FISHING AND PETROLEUM INTERACTIONS ON GEORGES BANK

VOLUME 1: AREAS OF PARTICULAR INTEREST TO THE INDUSTRIES

ENERGY PROGRAM TECHNICAL REPORT 76-3

NEW ENGLAND REGIONAL COMMISSION

Fishing and Petroleum Interactions on Georges Bank

Volume I: Areas of Particular Interest to the Industries

Distribution of: Areas of Primary Interest to the Petroleum Industries; Fishery Resources; Fishing Effort; Fishing Grounds; Spawning Grounds; Benthos; Bottom Sediments; Currents

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Preface

This report is a product of the New England Regional Commission's Energy Research and Policy Formulation Program. The energy program will have several major outputs including:

- A supply/demand balance for New England's energy requirements to 1990.
- Effects on New England from petroleum related industrial development (including OCS development).
- New England gas industry development study.
- A review of electric power demand and supply trends and forecasts.
- Impacts of recent energy shortages and price increases on New England.
- Guidelines and a handbook for power plant siting.
- Legal and Institutional project, including a compendium and analysis of energy facility related statutes, and an energy policy and decision-making study.
- The New England Fishing Industry and the projected impacts of Outer Continental Shelf development.

A complete list of Energy Program publications is available from the Commission's Energy Program Director.

The goal of the Energy Program is to supply the members of New England Regional Commission, which is comprised of the six New England Governors and a Federal Cochairman appointed by the President, with reliable baseline information on New England's energy requirements and vulnerability, and to provide the Governors and the region with viable energy policy options and recommendations to guide New England's energy future. The Commission's Energy Program staff works closely with the Energy Advisors to the Governors and Energy Offices of the six New England states in formulating, analyzing and disseminating the output and results of the Energy Program, thereby achieving a measure of regional coordination in tackling the complex of energy problems facing the region.

The Energy Program is also involved in a broad range of projects including examination and response to national energy policy, Outer Continental Shelf policy formulation, regional petroleum and natural gas industry development programs, the New England Energy Management Information System, regional power management program, energy capability grants to assist state energy agencies, energy conservation plans, regional regulatory assistance program, demonstration projects program, U.S.-Canadian cooperation on energy matters, and technical policy assistance to the staffs of the New England Governors on other numerous matters of regional energy policy formulation and analysis.

We sincerely hope that this report will be of use and will provide some contribution to the management of New England's energy problems.

Russell F. Merriman
Federal Cochairman

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Governor of Vermont
State Cochairman

Abstract

This report was prepared by the University of Rhode Island Coastal Resources Center under the supervision and direction of, and under contract with the New England Regional Commission pursuant to the Commission's Energy Research and Policy Formulation Program. The statements, findings, and recommendations contained in the report are solely those of the University of Rhode Island Coastal Resources Center and do not necessarily reflect the views of the New England Regional Commission.

The New England Regional Commission was created under Title V of the Public Works and Economic Development Act of 1965, as amended. The Commission is a Federal/State partnership whose membership is comprised of the Governors of the six New England States and a Federal Cochairman appointed by the President.

Acknowledgements

We are greatly indebted to the National Marine Fisheries Service, Northeast Fisheries Center at Woods Hole, Massachusetts, and especially to Dr. Brad Brown and Dr. E. G. Heyerdahl for providing us with the preliminary results of their analysis of domestic fishing activity statistics and Dr. Robert Livingstone who reviewed and corrected the information presented in the tables. Mr. Mickey Swain, President of the New England Fisheries Steering Committee spent many hours on the charts showing the location of prime trawling grounds on the Bank. Many other commercial fishermen provided information for these charts and their assistance is also much appreciated.

The extensive literature review required to compile the tables on spawning and migration was undertaken by Henry Parker. The analysis of Ground Fish Survey data was performed by Robert Pikanowski. The graphics were produced by Henrietta Crandall, Susan Parker and Kathie Oberdick.

List of Plates

Introduction

In June 1975 the Coastal Resources Center of the University of Rhode Island undertook a one year study for the New England Regional Commission to investigate the interactions between fishing and petroleum industries in light of exploration for, and the possible development of, petroleum resources on Georges Bank. Georges Bank is one of the most productive fishing grounds in the world and was recently selected as a site for offshore oil and gas exploration. The Bank lies between Cape Cod, Massachusetts, and Cape Sable, Nova Scotia, and includes some 12,000 square miles within the 100 fathom isobath.

At the request of five of New England's governors, this preliminary report has been prepared to summarize available geographic information on the distribution and relative intensity or abundance of various activities and environmental characteristics that will be of help in evaluating the potential interactions between two industries. This preliminary report is designed to provide summary information with a minimum of technical detail to those responsible for managing and planning for the resources and industries in question. The final report of the study will present an overview and analysis of New England's fisheries by port and by fishery and will attempt to define the present and potential status and economics of the region's fishing industries. The probable interactions, both on shore and at sea, between the petroleum and fishing industries will be investigated and recommendations will be made on how negative interaction might be softened or solved.

Information Sources

The information presented in Plates 1-13 has been gathered from a variety of sources; some are the preliminary results of ongoing data analyses, other sources have been available for several years. The following is a brief discussion of the accuracy, biases and area specificity of the information presented in each of the plates.

Plate 1. Areas of Interest to the Petroleum Industries. This information was compiled by the Department of Interior and is based solely on the nominations it received from petroleum industries for specific tracts on the Bank. The industries, in turn, have had to rely upon seismic data and a general knowledge of the geology of the area in attempting to predict which tracts are most likely to produce oil and gas. Whether oil and/or gas is present and in what quantities will not be known until wells are drilled. After exploratory drilling has taken place, a map showing the relative interest in lease tracts could be considerably different from the one presented here.

Plate 2. Tracts Selected for Study. These 206 tracts totaling 1,172,796 acres have been selected by the Department of Interior's Bureau of Land Management for intensive study for a draft environmental impact statement that will be prepared prior to the sale of any oil and gas leases. After considering the environmental impact statement, information gathered at public hearings, and comments submitted in writing, the Secretary of Interior shall decide whether there will be a sale, and if so what tracts will be offered and what stipulations will be included in the leases to protect the environment. The first lease sale, including all or some of the tracts shown in Plate 2, is expected to take place in the fall of 1976. A second sale is scheduled for February 1978.

Plates 3 and 4. Domestic Fishing Activity 1965-1974. These data were provided by National Marine Fisheries Service, Northeast Fisheries Center at Woods Hole, Massachusetts. The data are the same as the ones used to prepare Volumes I and II of the Fishing Vessel Activity report released by the same office in August 1975. The data presented here, however, have been expanded and corrected into a record showing fishing activity and catches by the entire domestic commercial fishery. Catches have been further prorated to show the live weight of all species taken. The original data were collected by interviewing 40 to 50 percent of those vessels making fishing trips lasting several days and approximately 15 percent of the vessels making one day trips. The interview data show the fisherman's estimate of the pounds of fish landed (the "hailed weight") and his statement of where the fish was caught. The number of days fished are calculated on the basis of a 24 hour day. The inherent biases in such information are obvious and they have been compounded by such problems as a turnover in the personnel responsible for making the interviews during the study period, and the reluctance of fishermen to divulge the exact positions of their best fishing spots. Despite these problems the data as presented here are felt to be reasonably accurate. No more detailed or accurate data base exists from which domestic fishing effort may be inferred.

Plates 5 and 6. Principal Domestic Fishing Grounds. These charts show the prime grounds fished by domestic fishermen. They were compiled through interviews with fishermen at several major New England ports. It is important to realize that the areas mapped, except where indicated, are the prime grounds. Virtually the whole bank is fished as indicated on Plates 3 and 4. As the intensity of fishing effort on Georges has increased and the abundance of all the most commercially valuable species has declined, patterns of fishing have changed. During the last several years, as fish have become more scarce, there has been a trend in longline fisheries toward deeper grounds, and in trawler fisheries toward deeper and rougher bottom. Pot grounds would extend over a larger area of the Bank if the intensity of trawler fishing did not preclude them. Most fishermen know specific areas where at certain times they can expect to make good catches. It would not be possible to gather together and map all these areas; the grounds shown here are generalized and represent those areas commonly recognized as the most important to the various fisheries.

Plate 7. Foreign Fishing Activity, 1974. This information was compiled from the monthly summaries of foreign vessel observations gathered by the NMFS Law Enforcement and Marine Mammal Protection Division. The data are collected during surveillance flights and are presented in the reports on a chart as discrete areas of fishing activity with the number and nationality of vessels working in each area noted. The chart presented here was drawn by overlaying the twelve monthly charts and adding together the total number of vessels working in each area. The relative intensity of fishing activity summed over the year is thus shown.

Plates 8 and 9. Distribution of Selected Commercial Groundfish Species. The NMFS Northeast Fisheries Center has conducted annual standardized ground fish surveys since 1963. The data presented here have been selected for years when a single gear type was used and a standard sample size taken. Fall cruises 1964-1974 were analyzed, but the spring cruises only include 1968-1972. The survey is conducted within survey areas that have been defined by sediment type and depth. The number of replicate tows taken within each area is roughly proportional to its size. In this report each survey area has been regarded as a statistical unit. The average relative abundance of the following eleven species is shown for the time periods studied: cod, haddock, pollock, whiting, red hake, American dab, yellowtail flounder, blackback flounder, gray sole, butterfish and scup.

Plate 10. Known Spawning Grounds. Some species spawn principally or entirely in specific locations. This chart is a compilation of those areas that are known to produce large quantities of eggs of the species indicated. Eggs of other important species are found dispersed over larger areas of the Bank, and no attempt has been made to show these. It may be assumed that important sites for some area-specific spawners are not shown. The International Commission for the Northwest Atlantic Fisheries (ICNAF) Areas A and B have been designated through international agreement for protection from fishing with certain kinds of gear because of their known value as spawning grounds. As may be seen, however, important spawning grounds lie outside these two areas.

Plate 11. Distribution of Benthos. This information is taken from a 1961 report by Wigley (29). The data were collected with a grab sampler and only animals retained by a sieve with 1 mm. apertures were collected and weighed when wet.

Plate 12. Distribution of Surface Sediments. The data presented are from a 1973 report by Schlee (31).

Plate 13. Currents. The data presented are from Bigelow (32) and show general patterns for surface currents only. More recent research has been reported by Bumpus (33) which infers both bottom and surface drift on Georges Bank. The results of this work have been summarized by month. The returns of the drift bottles by which the measurements were made, however, have been too fragmentary to discern trends for the fall and winter months. This more recent research is in general agreement with the patterns shown on Plate 13. The surface circulation suggests a large clockwise gyre, at least during the spring and summer, and a slow southwesterly drift.

The Potential for Oil and Gas on Georges

According to the U.S. Geological Survey (USGS)

there are at least ten structures on Georges that may bear petroleum (30). Present USGS estimates are for a 50 percent chance of 900 million barrels of oil and 4.4 trillion cubic feet of gas and a 5 percent chance of 2.4 billion barrels of oil and 12.5 trillion cubic feet of gas. It may be estimated that the former would require some 300 wells and 15 permanent platforms as opposed to 800 wells and 40 platforms if the higher estimates prove correct. The assumed life of fields yielding the higher estimate is 35 years.

It is possible that no oil or gas will be found on Georges. However, to condemn the area a minimum of 30 wildcat wells must be drilled and if these show any signs of promise 60 to 90 wells may be drilled before the search is abandoned. An exploratory rig may, on an average, drill four wells per year so we may expect to see eight to twenty rig years of exploratory drilling even if no exploitable resources are found. It is reasonable to expect that five rigs will begin exploratory drilling within a few months of the lease sale. If oil is found, exploratory rigs may continue to operate through the 1980's.

The Fishery Resources of Georges Bank

Georges Bank is one of the most productive fishing grounds in the world. Unlike petroleum resources, the fish on Georges are a renewable resource that can provide high protein food indefinitely so long as man does not so alter the environment that the fish cannot survive or fishermen cannot catch them. Statistics for domestic and foreign catches on Georges are gathered by ICNAF and tabulated by the areas shown in Figure 1. Area 5z was subdivided in 1968 and statistics for Georges Bank alone (5ze) have been available since then (Figures 2 and 3).

It is important to recognize that all the commercially important species on Georges Bank are presently over exploited and that many have been overfished for a decade or more. It is expected that in the near future there will be United States jurisdiction over all fishery resources within a wide zone, perhaps extending out 200 miles from the nation's shoreline. When this takes place, either through the Law of the Sea Conference or through unilateral action by the United States, it is hoped that meaningful measures will be taken to control fishing and to permit the stocks to recover. It is difficult to assess the potential maximum sustainable yield (MSY) the stocks could produce each year if they were properly managed. Some stocks fluctuate widely in abundance independent of fishing pressure. Long term trends in water temperatures also play an important role. Many species are on Georges for only a portion of their lives or only at certain seasons. However, a rough estimate of the MSY for Georges Bank as a whole is 420,000 metric tons per year. Estimates for the MSYs of some important species on Georges are as follows (28):

cod	35,000 metric tons
haddock	50,000 metric tons
yellowtail	16,000 metric tons
whiting	80,000 metric tons
other flounder	15,000 metric tons
red hake	25,000 metric tons

Even more difficult than attempting to assess MSY values is attempting to predict what the resources would be worth to domestic fishermen if they harvested the total catch, an event that is highly unlikely in the foreseeable future even with passage of a 200 mile national resource zone or its equivalent. World fish markets fluctuate widely and the impacts of a growing world food shortage may only be guessed. However, based upon calculations made by Rorholm and Holmsen (34) for Area 5, an estimate of the value in 1974 dollars for 420,000 metric tons of fish, of which a large proportion would be species that command a low price on domestic and world markets, is $142 million. It may be further estimated that such landings could generate an annual total of $420 million in transactions of which $166 million would be personal income.

Biological Characteristics of Georges Bank Species

Table 1 summarizes the migratory behavior of the principal species of commercial importance on Georges Bank. A few populations including lemon sole and yellowtail are continuous residents but most species undertake significant migrations on and off the Bank. Migrations appear to be triggered principally by temperature but the distribution of fish is also greatly influenced by the distribution of their foods and in some cases by spawning behavior. Wigley (13) has noted that groundfish are especially abundant where macrobenthic invertebrates, a major source of food, are abundant. Benthos, in turn, vary in abundance according to sediment type.

The feeding habits of most fish species are catholic. There is little specificity in the feeding of larvae, and the larvae of most species living near the surface depend upon copepods, minute crustaceans, diatoms and eggs and larvae of other species. When the larvae metamorphose into juveniles, feeding behavior becomes more specific but the range of potential foods remains great.

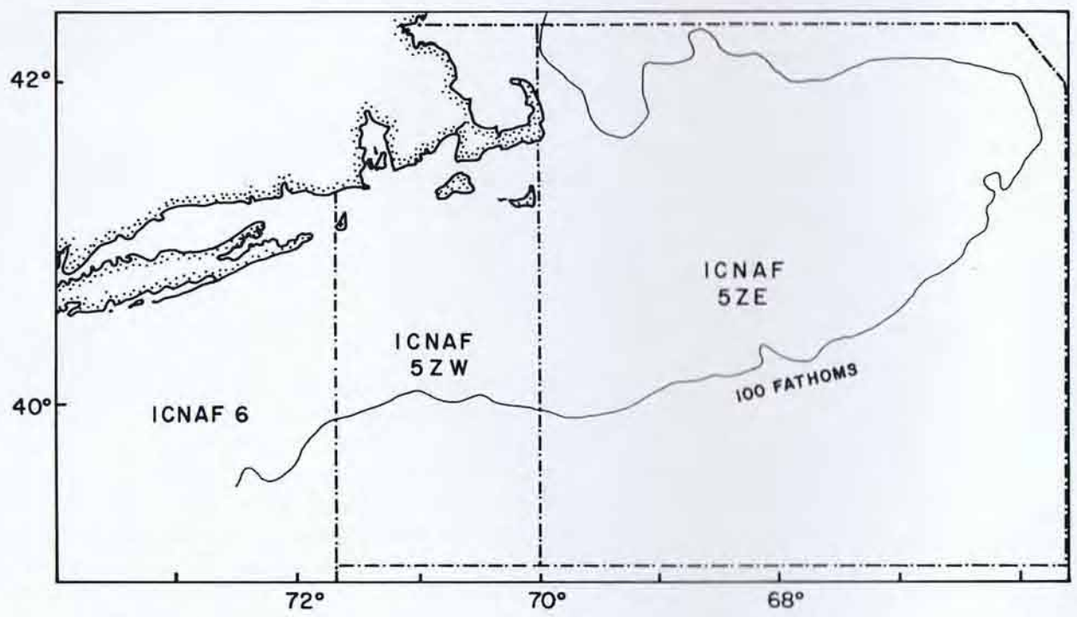

Figure 1. ICNAF statistical areas

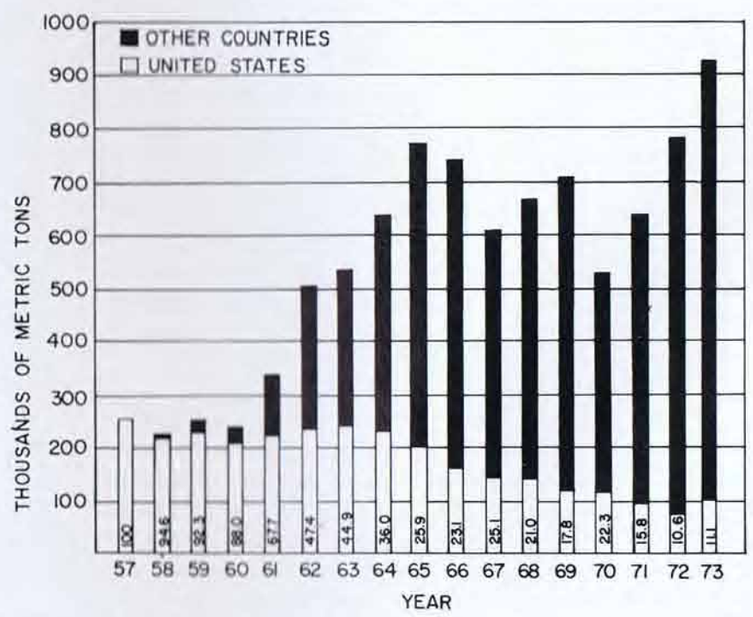

Figure 2. Total landings of all species from ICNAF area 5z showing percentage landed by the U.S.

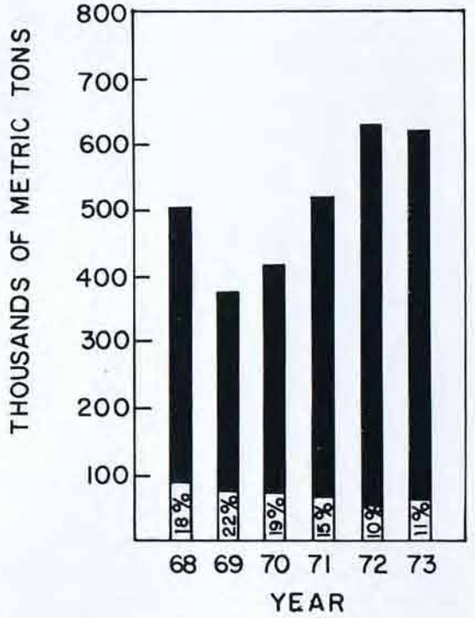

Figure 3. Total landings of all species from ICNAF area 5ze (Georges Bank) showing percentage landed by the U.S.

Juvenile and mature fish may be divided into three broad feeding categories: plankton feeders, bottom feeders and fish eaters. Many species, however, do not feed entirely within one of the three categories.

Georges Bank is a major spawning ground for many commercially valuable species, most importantly haddock, cod, pollock, whiting, red hake, cusk, American dab, yellowtail flounder, grey sole, sea herring and sea scallop. Six of these species spawn in the late winter and spring; five spawn in the summer and fall. All of these eleven species spawn at the bottom, but the larvae and, with the exception of herring, the eggs of these species drift passively in the upper water layers for a considerable period, generally two to three months. Summary information on the characteristics of eggs, larvae and juveniles of Georges Bank species are presented in Tables 2 and 3.

Fish and shellfish are most vulnerable to pollutants and adverse environmental conditions as eggs and larvae. The size of a year class (fish or shellfish spawned in a given year) is usually determined by the numbers that survive through the planktonic stages. The factors that determine the failure or success of a year class are poorly understood though it is known that water temperatures play a critical role. Clearly, predation and the availability of food shortly after hatching are also of the greatest importance. Species such as cod and herring spawn in specific areas, but several other species including yellowtail flounder, American dab, whiting, red hake and mackerel spawn over a wide area for a relatively long period of time.

To counteract the many dangers that beset eggs and larvae, most species produce enormous quantities of eggs. The year to year variability in success of year classes varies among species. On Georges Bank several important fisheries, most notably those for herring and haddock, are frequently dependent for many years at a time upon a single successful year class.

A study of the interrelationships between water currents and spawning on Georges Bank by Colton and Temple (7) has provided convincing evidence that most of the eggs and larvae produced on the Bank are carried offshore by currents where they cannot survive (See Plate 13). With the exception of midsummer, the drift of surface water on the Bank is offshore toward a band of northeasterly moving water. Colton and Temple concluded that egg production of the species that spawn on Georges is always sufficient to produce a strong year class but that because of the trend in surface currents, sufficient numbers survive to produce strong year classes only when unusual hydrographic conditions keep the larvae on the Bank until they metamorphose into juveniles.

The production of oil on Georges Bank could pose severe threats to eggs and larvae. It has been reported by several investigators that larvae appear to be 10-100 times more sensitive to oil than adults and that larvae are more sensitive than eggs. Typical lethal concentrations of soluble aromatic derivatives are 0.1-1 ppm but lower concentrations may result in death over a long time period (35).

Eggs and larvae are also vulnerable because they are planktonic and incapable of avoiding a polluted area and more importantly, because they are concentrated at the surface where the oil will be found in its highest concentration. One problem in attempting to assess the potential impact of oil spills or the chronic levels of concentration produced under the normal operation of oil production is that we do not yet know the type of oil that is in question. The toxicity of the various kinds of oil that may be present varies widely.

Methods of Fishing on Georges Bank

Domestic Fisheries

The great majority of the fish caught on Georges by domestic fishermen are captured by trawlers; the proportion was 93% in 1974. Lobsters are taken by trawlers and with lobster traps. Scallops are harvested with a scallop dredge. Each kind of gear has its own characteristics and is best suited to specific species and bottom types; each will have its own particular kinds of interactions and problems with activities related to gas and petroleum development on the Bank.

The trawler fishery: An otter trawl is a funnel shaped net that is towed over the sea floor behind a fishing vessel. The net is held open by two otter boards, or "doors", that are rigged ahead of the net on the towing warps in such a way that they shear sideways when pulled through the water. The leading bottom edge of the net is weighted and the upper lip is buoyed up with floats. The catch accumulates at the end of the funnel in what is known as the "cod end". Similar gear that fishes above the bottom, known as mid water, or pelagic trawls, is widely used by foreign trawlers but rarely by domestic vessels. When towing, the maneuverability of the vessel is much impaired.

Domestic trawlers that fish on Georges are primarily between 65 and 110 feet in length and powered by engines that deliver 300 to 700 horsepower. These vessels use doors that measure up to 12 x 8 feet and frequently weigh more than 1,200 pounds apiece. When fishing, the distance between doors is usually less than 200 feet and the headrope is seldom over 30 feet, and usually only 10 feet above the bottom. To enable fishing on rough bottom various kinds of rollers may be placed on the footrope. In recent years, as overfishing on Georges has become increasingly severe, there has been a trend for trawlers to work deeper and rougher bottoms that were seldom or never fished by trawlers in the past.

The domestic trawlers that fish on Georges are commonly manned by six to ten men. Fishing trips usually last four to seven days depending on the success of fishing, the weather and the distance of the fishing grounds from home port. The majority of domestic trawlers that fish on Georges are from New Bedford, Gloucester, Boston, Provincetown, Point Judith and Newport.

The fishing success of any trawler is in large part dependent upon the knowledge its skipper has of the bottom. The net can be easily torn or lost on wrecks, rocks or other obstructions of the sea floor. At the same time, some of the best fishing is found on rough bottom and in the vicinity of large obstructions. Through slow trial and error fishermen have learned the exact location of "hangs" and how to maneuver the net around them. The course that fishermen follow in navigating a known path that is clear of obstructions is called a "tow". Trawlermen are greatly concerned that petroleum exploration and development will cause significant losses in trawler ground. The development of petroleum reserves in the North Sea under environmental and fishing conditions similar to those on Georges Bank has clearly shown that debris on the sea floor left by the oil industry is a major problem for trawlers. Gear is damaged or lost to the fishery. The placement of a rig in trawling grounds can also have severe effects on trawler fisheries and the routing of pipelines through trawling grounds are a similar concern. Moving the position of a rig as little as a quarter of a mile may save a particularly productive tow. Special efforts to bury pipelines or otherwise make them safe from the impact of trawler doors would minimize their impact upon a trawler ground. Similarly, capped wells, valves in pipelines and the like should not be permitted to pose additional threats to towed fishing gear. This may be accomplished by placing shrouds over these protrusions. Where trawling is to be prohibited the exact locations of closed areas should be settled in consultation with fishermen. Much can be done to impress upon those working on rigs and supply vessels that every effort must be made to minimize the amount of debris on the seafloor.

The sea scallop fishery: Sea scallops are taken incidentally by trawlers but the directed domestic fishery is conducted with scallop dredges. These are large, rectangular steel frames up to 16 feet wide and 14-16 inches high, that are attached to a bag made of metal rings. Since scallops live on the surface of the seafloor, no blade is needed to dig into the bottom. Scallop dredges weigh up to 1½ tons and a single large vessel frequently tows two dredges simultaneously. Scallopers are commonly 70 to 90 feet in length and crewed by six to eleven men. The principal port for domestic scallopers is New Bedford. Since scallop dredges are towed in a manner similar to otter trawls, the two fisheries have similar operational characteristics. Though a scallop dredge is far more rugged than a net, large obstructions must be avoided. The damages that scallop dredges could cause to pipelines, valves, well heads and the like are potentially greater than those that could be caused by domestic trawlers. The problems involved in loss of good fishing grounds due to the placement of rigs, pipelines, well head leads etc. are similar to those described for the trawler fisheries.

The longline fishery: Longlines, as the name suggests, are single lines, several miles long, to which leaders, each armed with a single hook, are attached. Longlines may be set over the bottom for groundfish or at the surface, primarily for swordfish. Longlines are marked at the surface by buoys and bottom tending longlines are weighted and held in place by anchors. Groundfishing with longlines enables fishermen to work rough bottom where trawlers cannot operate. Bottom tending longlines are frequently 10 to 12 miles long and fish several thousand hooks each. Surface longlines are not anchored, may be 35 miles long, and may drift 30 miles or more in a single night. Bottom obstructions related to the petroleum industry would have a negligible effect upon longline fisheries unless the vessels were preempted from grounds by safety zones or petroleum related activities.

The principal port for bottom longliners that fish near or on Georges is Chatham. The vessels in this fishery are usually 40 to 50 feet in length and manned by two to three men. Surface longlines are usually operated from vessels in the 60 to 80 foot class.

The pot fishery: Lobsters and crabs are taken in pots along the southern edge of Georges Bank. Pots are commonly 48 x 24 x 15 inches in size and may be constructed from a variety of materials. Strings, or trawls, of pots frequently numbering 100 pots on a single line are set along the bottom. The ends of a pot trawl are marked at the surface with buoys and flags. Though a "fixed gear" when fishing, pots are frequently dragged along the bottom when they are hauled. The presence of pipelines, well heads etc. on the seafloor could therefore cause a pot trawl to be entangled as it was hauled in.

Offshore lobster pot vessels are commonly in the 55 to 80 foot range and manned by three to six men. Important ports for this fishery range from Boston to New Jersey.

Foreign Fisheries

As may be seen in Figure 3, foreign fishermen have in recent years taken the lion's share of the catches from Georges Bank. Foreign trawlers tend to be larger and more powerful than domestic trawlers; they may be up to 400 feet in length and powered by 3,000 horsepower or more. Foreign bottom trawls are also larger and the doors are heavier reaching a weight of some 2½ tons apiece. Though foreign bottom tending gear has been excluded from much of the Georges Bank area, the potential damage foreign trawlers could cause to pipelines, well heads etc. on the seafloor should be of great concern. Foreign trawlers operating pelagic trawls that fish above the bottom still fish on Georges in great numbers. Some trawls are towed between two vessels. The density of vessels in a given area may be very great at certain times and the sheer numbers of vessels could significantly influence the operation of petroleum related activities. Foreign fishermen operate a great variety of gear including all those described for domestic fisheries except pots.

Interrelationships Among Fishery Resources, Fishing and Petroleum Development

It should be apparent even from this brief discussion that the information available at present to evaluate potential problems on Georges Bank is not adequate. For example, multiple species population dynamics, trophic dynamics within the food chain and the interrelationships between individual species and variables in the physical environment are poorly understood. Natural cause of fluctuations in the abundance of populations are little known; we still cannot confidently explain why some year classes are more successful than others. The effects of fishing as opposed to environmental changes on the abundance of a stock are known for only a few species. The lethal levels of petroleum pollutants upon some species of fish and shellfish are known but sublethal effects are largely unknown.

Despite these problems we do know enough to effectively manage fisheries so long as the political and social problems involved can be solved. However, the potential conflicts caused by petroleum exploration and development now add a new unknown and potential threat to this highly productive and valuable area. The two major issues between petroleum development and fisheries appear at this time to be (1) the potential for catastrophic kills of eggs and/or larvae if a spill takes place in the wrong place at the wrong time and (2) the problem of loss of fishing ground due to debris on the sea floor and the preemption of fishing in the immediate vicinity of rigs and possibly of pipelines. The latter problem is considered the major issue in the North Sea at present and can be greatly eased if representatives from the two industries discuss conflicts and work out methods of compensating fishermen for lost gear. These discussions should take place both during the planning and the operation of petroleum related activities on the Bank. Experience in the North Sea and elsewhere indicates that the problem of physical damages to oil related operations by fishing operations are relatively minor. The greatest concern is that towed gear could damage or rupture exposed pipelines on the sea floor. Political and economic problems stemming from disagreements and ill feeling between the two industries can, however, be costly to both industries. Again, good planning and communications would do much to soften these problems.

It is not possible at this time to rate the relative value or vulnerability of individual lease tracts. The information presented here may be used to identify larger areas of concern. Any proposal to place rigs in or near known important spawning grounds should be viewed with great care and only permitted if the total spawning ground is large and stringent measures are taken to prevent spills. The placement of rigs, pipelines and the like in areas recognized as prime trawling and/or scalloping grounds should be permitted only after consultation with fishermen. It may be desirable to make minor shifts in structure locations to prevent the loss of prime tows. The utmost efforts should be made to control the amount of debris on all trawling and scallop grounds. Potential conflicts with foreign fishing fleets may be expected in areas where fishing activity is known to be most intense and this should also be carefully considered during the planning of petroleum related activities. Large foreign vessels using large heavy doors have a greater potential than domestic vessels for damaging pipelines. The danger of damage to pipelines could be minimized if studies were made on possible protective coatings for pipelines, the design of trawl doors and the possibility of installing clutches on the winches of large trawlers that would allow slippage if the fishing gear became snagged. No attempt has been made here to discuss environmental problems other than those directly related to fisheries that must also be given careful consideration; these are beyond the scope of this study.

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Table 1. Migratory Behavior of Principal Georges Bank Species

Species	Migration Characteristics
BONY FISHES	
Argentine *(Argentina silus)*	no information
Bluefish *(Pomotomus saltatrix)*	juveniles move south in late fall; adults migrate inshore/offshore;* adults arrive inshore southern N.E. in May (12-15°C) and depart in fall; spawn offshore (2)
Butterfish *(Poronotus triacanthus)*	Close inshore in Southern N.E. coastal waters in mid-April, plentiful at elbow of Cape Cod by July; leave in late fall for edge of continental shelf (1)
Cunner *(Tautogolabrus adspersus)*	year-round resident but "hibernates" in crevices in winter (2)
Flounders and Soles	relatively stationary; possible slight inshore migration in winter (1)
Dab, American *(Hippoglossoides platessoides)*	
Flounder, Fourspotted *(Paralicthys oblongus)*	no information
Flounder, Summer (Fluke) *(Paralicthys dentatus)*	move inshore to coastal waters in summer; move offshore in winter (2)
Flounder, Windowpane (Sand Flounder) *(Scophthalmus aquosus)*	Year-round resident, no evidence of inshore/offshore migrations by adults; individual adults may wander considerable distances (1)
Flounder, Winter (Blackback, Lemon Sole) *(Pseudopleuronectes americanus)*	Georges Bank stock non-migratory; slight movement offshore in winter; inshore stocks distinct (2)
Flounder, Witch (Gray Sole) *Glyptocephalus cynoglossus)*	no seasonal migrations evident (1)
Flounder, Yellowtail *(Limanda ferruginea)*	stationary species; prefer sand bottom, 40-100 m; distinct localized population on Georges Bank (2)
Halibut *(Hippoglossus hippoglossus)*	complicated migrations from bank to bank and on banks related to spawning and food supply (2)
Goosefish, American *(Lophius americanus)*	Goosefish tend to move offshore in July and inshore in Oct. (1)
Hakes and Cods	separate Georges Bank stock; 2 major movements: 1. spawning movements: localized only 2. seasonal movements: slight inshore/offshore for Georges Bank stock (2)
Cusk *(Brosme brosme)*	no evidence of seasonal migrations (1)
Haddock *(Melanogrammus aeglefinus)*	limited seasonal migrations to and from spawning grounds; some move south to Cape Cod in winter; prefer broken bottom, 10-450 m (2)
Hake, Red *(Urophycis chuss)*	move into shoal water to spawn in spring; prefer soft bottom up to 1000 m (2)
Hake, Silver (Whiting) *(Merluccius bilinearis)*	shoal inshore water in spring; presence offshore in late autumn and winter related to temperature
Hake, White *(Urophycis tenuis)*	see Red Hake
Pollock *(Pollachius virens)*	seasonal movements to and from spawning grounds; present all year on Georges; especially abundant in winter (1)
Rockling (Four-bearded) *(Enchelyopus cimbrius)*	generally year-round residents (1)
Herrings	spawn in freshwater streams in spring; adults return offshore in summer
Alewife *(Pomolobus pseudoharengus)* *(Alosa pseudoharengus)*	
Herring, Sea *(Clupea harengus)*	some migrate south and inshore from Georges in winter (2); spawn on Georges in fall
Mackerels	along edge of continental shelf in winter; inshore in summer (2)
Mackerel, Atlantic *(Scomber scombrus)*	
Tuna, Bluefin *(Thunnus thynnus)*	seasonal north-south migrations; move north along East Coast of U.S. May-October; juveniles move offshore in October-November and winter in Gulf Stream and Sargasso Sea. Transatlantic migrations observed (2)
Pout, Ocean *(Macrozoarces americanus)*	no extensive migrations; congregate over rocky grounds during and after spawning (late summer to early winter); disperse to smooth bottom in midwinter; also some seasonal movement to deep water in autumn and inshore in spring (1)
Redfish (Ocean Perch, Rosefish) *(Sebastes marinus)*	apparent seasonal vertical migration (descend to bottom in summer) but no evidence of horizontal migrations (1)
Sand Launce *(Ammodytes americanus)*	probably a Georges Bank resident though extensive wanderings have been noted (2) (1)
Saury (Needlefish) *(Scomberesox saurus)*	oceanic, schooling; no record of migratory patterns (1)
Sculpin, Longhorn *(Myoxocephalus octodecimspinosus)*	Some migration to offshore waters in summer from shallow, enclosed areas (2)
Scup (Porgy) *(Stenotomas chrysops)*	migrate offshore to 82-137 m in fall; return to coastal waters in spring (2)
Sea Robin, Common *(Prionotus carolinus)*	seasonal inshore/offshore migration; move offshore to warmer waters in fall and return inshore in late spring or summer (1)
Swordfish *(Xiphias gladius)*	move north from open ocean to Georges Bank in late May-June; leave by last week of October (1)
Whiting, King (Kingfish) *(Menticirrhus saxatilis)*	move inshore in summer, offshore in fall and winter (1)
Wolffish *(Anarhichas lupus)*	non-migratory; resident on Georges Bank (1)
CARTILAGINOUS FISHES	
Dogfish, Spiny *(Squalus acanthias)*	seasonal inshore/offshore migration; move onto Georges Bank in March-April and leave in late fall (2)
Skate, Little *(Raja erinacea)*	slight offshore movement to deeper water in winter (2)
SHELLFISH	
Crab, Rock *(Cancer irroratus)* *(C. borealis)*	little information; limited seasonal inshore/offshore movements (2)
Lobster (Georges Bank stock) *(Homarus americanus)*	evidence for seasonal inshore/offshore patterns (inshore in spring and early summer) (2)
Scallop, Sea *(Placopecten magellanicus)*	no predictable movements; inhabit sand or silty-sand bottoms up to 200 m (2)
Squid *(Loligo paelei)*	seasonal north/south movements; move offshore to edge of continental shelf in winter and inshore in spring (3)

* *Note: the term "offshore" as used in this table includes Georges Bank*

Table 2. Spawning Behavior of Principal Georges Bank Species

Species	*Principal N.E. Spawning Locations*	*Spawning Dates*	*Eggs (a)*	*Larvae (b)*	*Juveniles (b)*
BONY FISHES					
Argentine	Some spawning on Georges		large 3.5 mm; float in deep water (1)	7.5 mm on hatching (1) yolk sac absorbed at 12 mm (1)	
Bluefish	Offshore south of Cape Cod; 18m to Con. Shelf edge; (2)	May-June (2)	Pelagic; .9-1.20 mm; 48 hour incubation at 20°C (2)	Pelagic; 2.0-2.2 mm on hatching (2)	Fast-growing; 35-42 cm in one year (2)
Butterfish	nearshore (minimum 15°C) (2); No evidence of spawning on Georges Bank	June-July; peak in July (36)	Pelagic; buoyant 0.7-0.8 mm; 2 day incubation at 18°C (1)	Pelagic; 7 mm at hatching (1)	mature in 2 years; reach 120 mm in one year; fry often associated with jellyfish (1)
Cunner	Estuaries; shallow coastal waters (2); no evidence of Georges Bank spawning (1)	May-Aug. (1)	Pelagic; .75-1 mm; hatch when 2.0-2.2 mm after 3-4 days	Pelagic (2)	mature in 2 years; 2½ inches in one year
Flounders and Soles					
Dab, American* (Plaice)	inshore and offshore banks (incl. Georges) to 50 fm; spawning over large area (2) bottom spawner (7)	Feb.-May (36)	Pelagic; buoyant 11-14 day incubation; 2.5 mm (1); drift near surface (2)	Pelagic; drift until metamorphosis (3-4 mos.) (1)	seeks bottom upon metamorphosis; 3 inches after one year (1)
Flounder Fourspotted*(?)	no information	May-mid-July (1)	buoyant; 0.95-1.05 mm (1)	3 months to metamorphosis (1)	take to bottom on metamorphosis (1)
Flounder, Summer*(?) Fluke	On bottom in deep water—near 19°C (2)	Early Sept.—off Southern New England (2)	Pelagic or near surface; 1 mm; 3 days to hatch (2)	Pelagic; 3 mm when hatched (2)	15-18 cm in one year (2)
Flounder, Windowpane* (Sand flounder)	In Gulf of Maine some spawning occurs in Mass. Bay, Casco Bay, Minas Channel, & perhaps at heads of warmer & shoaler bays between Casco Bay & Grand Manan (1)	April-July (36)	Transparent, buoyant, 1-2 mm; about 8 day incubation at 51-56°F (1)	Pelagic (36) Rapid development, 1-2 mos. to complete eye migration (1)	Demersal (36) 4½" long at 2 years (1)
Flounder, Winter* (Blackback)	46-73 m; 5°C (2)	March-June (36)	adhere to bottom in clusters; .74-.83 mm; 15-18 day incubation (2)	mixed planktonic-benthic; 3 mm at hatching; 306 mm in 25 days; metamorphose in 53 days (2)	mature in 3 years 4-6" in one year (2)
Flounder, Witch* (Gray Sole)	SW Gulf of Me. (1) and Georges Bank (2), (7) bottom spawner (7)	March-June (36)	Pelagic; buoyant; near surface 1-1.25 mm; 7-8 day incubation (1)	Pelagic; 4.9 mm on hatching; drift up to 4-6 months (1)	seek bottom when 40-50 mm long (1)
Flounder, Yellowtail*	sand bottom; over large area incl. G. Bank (2)	March-June (36) Peak in mid-May (1)	Pelagic; buoyant .8-1 mm; 3 days to hatch at 10°C; drift near surface (2)	Pelagic; 2.0-3.5 mm on hatching (1) metamorphosis at 14 mm (1)	8-11 cm in one year; seek bottom when 14 mm (2)
Halibut*(?)	on bottom in definite spawning grounds—up to 500 fathoms (1)	Jan.-June; peak in Mar.-May (2)	Pelagic; buoyant; drift in 30-50 fathoms; 16 day incubation at 43°F 3-3.8 mm (1)	Pelagic; 13.5 mm or larger on hatching (1)	about 4" in one year (1)
Goosefish, American*	In shoal & deep water throughout geographic range (1)	May-Sept. (36)	In egg veils near surface; individual eggs 1.61-1.84 mm (1)	Pelagic; 2.5-4.5 mm long upon hatching; yolk absorbed when 6-8 mm long (1)	Seek bottom after reaching about 50 mm; 2½-3" by onset of first winter; mature when reach about 30" (1)
Hakes and Cods					
Cod*	offshore including Georges Bank in well-defined areas, 40-60 m (2) bottom spawner (7)	Jan.-June on Georges Bank (36)	prolific; pelagic; 14-30 day incubation (2)	Pelagic; 4 mm long at hatching; fully developed in 6-12 days	12-20 cm long by first autumn; seek bottom at 4 cm (2)
Cusk*	Georges Bank bottom spawner (7)	March-June (36)	Pelagic; buoyant, 1.3-1.5 mm (1) drift near surface (2)	drift near surface; 4 mm on hatching; yolk sac absorbed in one week (1)	drift at surface until 2" (1)
Haddock*	NE part of Georges Bank just east of Georges shoals–1600 mi² area; 30-100 fathoms; broken ground (1) Great South Channel well-defined areas (2) bottom spawner (7)	Feb.-June (36); peak in Mar.-April (2); temp dependent (12)	Pelagic; 1.1-1.7 mm; 9-23 days to hatch (2)	Pelagic; 3-5 mm on hatching; 6 week larval phase concentrated near surface; then fry seek bottom (1)	31 cm in 2 years (2) fry associated with jellyfish (1)
Hake, Red*	North and South of Cape Cod; incl. Georges Bank (South Channel) (25)	May-Aug. (36)	Pelagic; buoyant .63-.97 mm (1); drift near surface (21)	Pelagic; 2 mm at hatching; drift at or near surface several months (1); metamorphose at 40 mm (2-3 mos.) (2)	seek bottom at 2-6"; 200 mm in one year (1) often live in sea scallop mantle cavity (20)
Hake, Silver* (Whiting)	S.E. Georges Bank in 85-299 m especially on north slope (4) bottom spawner (7)	May-Oct. (36); peak in June (4)	Pelagic; in upper 9m; incubation time 48 hrs. (2); about 1 mm (1)	Pelagic; 2.8 mm on hatching; metamorphose at 20-35 mm (2-3 mos.) (2)	14-19 cm in one year (2) take to deeper water in first autumn (1)
Hake, White*(?)	See Red Hake	May-Aug. (?) (36)		not yet positively identified	
Pollock*	bottom spawner (7); 6-8°C; 27-90 m; well defined areas (2)	Oct.-March (36)	Pelagic; 9 day incubation drift near surface (2)	Pelagic; 4.5 mm at hatching; metamorphose at 20-25 mm (2 mos.) (2)	192 mm in one year; remain near surface for about 3 months (1)
Rockling, Fourbearded	All around peripheral belt of Gulf of Maine (1)	Apr.-June (36); eggs most abundant in waters of 9-10°C (1)	Buoyant, 0.66-0.98 mm (1)	Pelagic (36) slightly over 2 mm when newly hatched; yolk absorbed at about 3.6 mm (1)	Pelagic for a few months, then on bottom when reach a length of about 2" (1)
Herrings					
Alewife	Anadromous; streams, coastal ponds	April (1)	Demersal (2); 6 day incubation	no information	return to salt water by autumn when 2-4" (1)
Herring, Sea*	on gravel bottom in high current; esp. N.E. Georges Bank in well defined areas (2,23,6); grounds on Georges Bank associated with sand waves (23)	Sept.-Nov. (36) 2-3 day spawning period (16)	Demersal; eggs adhere to bottom in sheets (2); 10-15 day incubation (16); egg sheets 1-2 cm thick (17)	Pelagic; concentrated near surface for 5-8 mos. Some vertical migration; 5-6 mm at hatching (1); newly hatched larvae may remain close to sea floor (18 in 17); largest concentrations on N.E. slopes of Georges Bank (16)	4" in one year (1)

Species	Principal N.E. Spawning Locations	Spawning Dates	Eggs (a)	Larvae (b)	Juveniles (b)
Mackerels					
Mackerel, Atlantic*	no particular breeding grounds; primarily Chesapeake Bay but also Georges Bank (1)	April-July; peak in May-June (3)	Pelagic; drift mainly shoaler than 5 fathom level; incubation 150 hrs. at 12°C; 50 hrs. at 21°C; 1-1.4 mm (1)	Pelagic; 3.2 mm at hatching (1)	About 30 cm in one year (2)
Tuna, Bluefin	Mediterranean; Gulf of Mexico; Florida straits (2)	Carried north by Gulf Stream; buoyant; about 1mm (2)			
Pout, Ocean* (?)	rocky grounds (2)	Sept.-Feb. (36)	Demersal; gelatinous masses in crevices and among stones; 3½ month incubation; parents guard eggs (2); 6-7 mm (1)	Demersal; 30 mm at hatching; hold to bottom (2); larvae are nearly adult in form (1)	11.5-15 cm in one year
Redfish*	no special grounds; deepwaters, Gulf of Maine and offshore on Banks (2) 30-50 fathoms; esp. 50 fathom contour and south channel of Georges Bank (1)	hatch April-Sept.; peak in late June early July (2)	eggs develop and hatch in oviduct of mother (2)	Pelagic; 6 mm at birth; drift in upper and intermediate water levels until 25-30 mm then seek bottom or stay pelagic	descend to bottom in early autumn (1); mature at 8 weeks (23-25 cm); slow growing (2)
Sand Launce* (?)	Coastal and offshore banks (1) on sandy bottoms less than 27 m (2)	Oct.-Mar. (36)	Demersal; hatch after 2 months (2)	no information	3-4″ in one year (1)
Saury (Needlefish)	to 40° N; specific areas not known (1)	no information	drift near surface; 2.2 mm (1)	no information	no information
Sculpin, Longhorn*	On clean, hard bottom substrates, in cavities; (2) no particular depth or locality sought (1)	Nov.-Feb., peak in late Dec. & Jan. (1)	Demersal, strongly adhesive; ripe eggs are 0.85 mm in diameter, swell when they come in contact with water (1)	Hatch in no more than 3 months; Pelagic for about a mo., then demersal (2)	Demersal; Reach 5.6 cm in first year, maturity reached in third year (2)
Scup (Porgy)	Estuaries, bays, inshore, below Cape Cod mainly (2)	May-Aug.; peak in May-mid July (2)	Pelagic; .9-1 mm; 40 hrs. incubation at 22°C (2) buoyant (1)	Pelagic; 2 mm at hatching (2)	100 mm in one year (2)
Sea Robin, Common*	mainly southern N.E.; Eastern Georges Bank probably its eastern limit (1)	June-Sept.; peak in July-Aug. (1)	buoyant 0.94-1.15 mm; 60 hr. incubation at 72°F (1)	2.5-2.8 mm on hatching (1)	resemble adults at 25-30 mm (1)
Swordfish	sub tropical Atlantic basin ? (1) no evidence of N.E. spawning (1)	no information	not identified; probably buoyant (1)	no information	no information
Whiting, King (Kingfish)	Bays & Sounds; mainly south of Cape Cod (1)	June-Aug. (1)	no information	no information	4-6″ by first winter (1)
Wolffish*	Gulf of Maine; offshore Banks incl. Georges (1)	Nov.-Jan. (1)	5.5-6 mm; stick in clumps on bottom in shoal water (1) long incubation period is probable (1)	12 mm at hatching; lie on bottom for several weeks (1)	rapid growth first summer (1)

Species	Principal N.E. Spawning Locations	Spawning Dates	Eggs (a)	Larvae (b)	Juveniles (b)
CARTILAGINOUS FISHES					
Dogfish, Spiny* (?)	offshore wintering grounds in deep water (2)	gestation up to 2 years in oviduct; born Feb.-Mar. (36)	ovoviviparous (2)	ovoviviparous (2)	22-23 cm at birth (2)
Skate, Little* (?)	offshore banks; sandy bottoms (2) 15 fathoms (1)	Nov.-Jan. and June-July (2)	in cases which adhere to substrate (2); 6-9 months to hatch (2)	9-10 cm on hatching (2)	3-4 mos. to maturity; 16-26 cm after one year; 9-10 cm on hatching (2)
SHELLFISH					
Crab, Rock* (?)	Sand mud bottom to 800 m (2)	eggs laid and fertilized in late fall/winter (1) spawning from May-early June (*C. irroratus*) & July (*C. borealis*) (3)	hatch May-Aug. (2)	30-40 days in larval stage (2)	10 mm carapace length in first year (2)
Lobster* (Georges Bank Stock)		breed in summer; eggs hatch following June/July (2)	carried in female until hatching (2)	Pelagic; settle to bottom in 2-3 weeks (2)	15 mm carapace length in one year (2)
Scallop, Sea*	includes Georges Bank (2)	Georges Bank last week in September, 8-11°C (5)	Pelagic; little information (2)	Pelagic; approx. 40 days to metamorphosis (2)	20 mm in 2 seasons (2)
Squid* (?)	little information but less than 45 fathoms (3)	June-Oct. (36)	no information	no information	increase of 1.8 cm/month in mantle length for first 4 mos. (3)

code: (a)—*size dimensions refer to egg diameter* (b)—*size dimensions refer to length* *—*known Georges Bank spawner*

PLATE I

AREAS OF INTEREST TO THE PETROLEUM INDUSTRIES

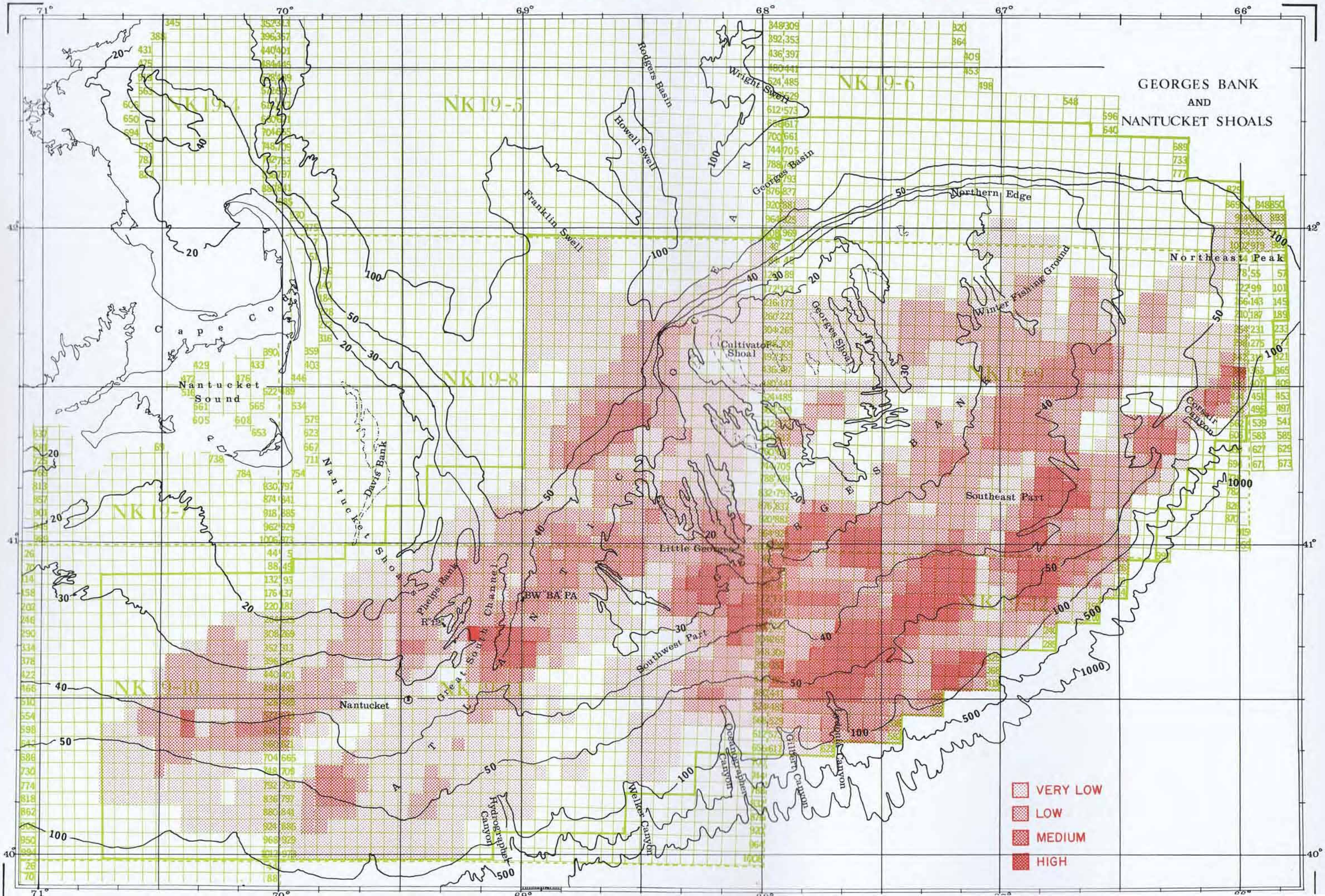


PLATE 2

TRACTS SELECTED FOR STUDY BY THE DEPARTMENT OF INTERIOR, JAN. 1976

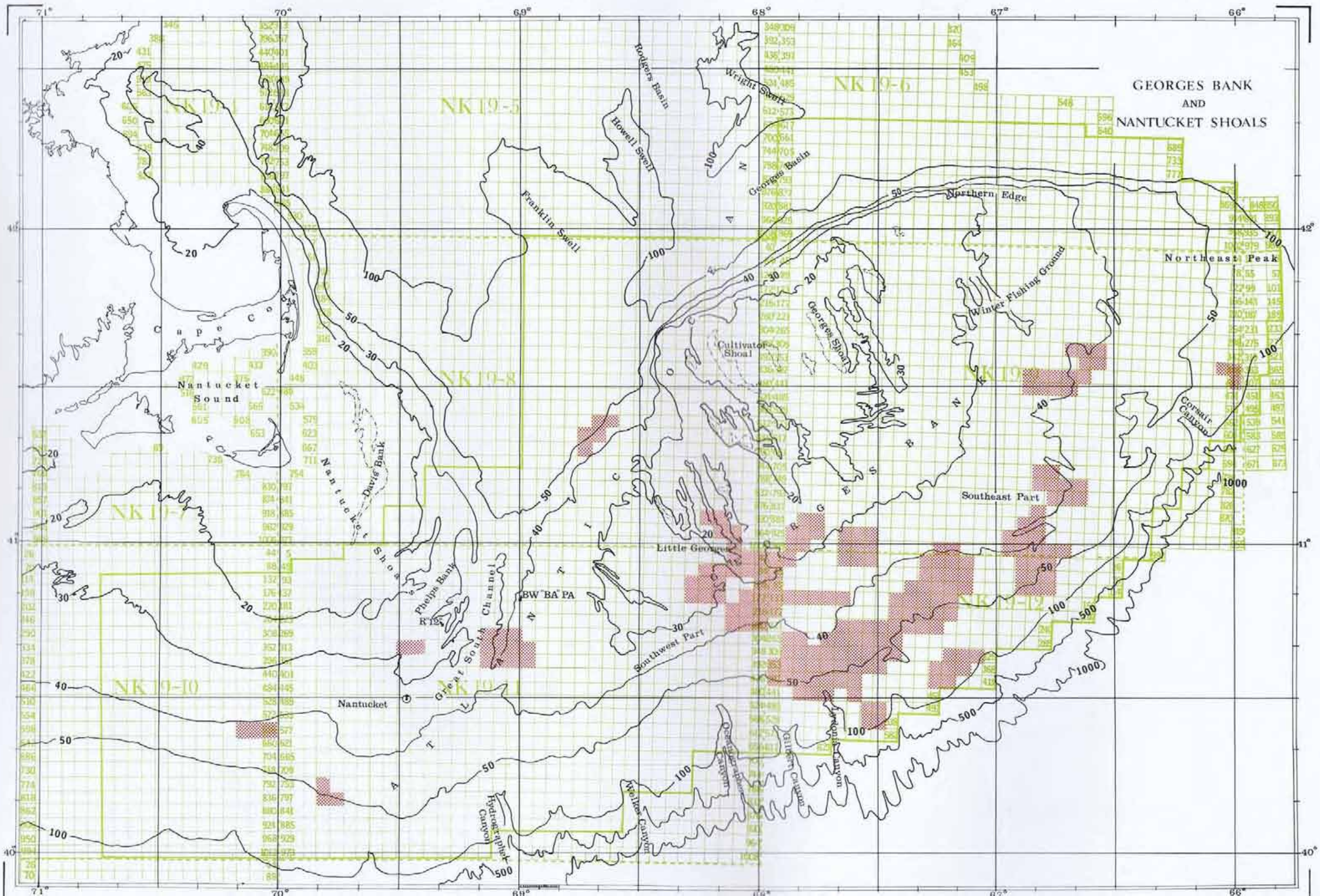


PLATE 3

DOMESTIC FISHING ACTIVITY; DAYS FISHED 1965-1974

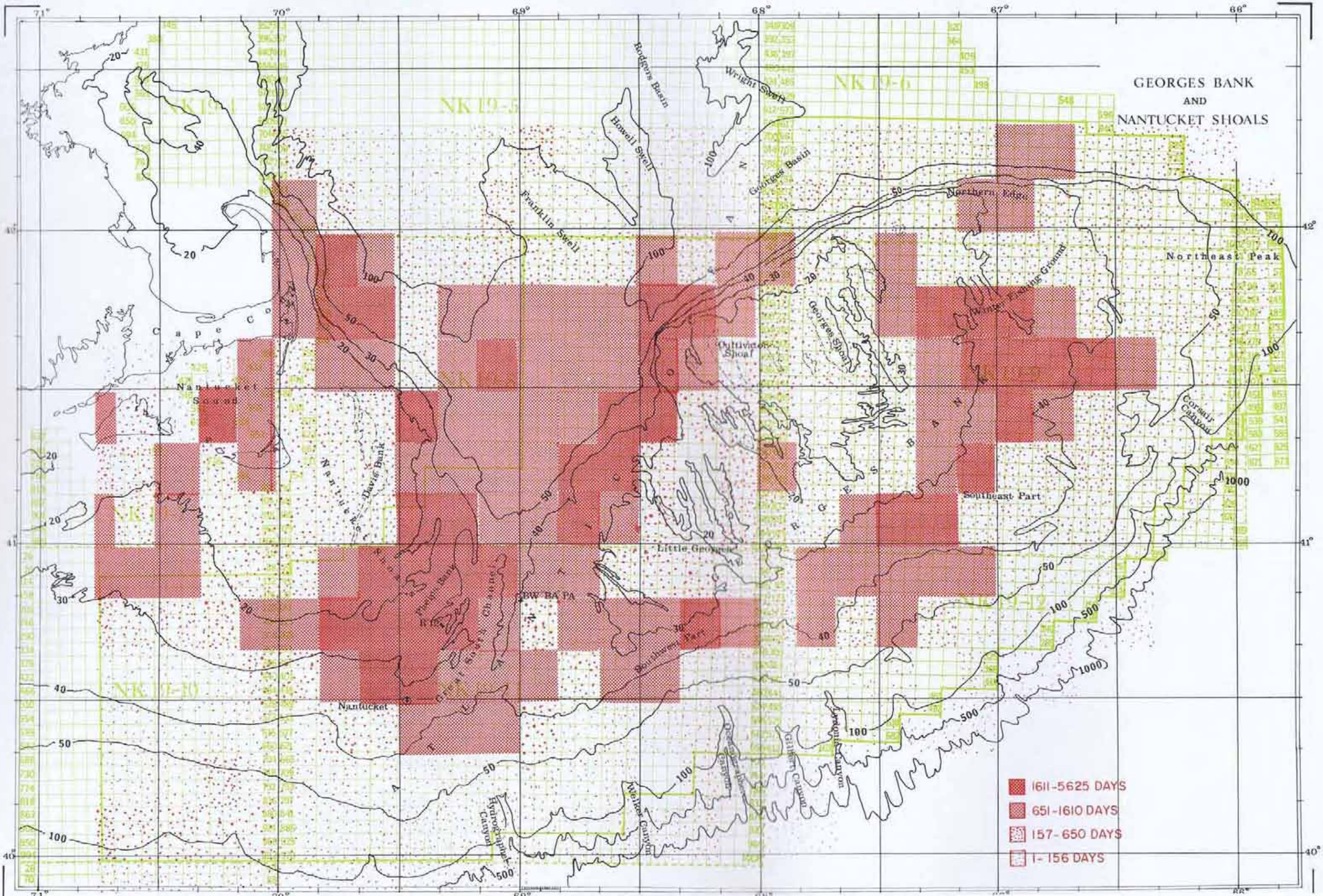


PLATE 4

DOMESTIC FISHING ACTIVITY; TOTAL LANDINGS 1965-1974

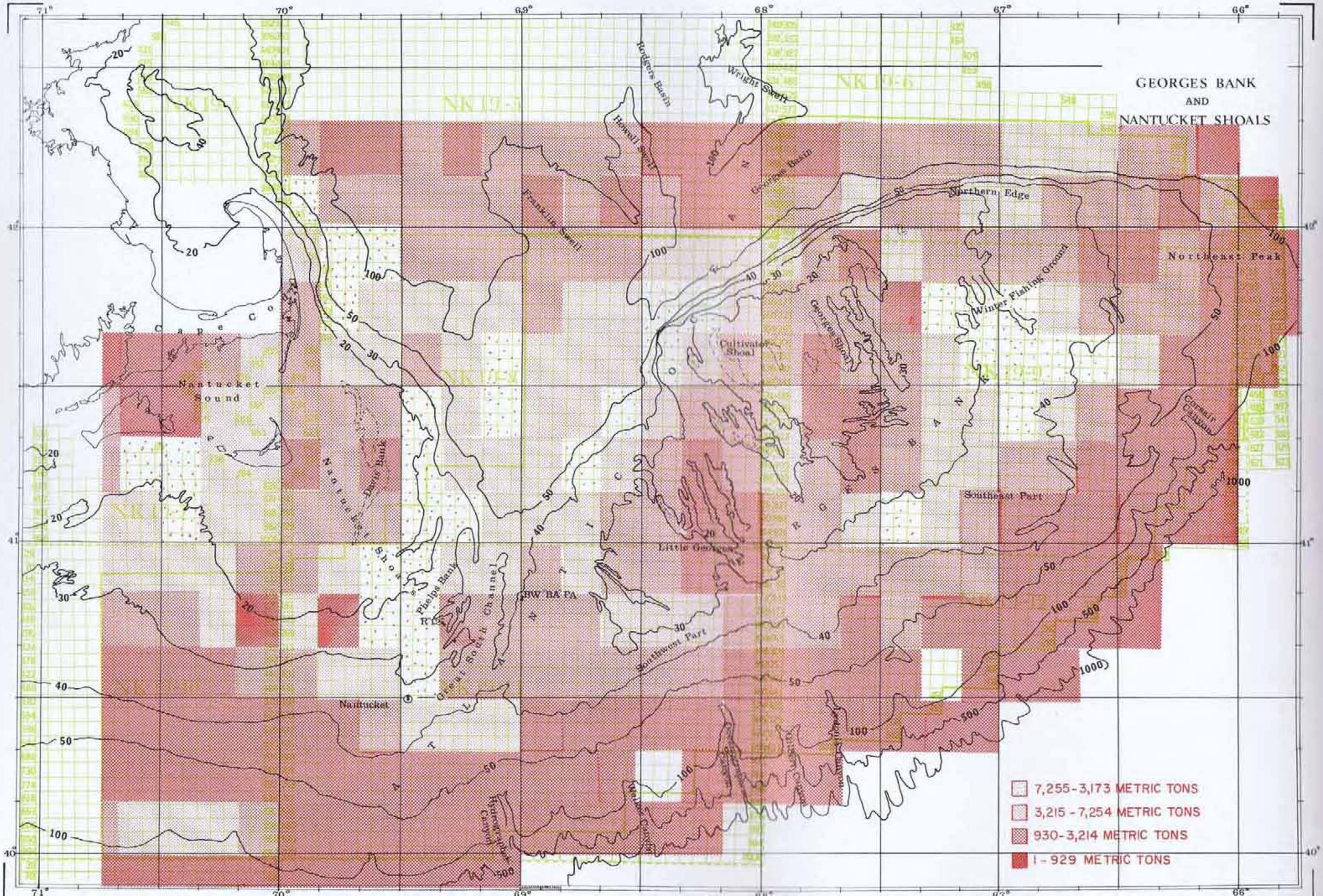


PLATE 5

PRINCIPAL DOMESTIC TRAWLING GROUNDS

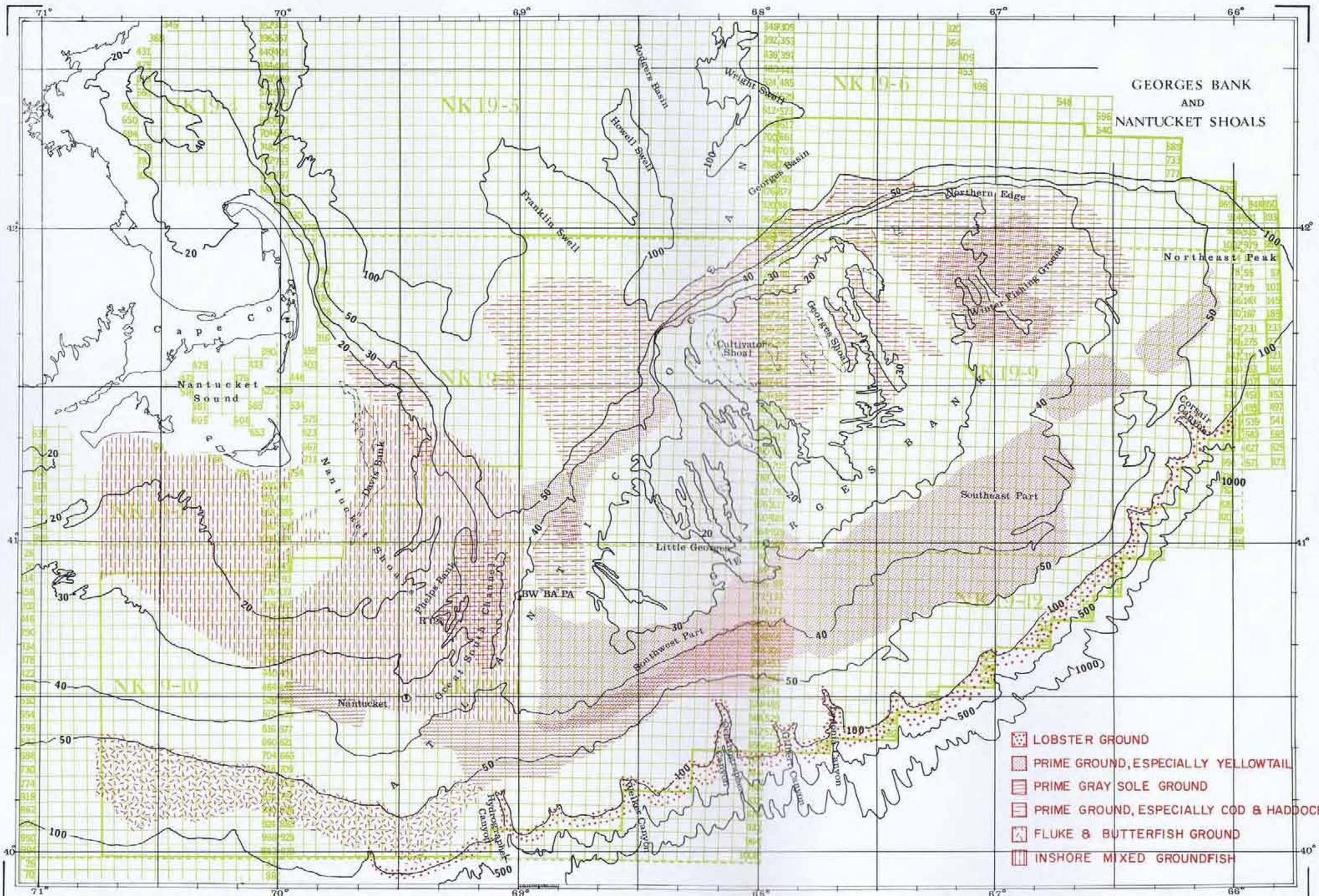


PLATE 6

PRINCIPAL DOMESTIC SCALLOP, LONGLINE AND POT GROUNDS

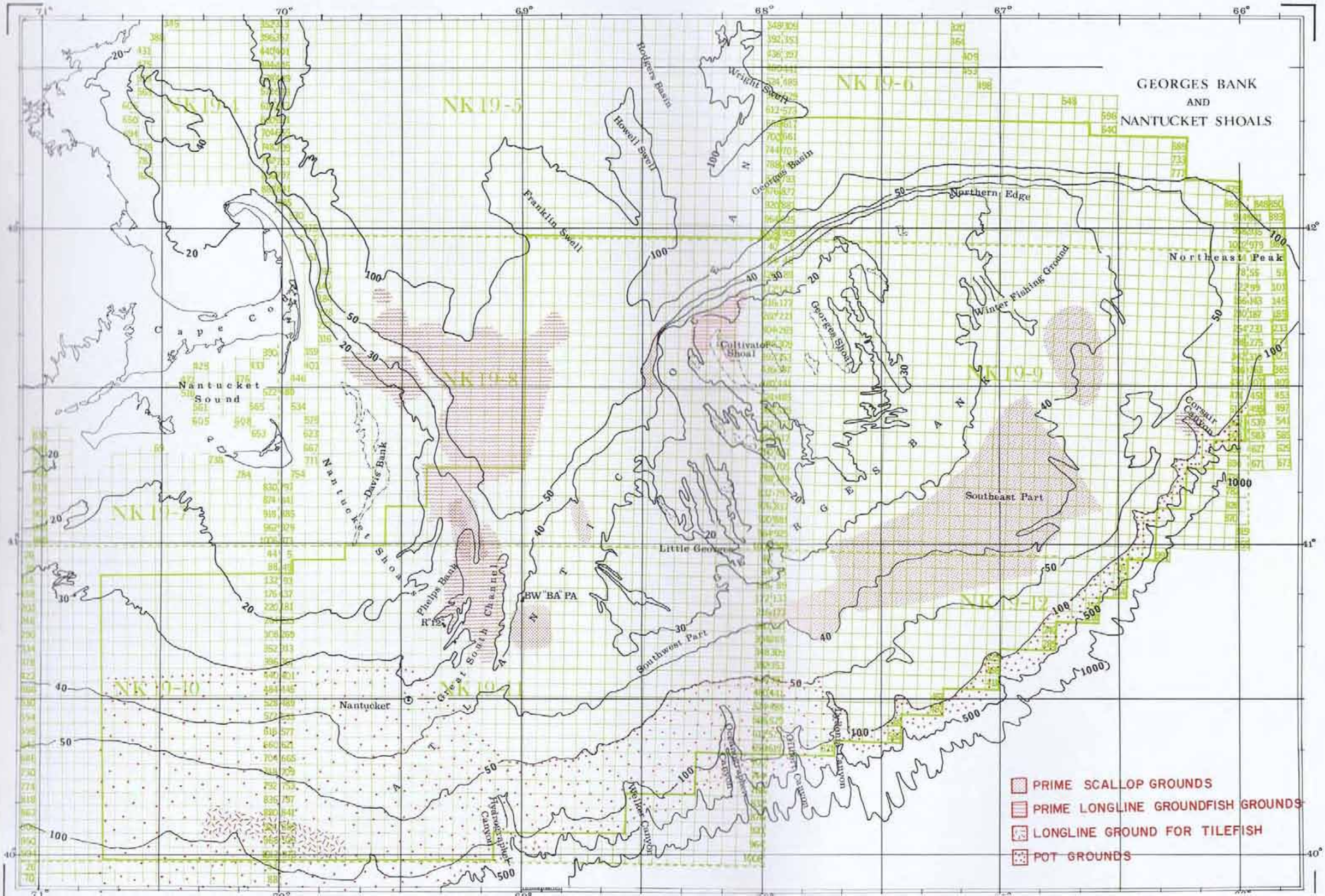


PLATE 7

FOREIGN FISHING ACTIVITY, 1974

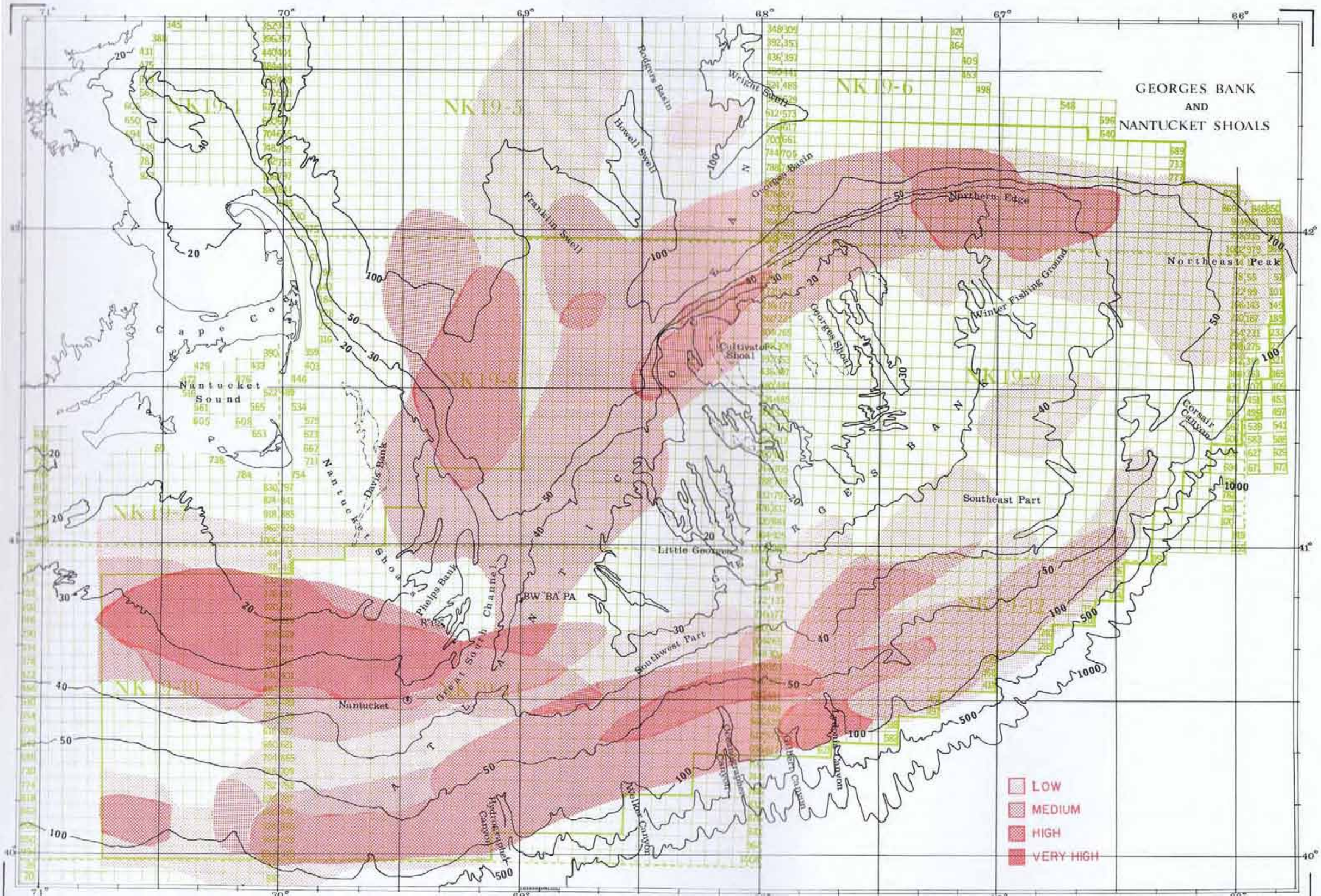


PLATE 8

SPRING DISTRIBUTION OF SELECTED COMMERCIAL SPECIES 1968-1972

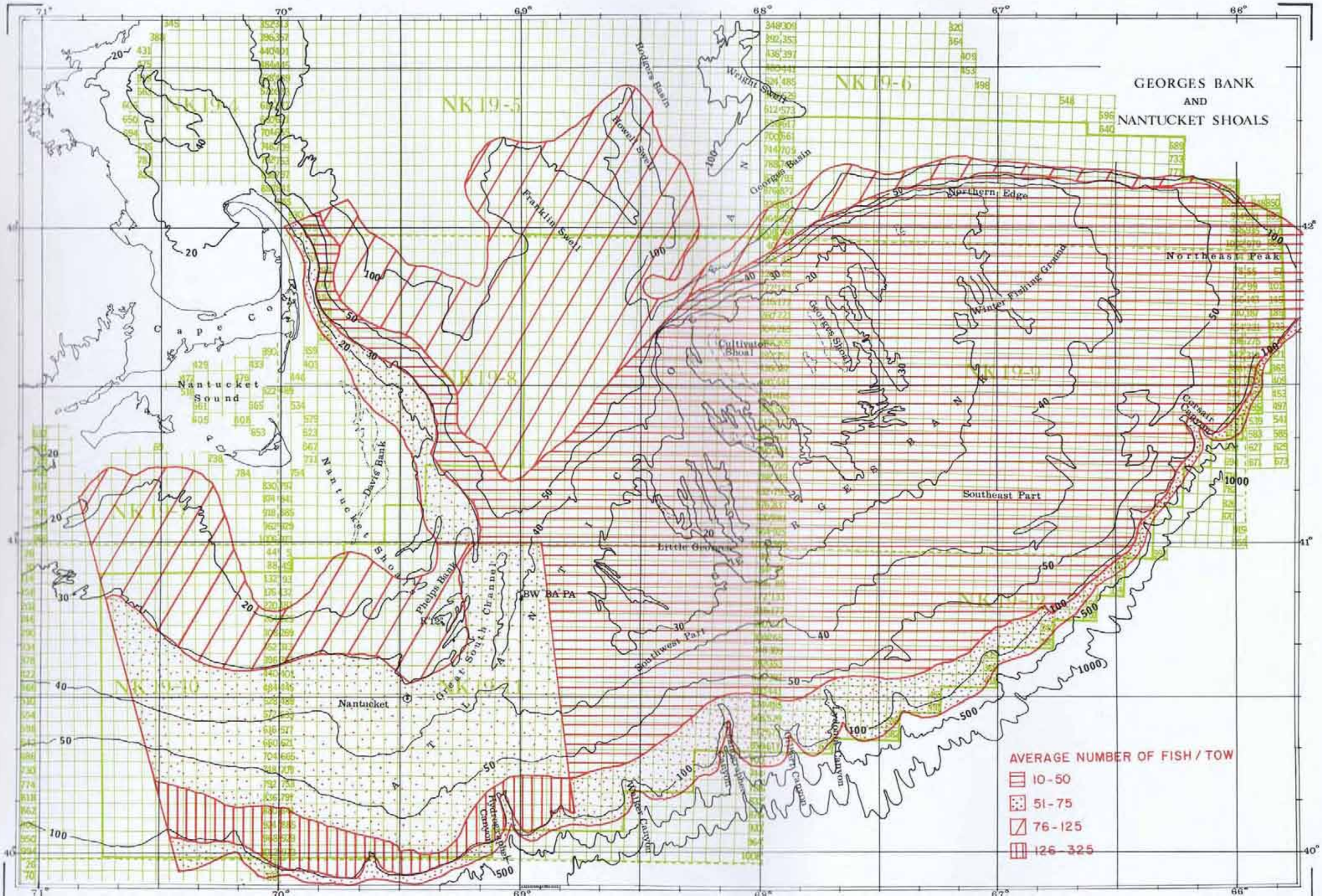


PLATE 9

FALL DISTRIBUTION OF SELECTED COMMERCIAL SPECIES 1964-1974

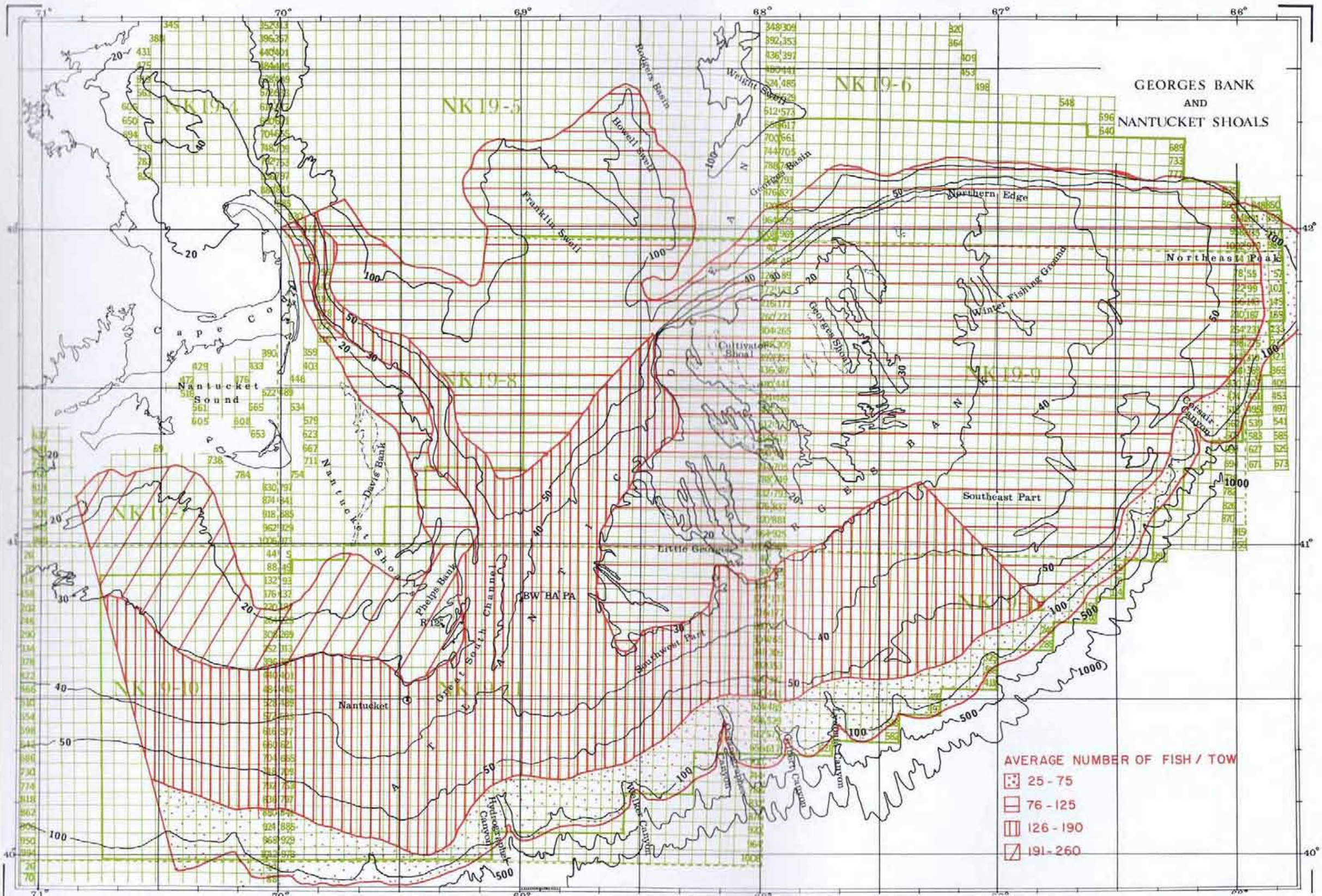


PLATE 10

KNOWN SPECIFIC SPAWNING GROUNDS

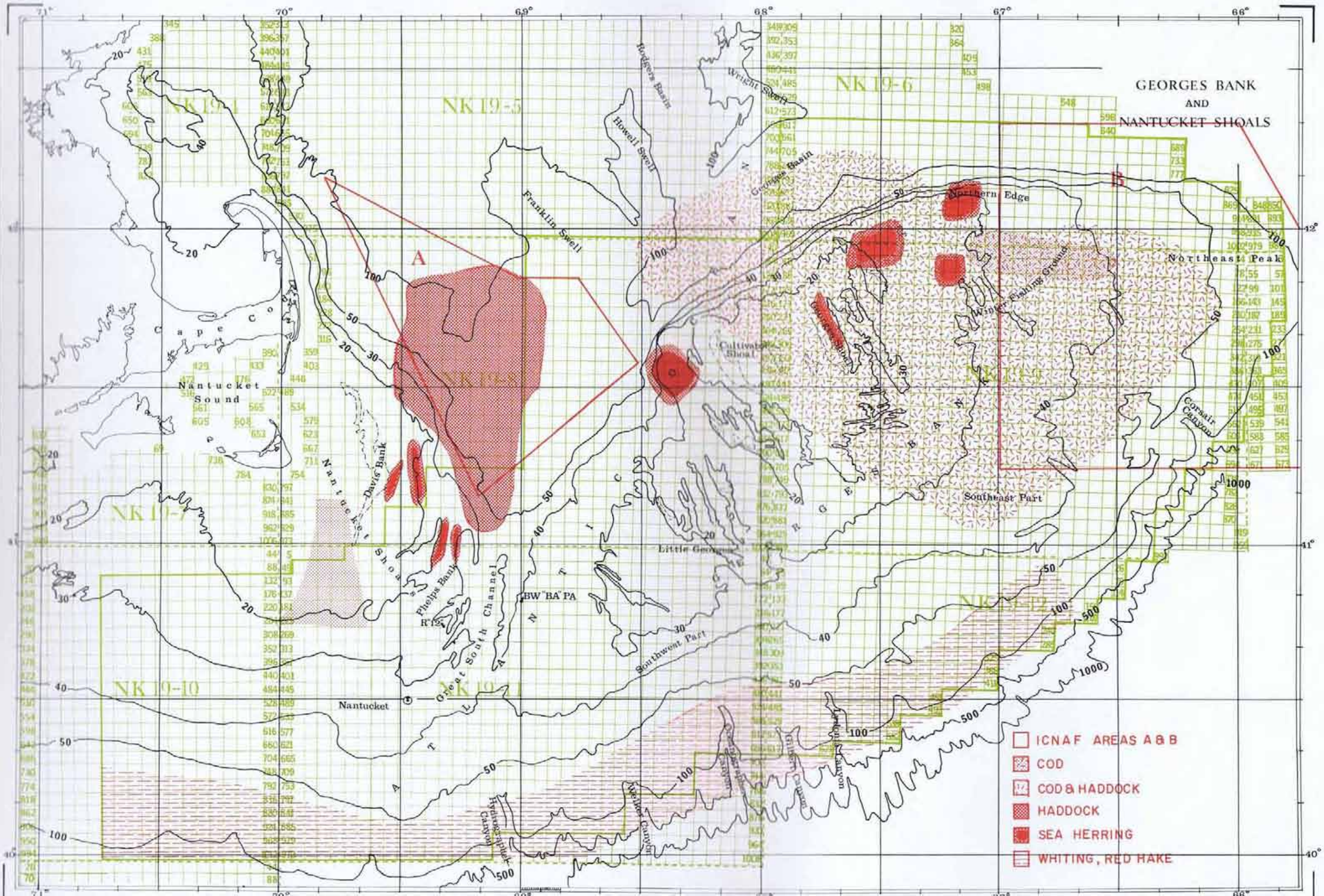


PLATE II

DISTRIBUTION OF BENTHOS (WIGLEY, 1961)

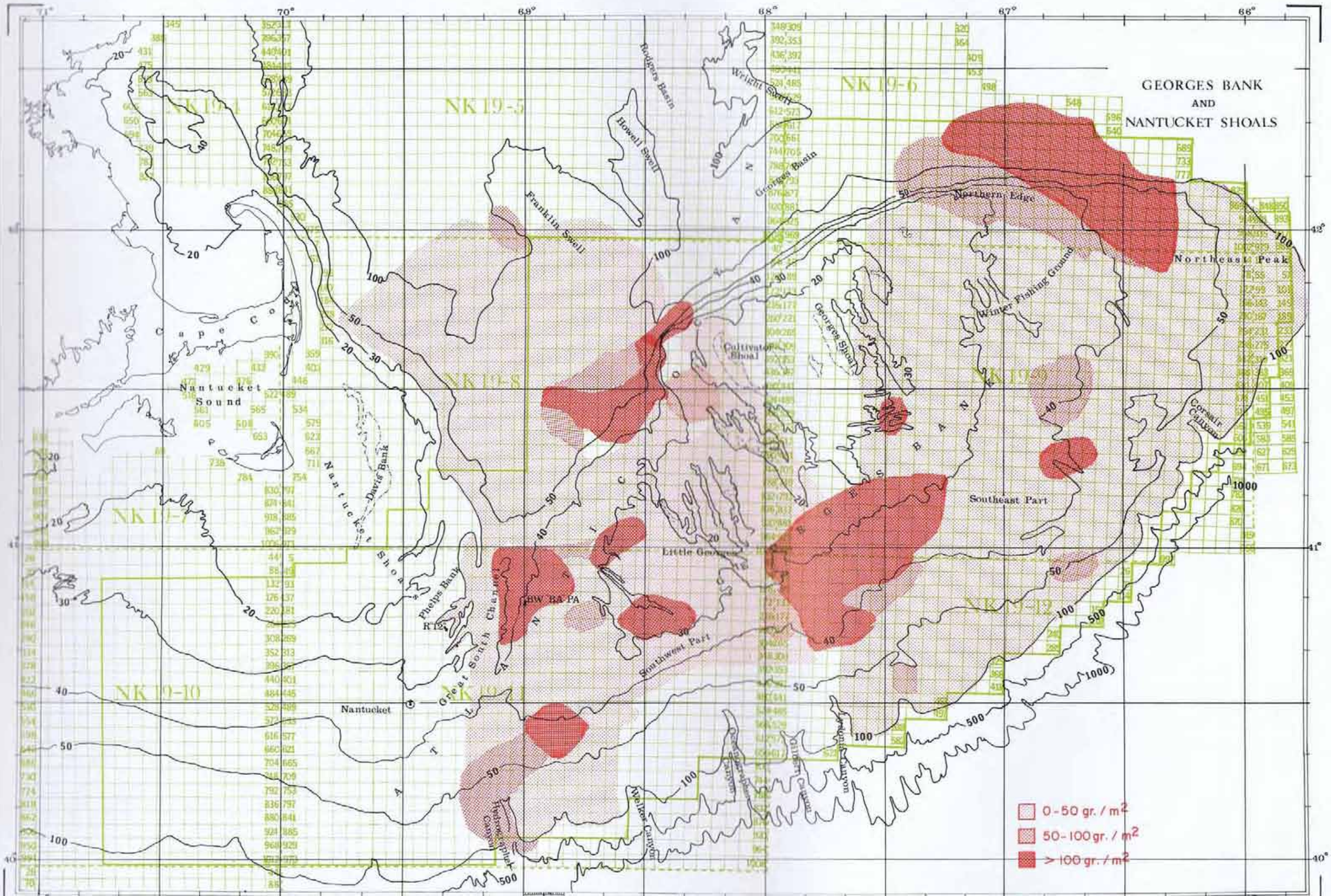


PLATE 12

DISTRIBUTION OF SURFACE SEDIMENTS (SCHLEE, 1973)

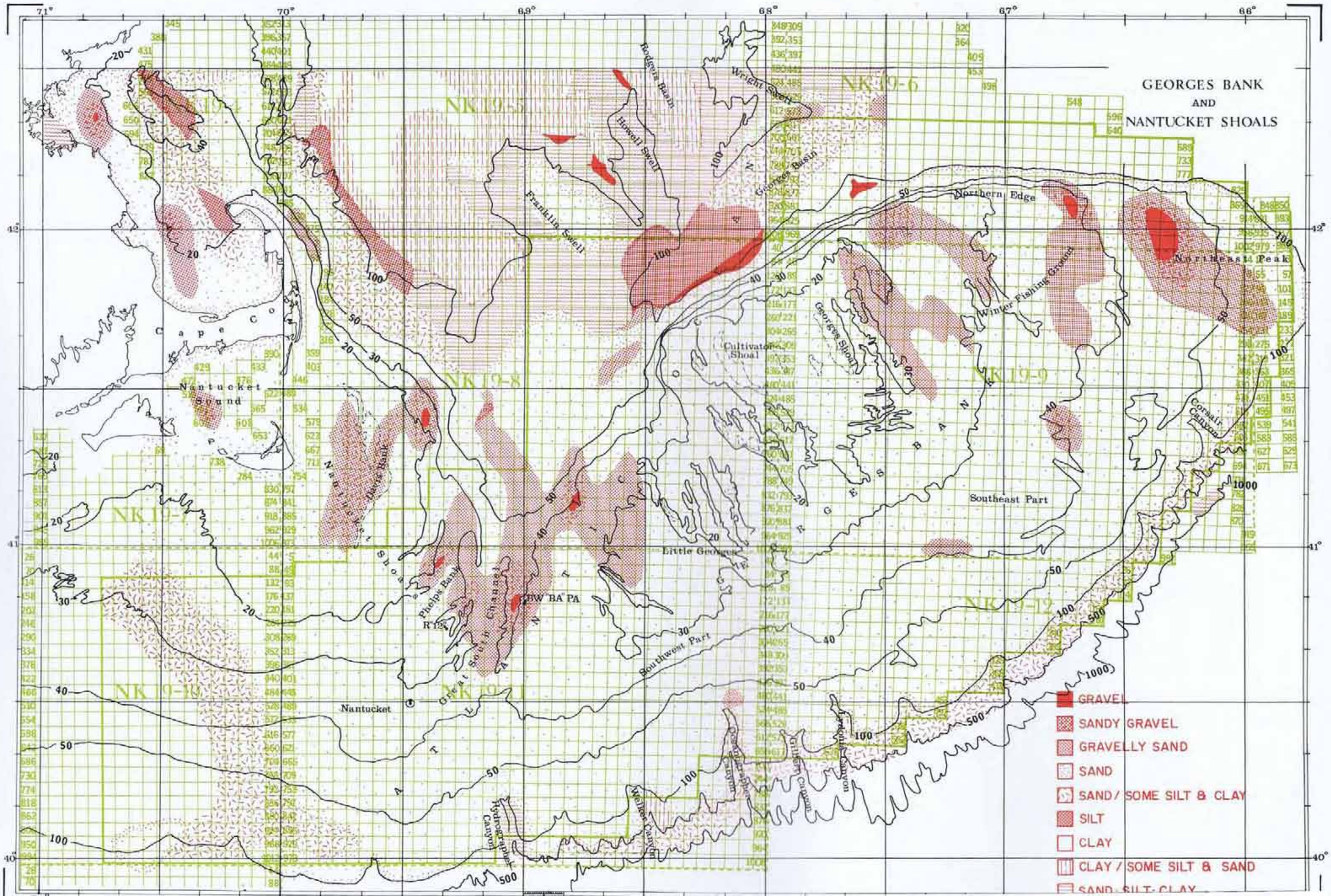
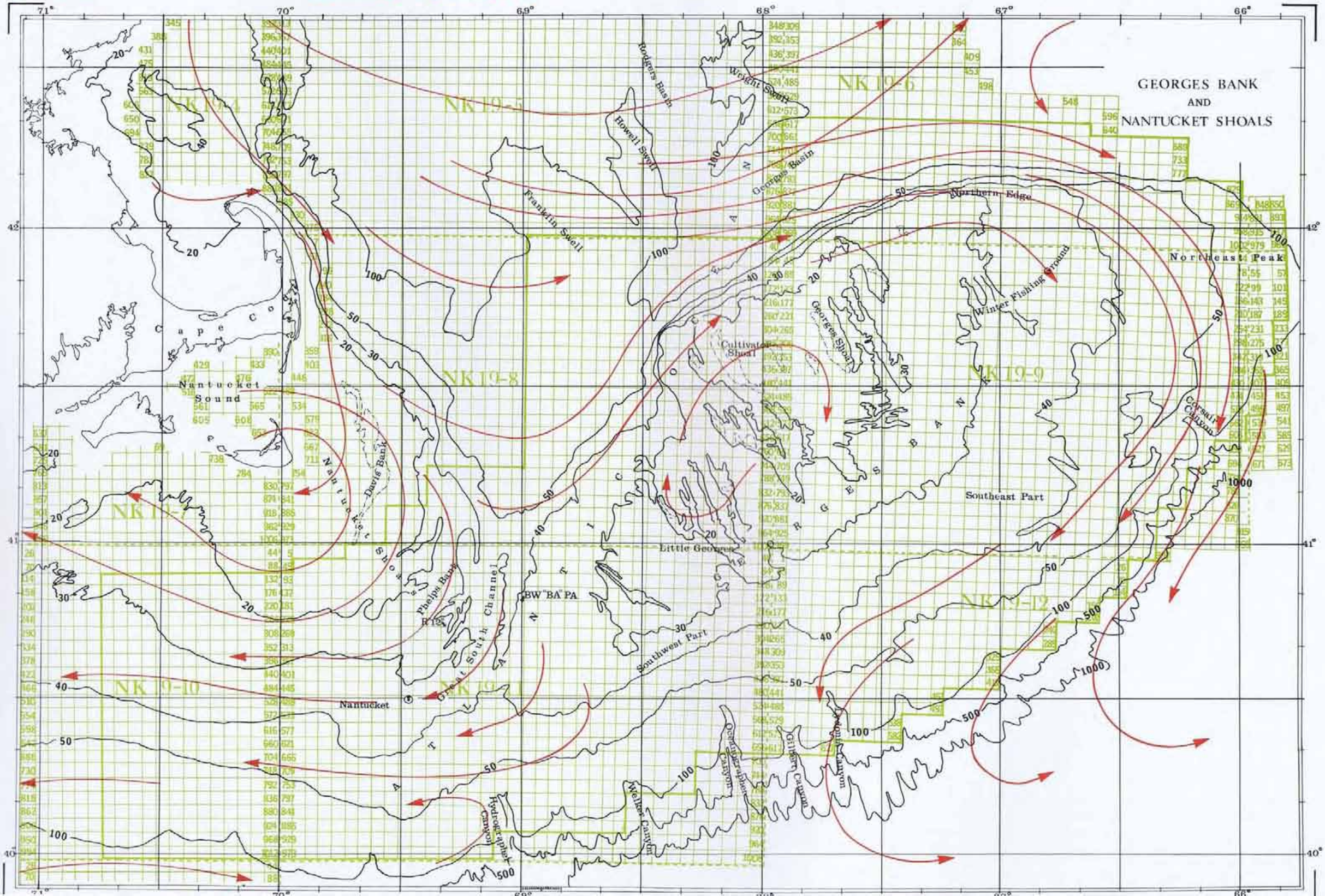


PLATE 13

SURFACE CURRENTS



Energy Program Publications

The following publications of the New England Regional Commission's Energy Program are available upon request from the Energy Program Director, New England Regional Commission, 53 State Street, Boston, Massachusetts 02109.

Code No.	*Title and Date*
76-1	Energy Flows in New England: Historical and Projected, January, 1976
76-2	New England Power Pool: Analysis and Regulatory Implications, February, 1976
76-3	Fishing and Petroleum Interactions on Georges Bank: Vol. I, Areas of Particular Interest to the Industries, January, 1976
75-0	Collected Staff Papers on OCS/Policy Considerations/Reviews of Legislation, etc.
75-1	Electric Power Demand and Supply in New England: A Review of Trends and Forecasts, January, 1975
75-2	Analysis of the Impacts on New England of Recent Energy Shortages and Price Increases, January, 1975
75-3	A conventional Energy Demand Projection for New England, January, 1975
75-4	Annotated Index of Energy Facility Related Statutes, February, 1975
75-5	Municipal Energy Facility Siting Regulations in New England, April, 1975
75-6	Petroleum Development in New England: Economic and Environmental Considerations, October, 1975; Summary Report; Main Report (3 volumes)
75-7	Decision Making for Energy Facilities in New England: The Institutional and Legal Process, October, 1975
75-8	Power Facility Siting Guidelines in New England, October, 1975
75-9	Gas Industry Development in New England: Analysis of Alternatives, October, 1975
74-1	Emergency Air Quality Management for the New England Region, January, 1974
74-2	Emergency Air Quality Management for the New England Region, September, 1974
74-3	New England Energy Management Information System: New England Dependence on Oil and Fuel Allocation, July, 1974
74-4	The Electric Rate Problem in New England, May, 1974
74-5	Historical Data on New England's Energy Requirements, September, 1974
74-6	Supply and Demand Projections of New England's Energy Requirements, October, 1975
74-7	New England Energy Management Information System: Base Period Analysis of Gasoline Distribution in New England, December, 1974
74-8	New England Energy Management Information System: Climatic Determinants of Heating Oil Demand, December, 1974
74-9	New England Energy Management Information System: The Petroleum Distribution Network for New England, December, 1974