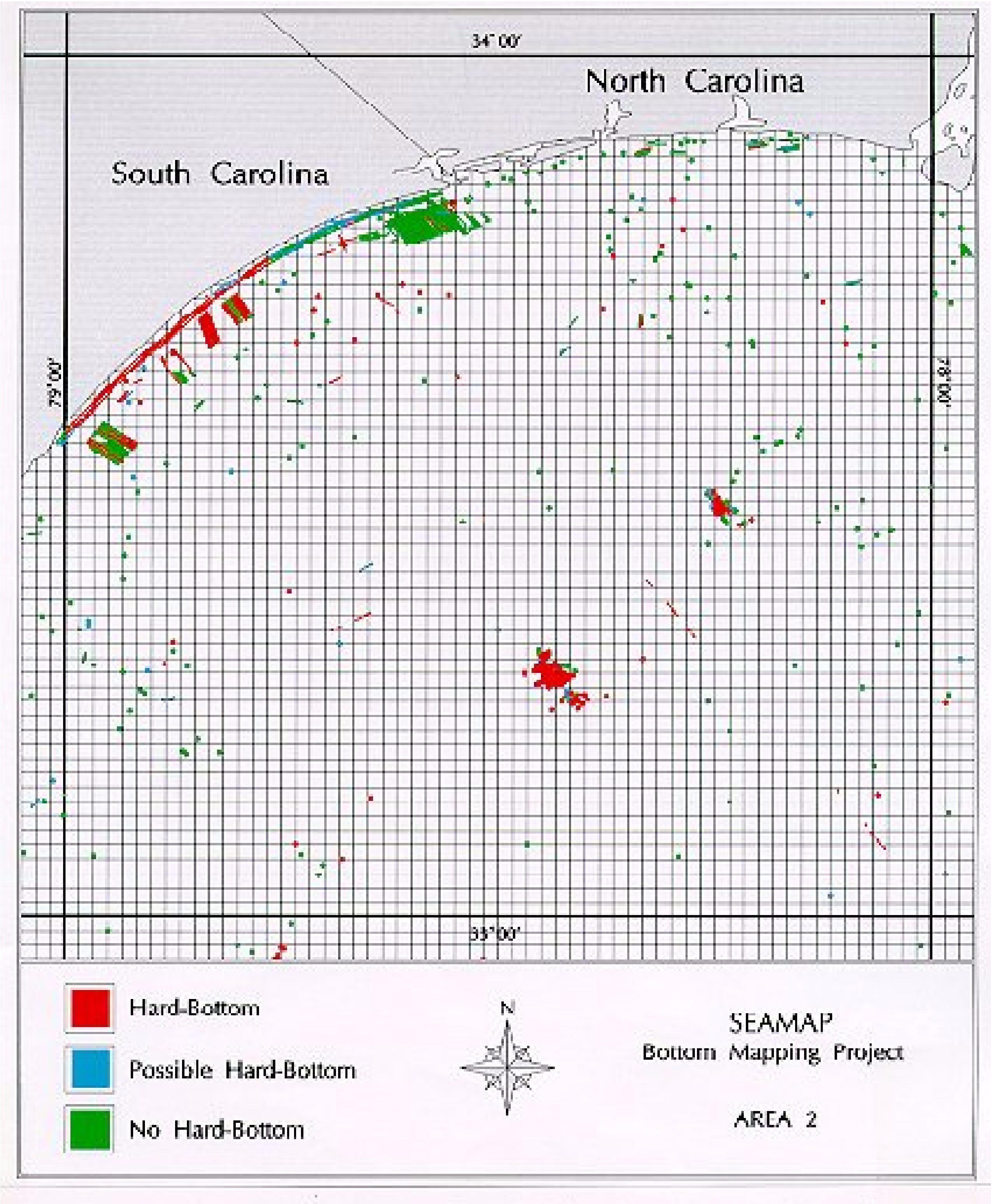
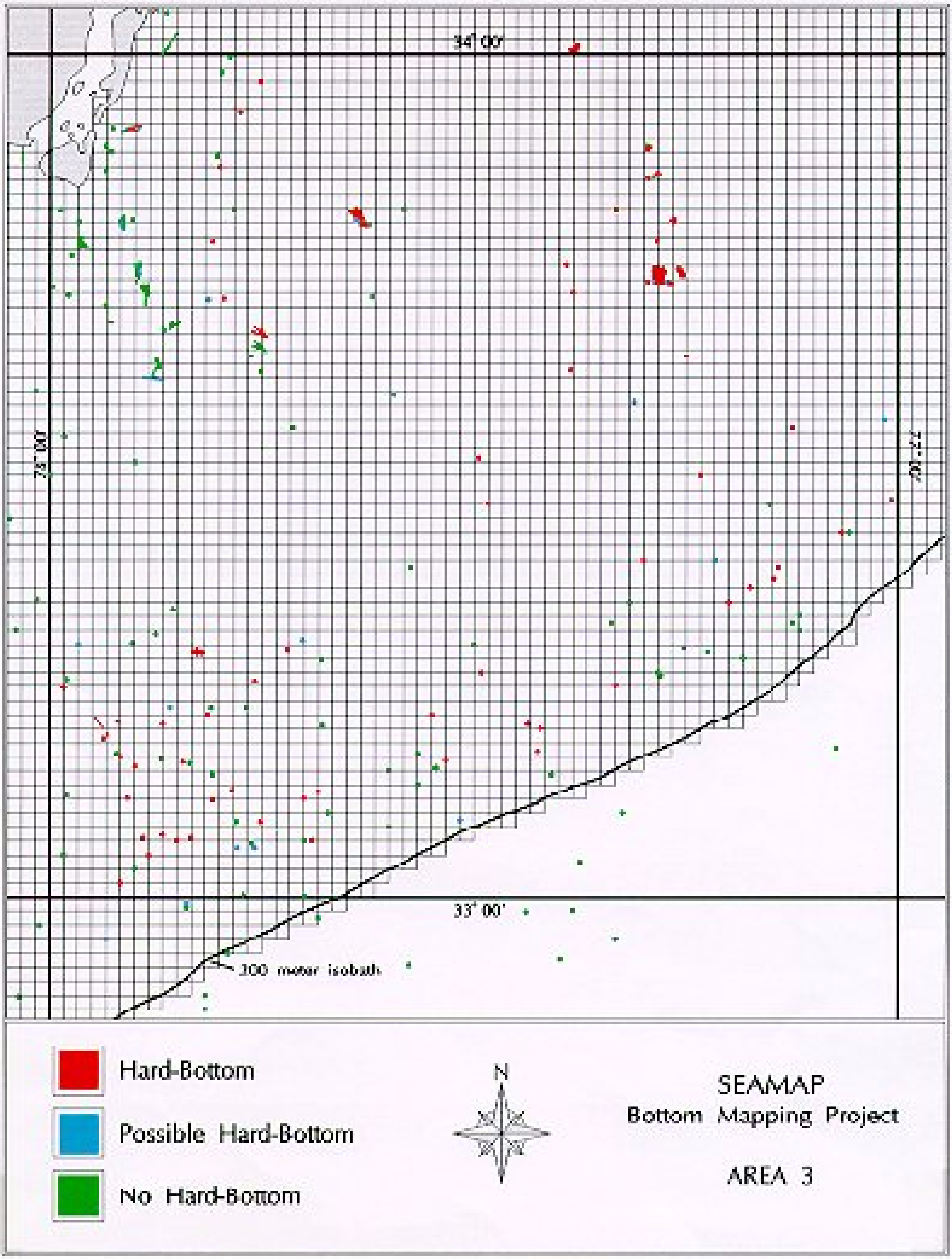
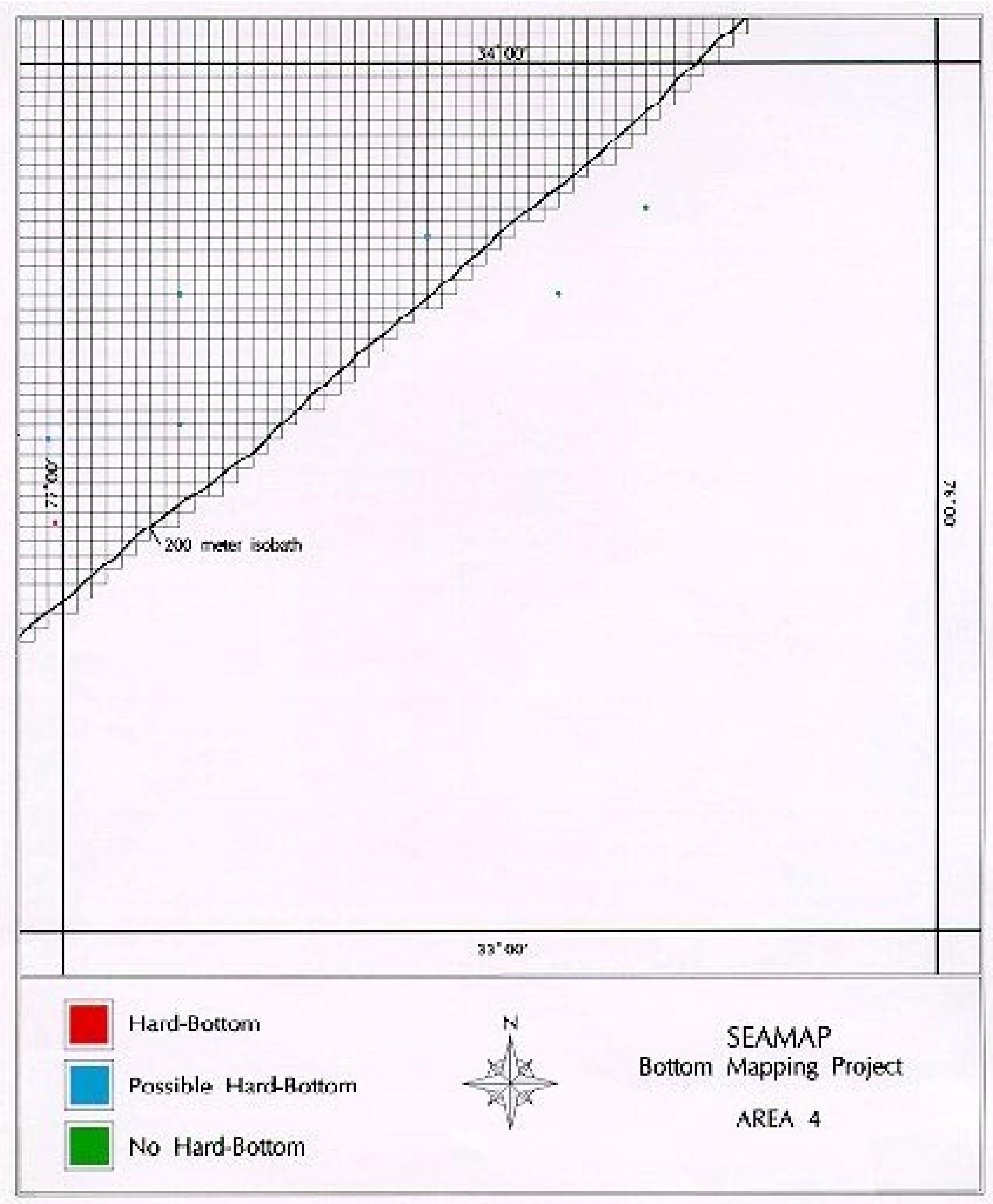

34°00'
North Carolina
South Carolina
79°00'
78°00'
33°00'
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 2

Figure 8. **Location of point and line data which provide information on bottom type in Area 3 of the South Carolina - Georgia survey area shown.**



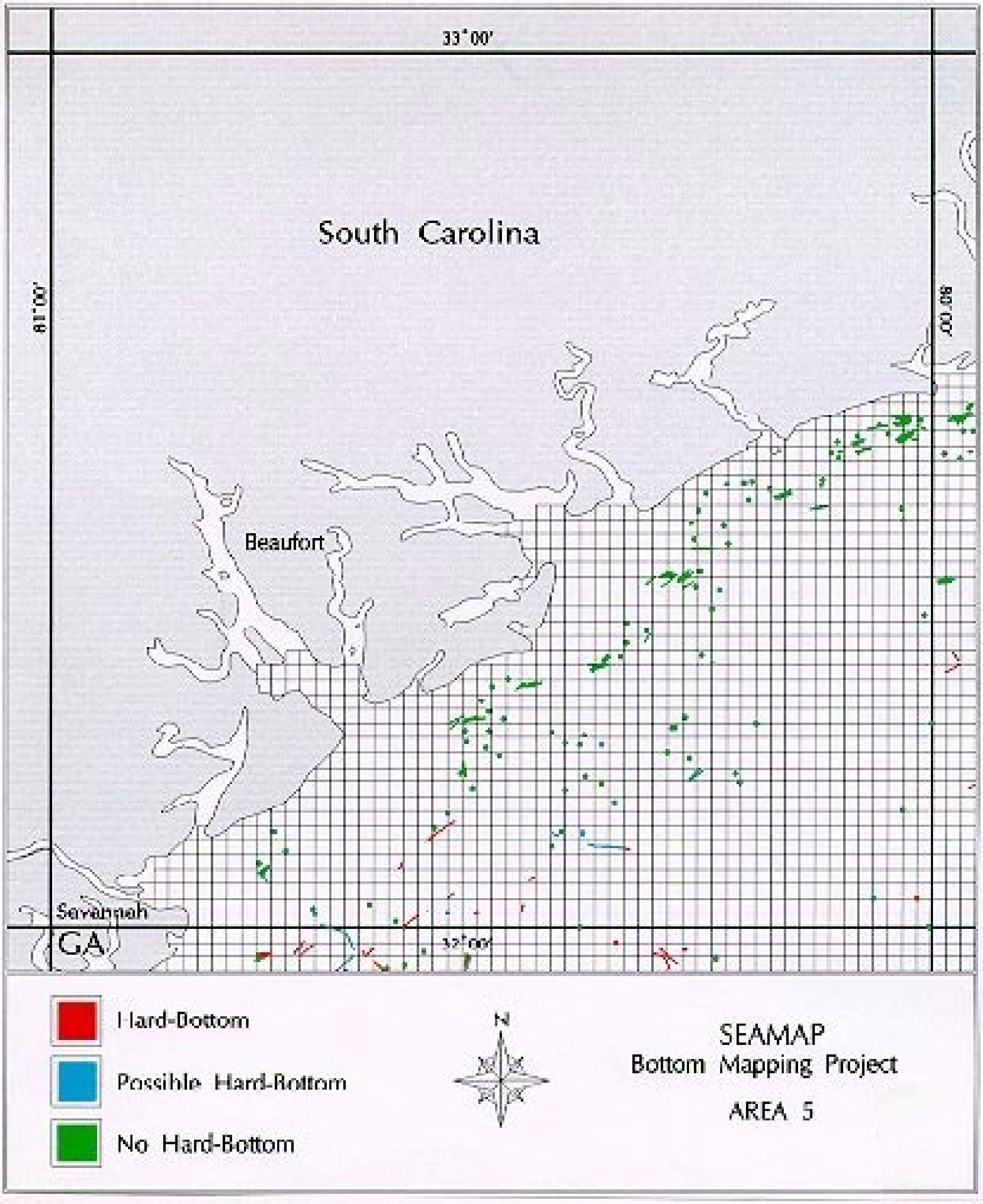
34° 00'
78° 00'
77° 00'
33° 00'
300 meter isobath
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 3

Figure 9. **Location of point and line data which provide information on bottom type in Area 4 of the South Carolina - Georgia survey area shown.**



34°00'
77°00'
200 meter isobath
76°00'
33°00'
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 4

Figure 10. Location of point and line data which provide information on bottom type in Area 5 of the South Carolina - Georgia survey area shown.



33°00'
81°00'
80°00'
South Carolina
Beaufort
Savannah
GA
32°00'
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 5

Figure 11. Location of point and line data which provide information on bottom type in Area 6 of the South Carolina - Georgia survey area shown.

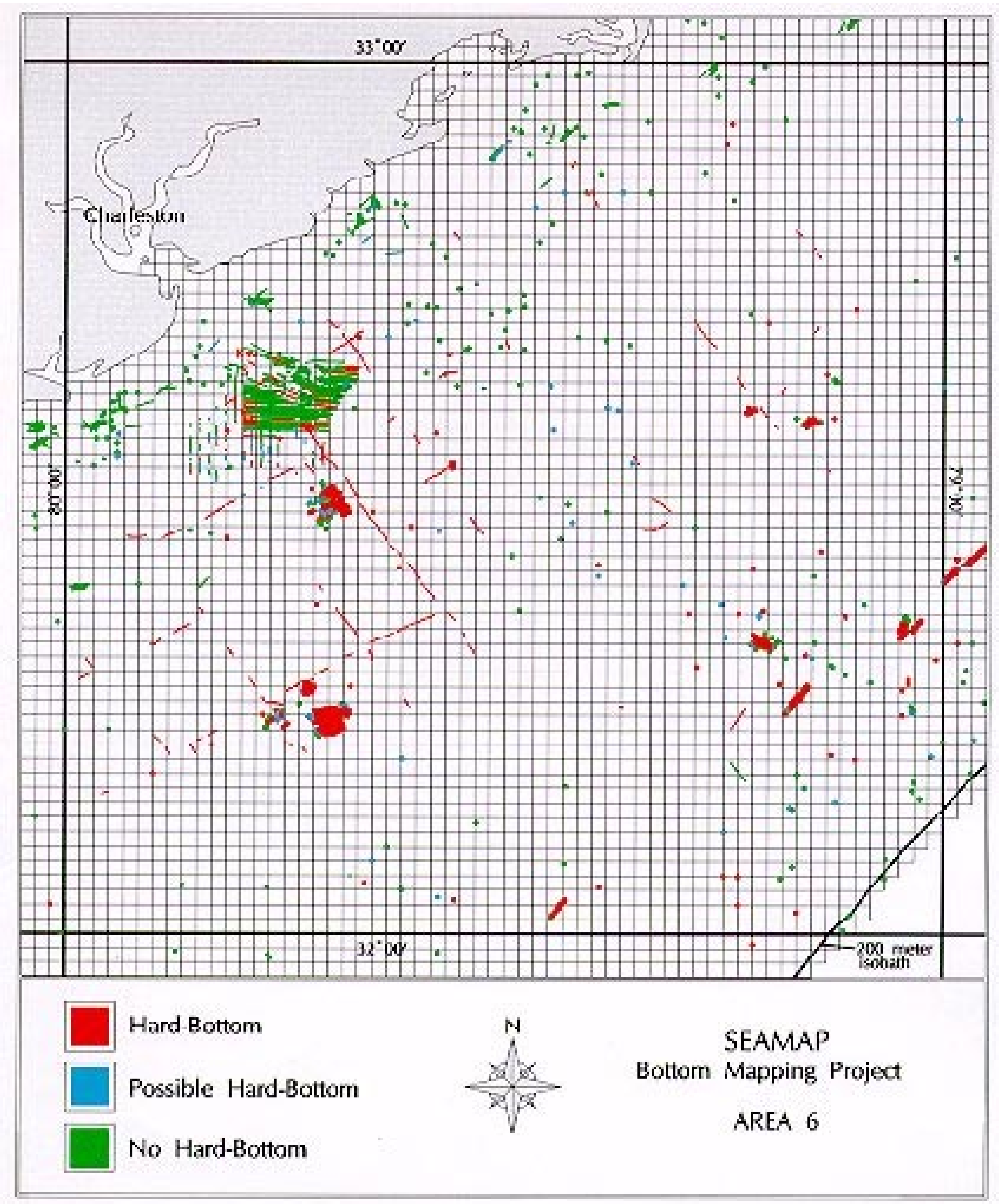
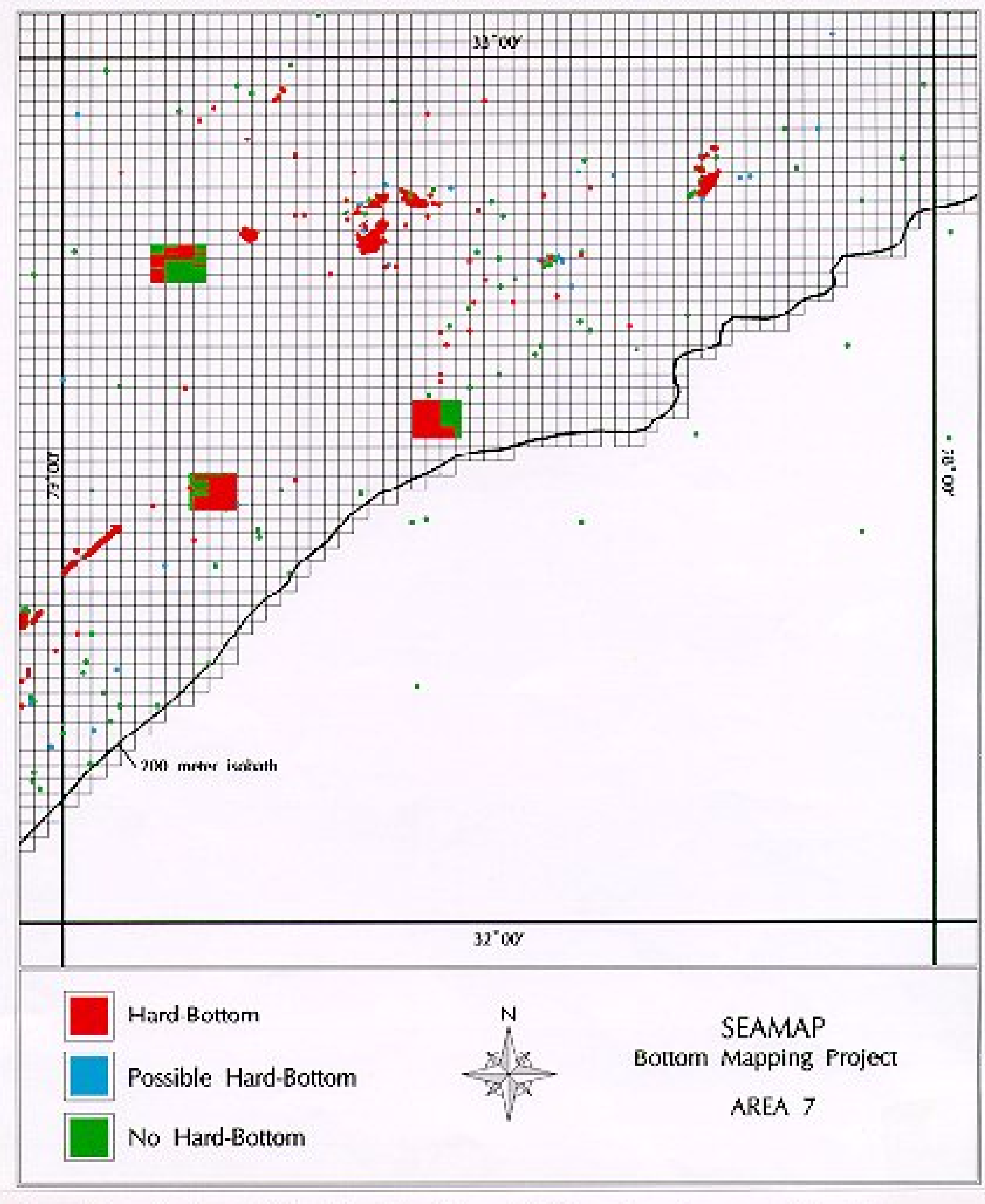

33°00'
Charleston
80°00'
79°00'
32°00'
200 meter
isobath
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 6

Figure 12. **Location of point and line data which provide information on bottom type in Area 7 of the South Carolina - Georgia survey area shown.**



33°00'
79°00'
78°00'
200 meter isobath
32°00'
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 7

Figure 13. Location of point and line data which provide information on bottom type in Area 8 of the South Carolina - Georgia survey area shown.

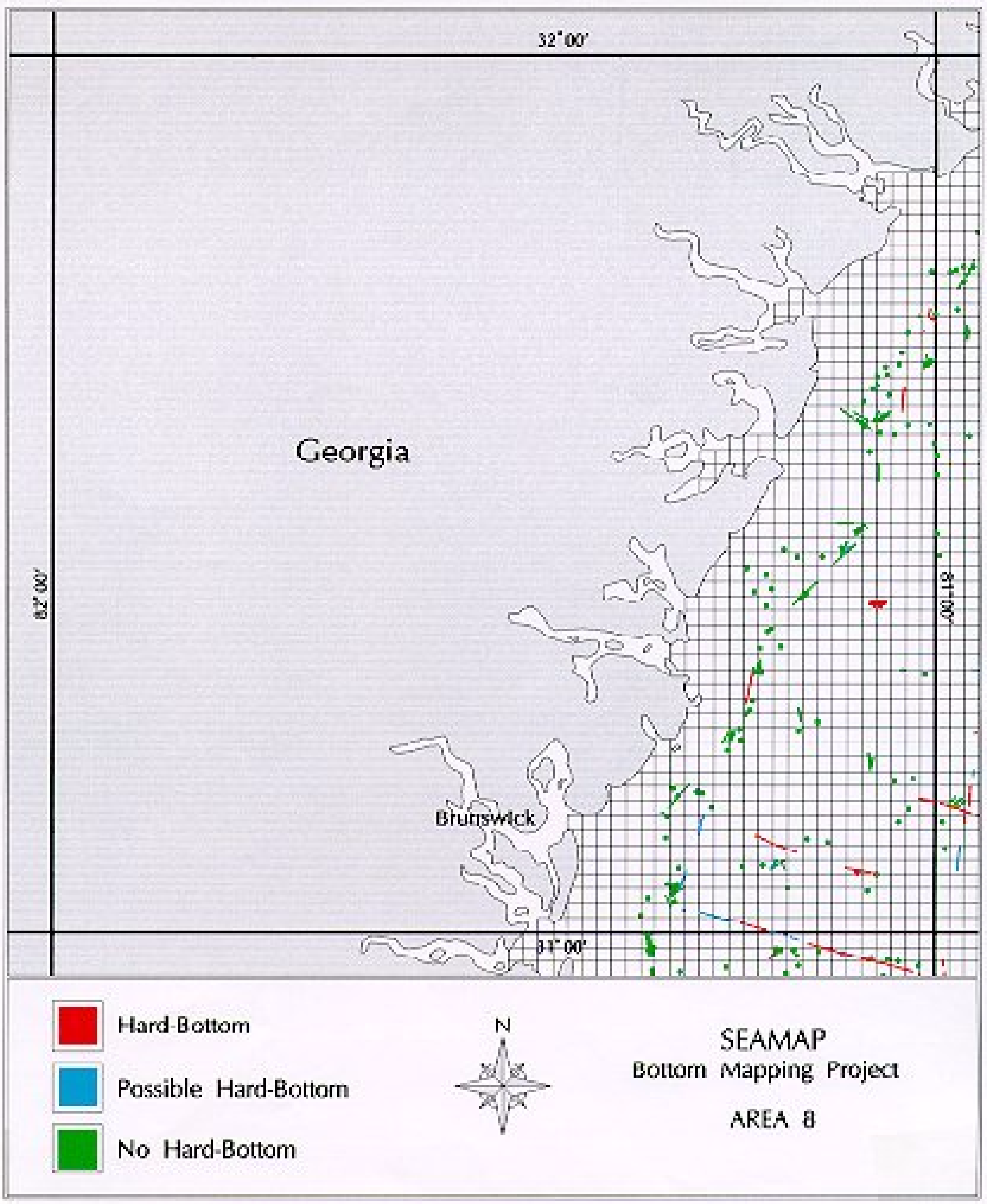

32°00'
Georgia
82°00'
81°00'
Brunswick
31°00'
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 8

Figure 14. Location of point and line data which provide information on bottom type in Area 9 of the South Carolina - Georgia survey area shown.

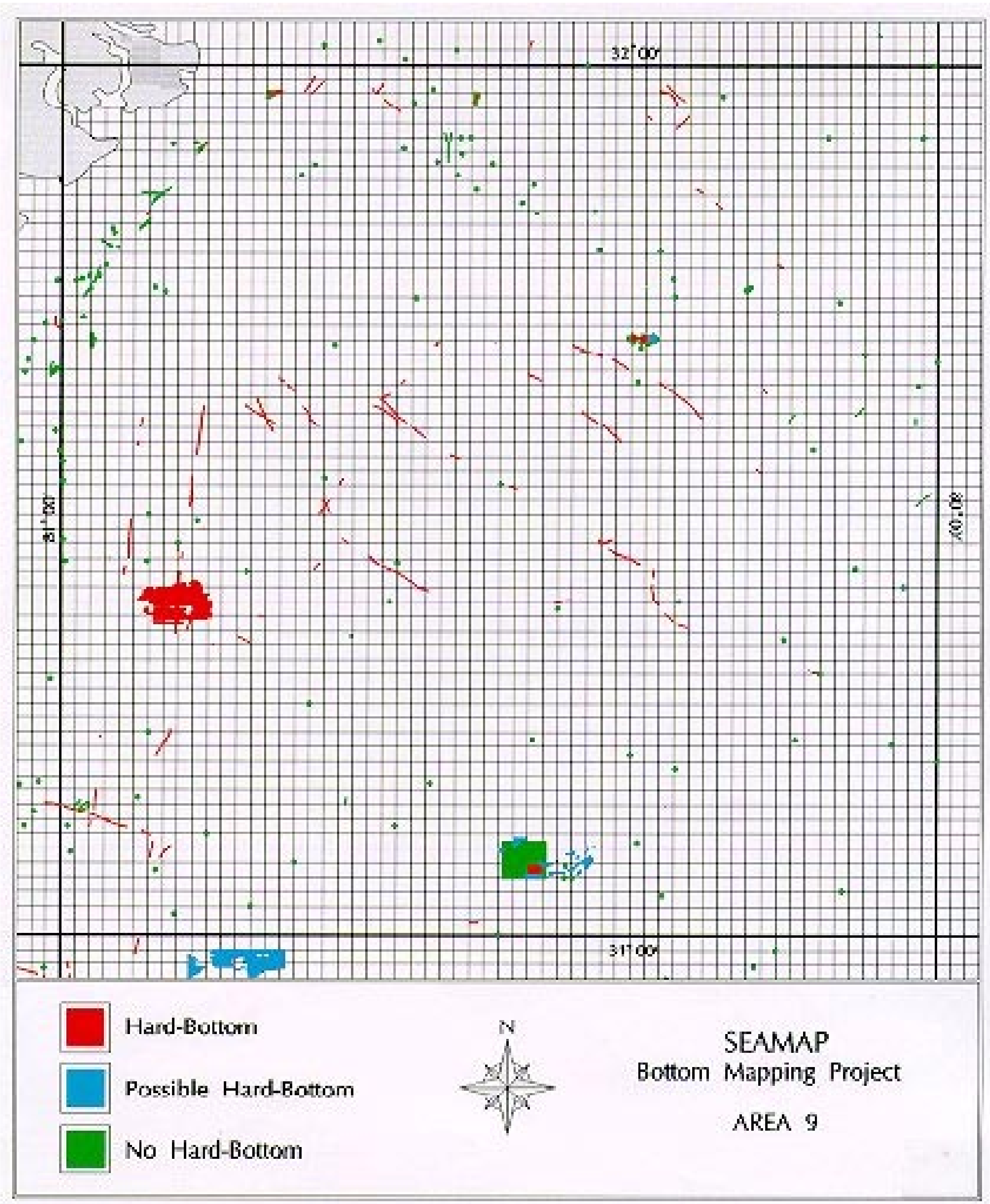
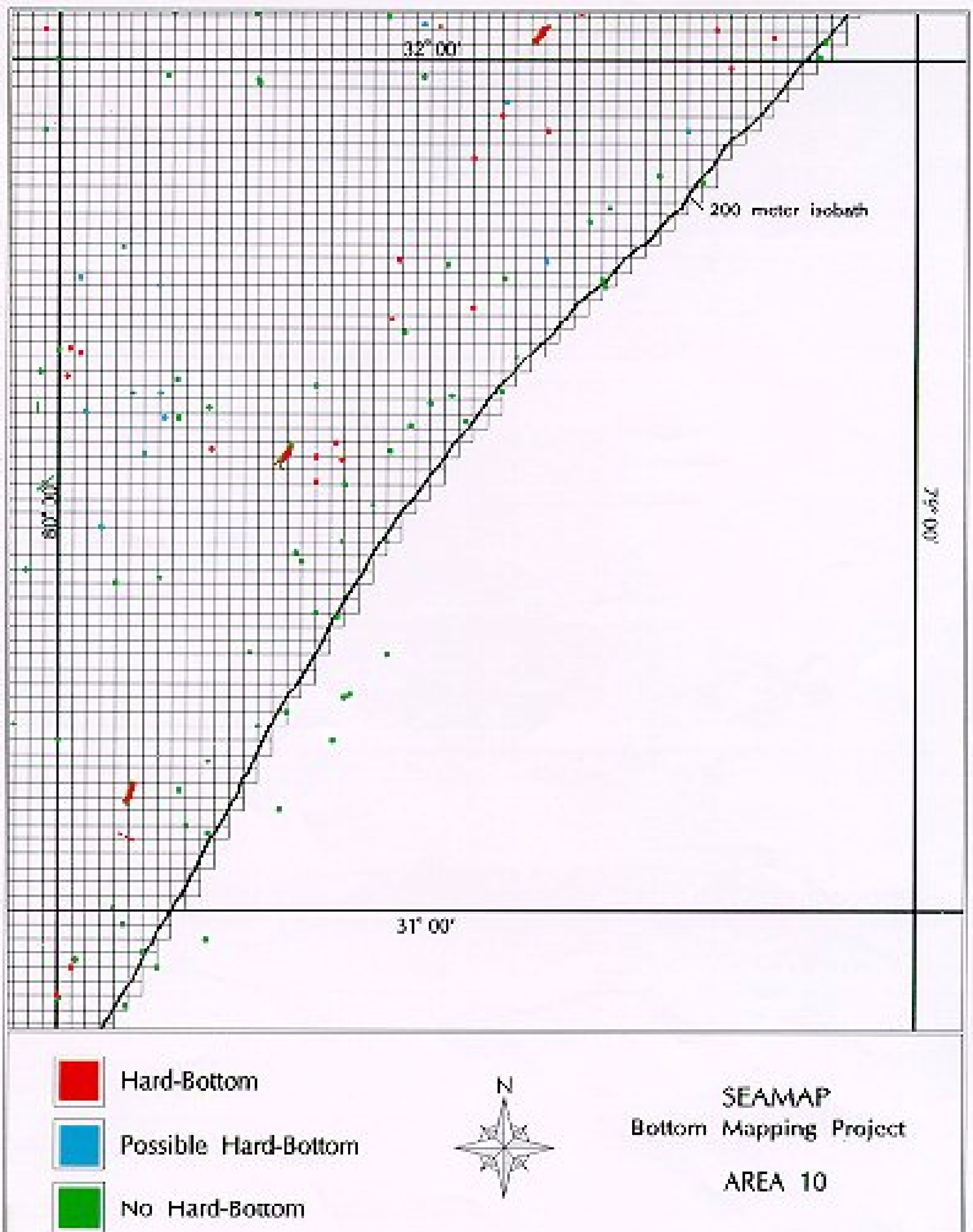
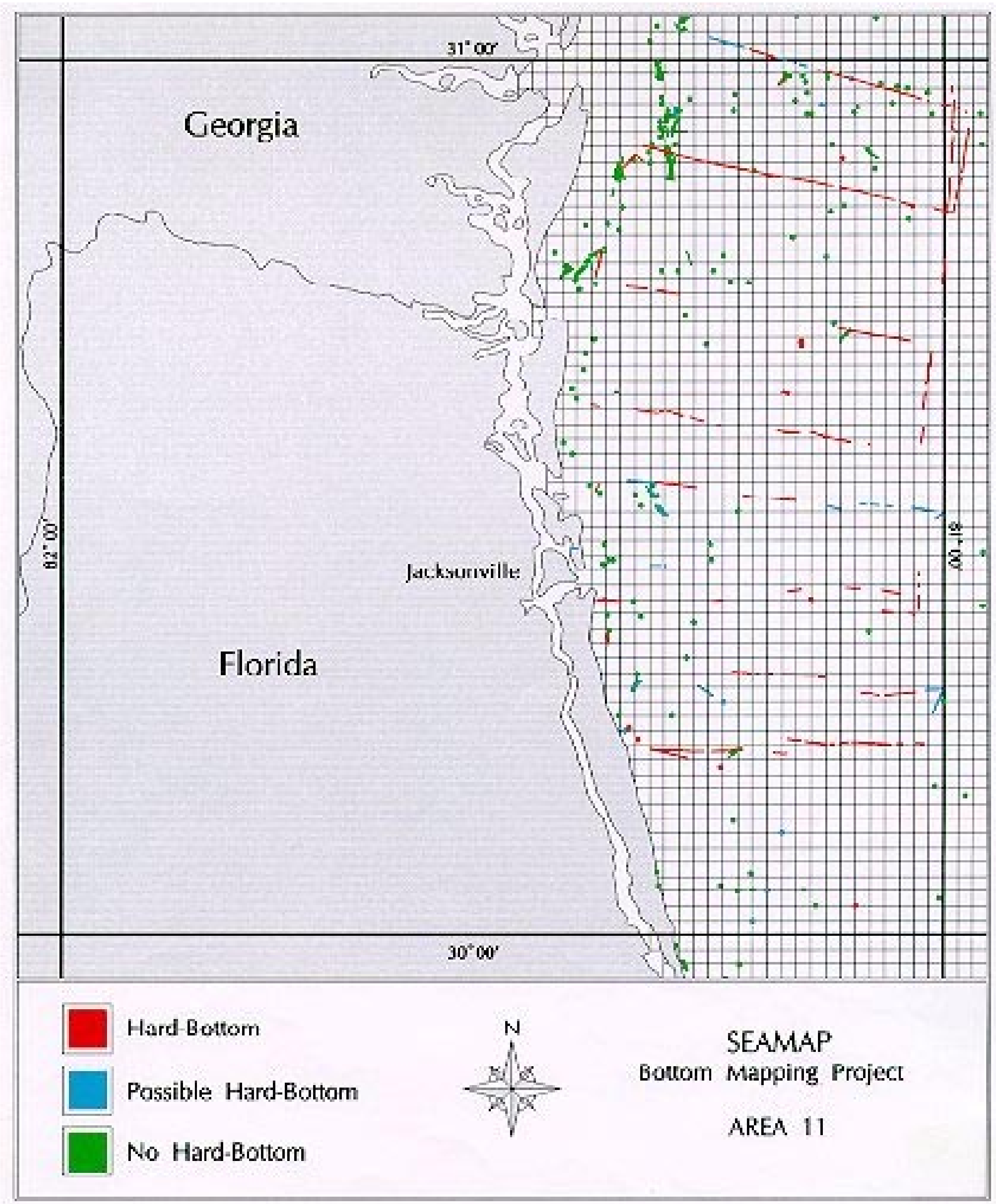

32°00'
31°30'
80°00'
31°00'
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 9

Figure 15. Location of point and line data which provide information on bottom type in Area 10 of the South Carolina - Georgia survey area shown.



32° 00'
200 meter isobath
80° 00'
79° 00'
31° 00'
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 10

Figure 16. Location of point and line data which provide information on bottom type in Area 11 of the South Carolina - Georgia survey area shown.



31° 00'
Georgia
82° 00'
Jacksonville
81° 00'
Florida
30° 00'
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 11

Figure 17. **Location of point and line data which provide information on bottom type in Area 12 of the South Carolina - Georgia survey area shown.**

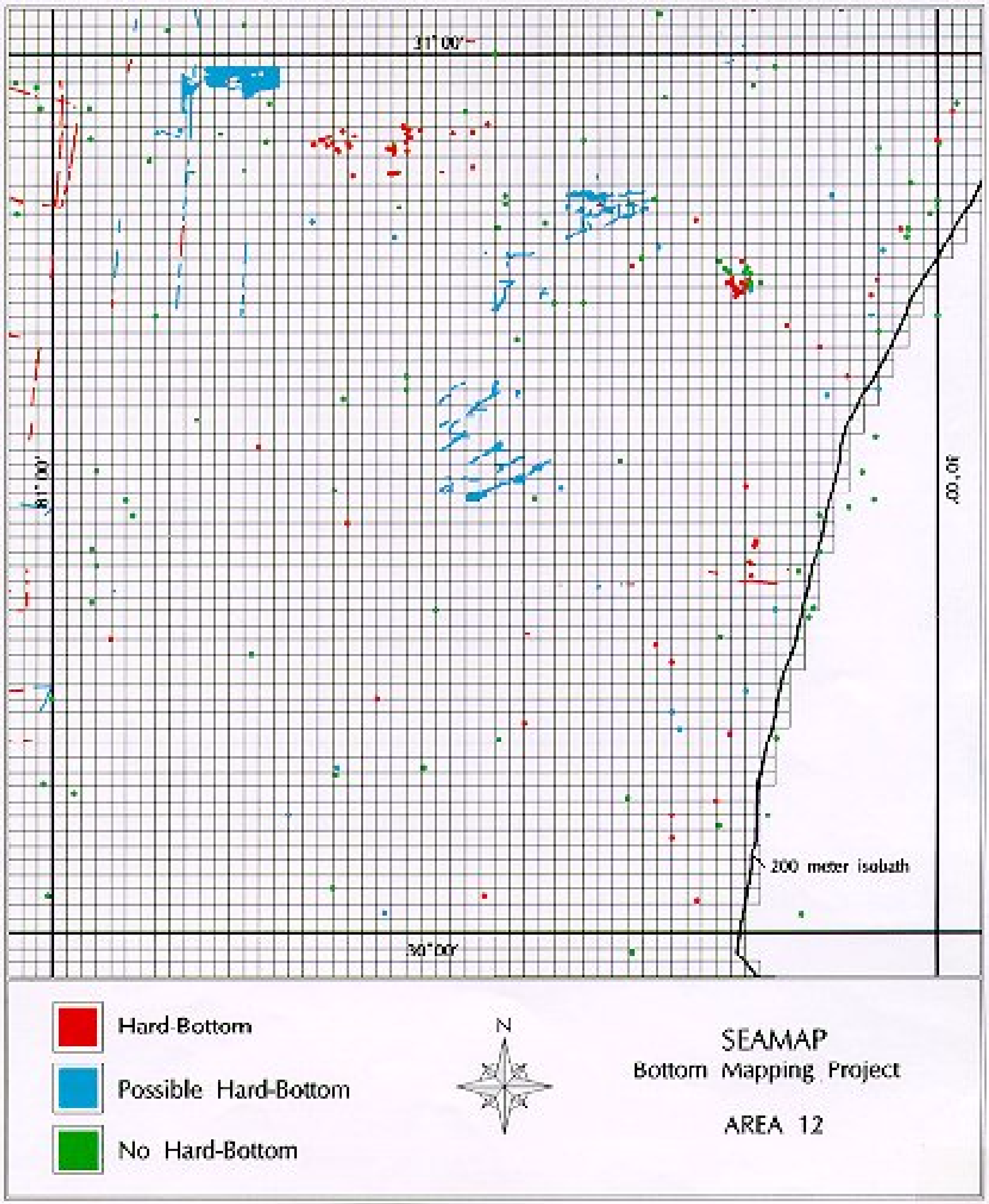
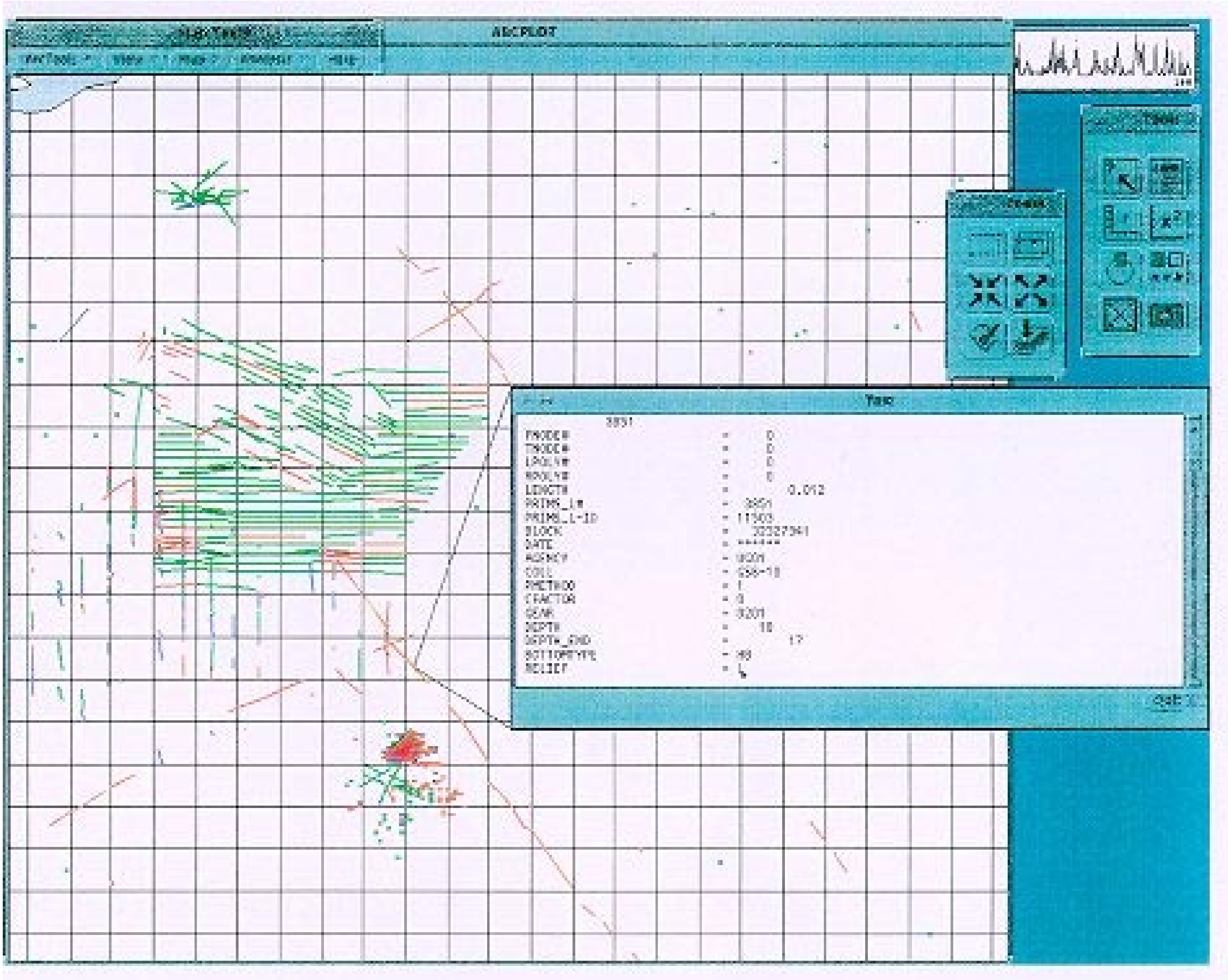

31°00'
81°00'
80°00'
200 meter isobath
30°00'
Hard-Bottom
Possible Hard-Bottom
No Hard-Bottom
N
SEAMAP
Bottom Mapping Project
AREA 12

Figure 18. Example of expanded graphical view of database, with data attributes shown in the window for one line segment.


ARCPLOT
Text
FNODE# = 0
TNODE# = 0
LPOLY# = 0
RPOLY# = 0
LENGTH = 0.012
DEPTH = 10
DEPTH_END = 17

Review of Desktop Mapping Software

Several articles in computer-oriented publications (Bernard and Miellet, 1993; Marshall, 1992; Smith and Eglowstein, 1993; Steinberg, 1991) were reviewed to evaluate the functional aspects of popular mapping/GIS software programs that have been recommended for use in conjunction with the bottom-mapping database. These programs included ArcView 1.0/2.0, Atlas GIS 2.0, IDRISI 4.0, and MapInfo for Windows. The following sections provide a brief overview of each program.

ArcView 1.0/2.0

ArcView 1.0, the current version of this program, belongs to a recent class of GIS data viewers that are related to more sophisticated programs like ArcInfo. ArcView imports data from ArcInfo to perform simple queries, analysis and map viewing. The only review of this software (Bernard and Miellet, 1993) indicates that the program is easy to use, has a very good interface, powerful tools for querying data, and can overlay raster and vector (i.e., strings of x, y coordinate values for pixels or grid cells) data within the same window (advantage over Mapinfo). Activating and running Arcview 1.0 is relatively slow without at least 4 Mb of RAM on a 486 Processor and import formats are limited to dBase and arcdata files. It also lacks the ability to edit attribute files. ArcView 2.0, which is due out in 1994, may posess numerous improvements, including an application-development language called Avenue which includes a command language, much greater import flexibility, a charting option and an "acetate layer" which allows objects to be superimposed over graphic images as though on a clear overlay.

Atlas GIS

Marshall (1992) indicated that Atlas GIS was the strongest all-around software package, offering the best combination between power and user-friendliness. According to the article, it does not have the capabilities of large systems, like ArcInfo, but it has strong analytical abilities, is easy to use, can import dBase, Lotus or Excel files and allows users to build their own applications. This software package has a very good collection of maps and data, but the utility of these maps for the bottom-mapping survey area is questionable. This package is only available in DOS at the present time, and it lacks the ability to do charts.

IDRISI 4.0

Bernard and Miellet (1993) provided the only comparative review of this package versus others. IDRISI stores graphic data in raster format rather than in vector format like AtlasGIS and Mapinfo for Windows. This program is designed as a series of modules linked by a common interface; however, its raster format and strong analytical potential make it more difficult to learn than some of the other software reviewed. IDRISI's ability to import files in many formats (graphics, spreadsheet, raster and vector GIS and dBase) is extensive. Advanced statistical functions include principal components analysis, regression, auto-correlation and time-series analysis (in the 4.1 version). The principal complaints of the reviewers were the generally poor user interface and lack of illustrations in the support documents.

MapInfo for Windows

Mapinfo for Windows makes basic mapping operations simple; its Windows interface is very user-friendly. Like Atlas GIS, this package can import files in several formats including dBase. Although it lacks the analytical power of Atlas GIS and larger packages to which ArcView belongs, it is one of the few packages that has a fully relational internal database engine (i.e. several files can be queried simultaneously, one for each map layer, if you desire). Other software packages generally store all attribute information in one file. A programming language, Mapbasic, is also available for querying external databases. MapInfo for Windows has powerful chart creation abilities, is available in many computer platforms and is one of the least expensive mapping software packages.

In summary, all four of the software programs we reviewed appeared to be suitable for displaying the data in a manner similar to that shown in Figures 5-17. Features considered to be of greatest value to accessing the bottom-mapping database included: ease of use, ability to read dBase files directly, ability to plot data as lines or points on maps depicting the shelf area, and cost. Comparative information on these and other features is summarized in Table 9. While some of the programs have advantages over the others in several of these features, no one program appeared to be better than all others with respect to all features of interest. Users who already own one or more of the software programs, or other programs not reviewed, will probably not have difficulties incorporating the SEAMAP hard-bottom database into their program.

Table 9. Characteristics of mapping software that are compatible with the database.

System Requirements	ArcView 2.0	AtlasGIS 2.0	IDRISI 4.0	MapInfo 2.0
Category	**Data Viewer**	**Medium Vector**	**Raster**	**Medium Vector**
Available Platforms	Windows, DOS, NT, MacIntosh, Workstations	DOS, Windows	DOS	Windows, DOS, HP, Sun, Macintosh
Recommended				
Processing Unit	486	486	286 or higher w/ math co-processor	386
Needed Memory RAM	4Mb-8Mb	4Mb-8Mb	512K	4Mb
Hard Drive Space	6Mb	6Mb	80Mb recommended	6Mb
Card and Monitor	VGA	VGA	Super VGA	VGA
Features				
Importing files	dbase,ASCII,Excel,	dbase,ASCII,Excel, INGRES, ORACLE	dbase,TIFF,DEM, Lotus	dbase,Lotus,Excel pMAP,ARC/info
Ease of Use	Good	Very Good	Good	Very Good
Spatial Analysis	Very Good	Very Good	Very Good	Satisfactory
Chart Creation	Good	N/A	N/A	Very Good
Database Management	Good	Good	Unknown	Very Good
Map Availability	Unknown	Very Good	Unknown	Good
Expandability[1]	Very Good	Satisfactory	Very Good	Satisfactory
Documentation	Good	Very Good	Good	Very Good
List Price[2]	$995	$2595	$640	$995

[1] Refers to availability of add-on products from the vendor.
[2] Price estimate as of January 1994; product not released for general distribution at time of review.

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APPENDICES