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IDENTIFICATION OF CRITICAL NATURAL RESOURCES PARTICULARLY VULNERABLE TO OIL SPILLS

OCS Task 7.6

Prepared by

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June, 1977

COASTAL ZONE
INFORMATION CENTER

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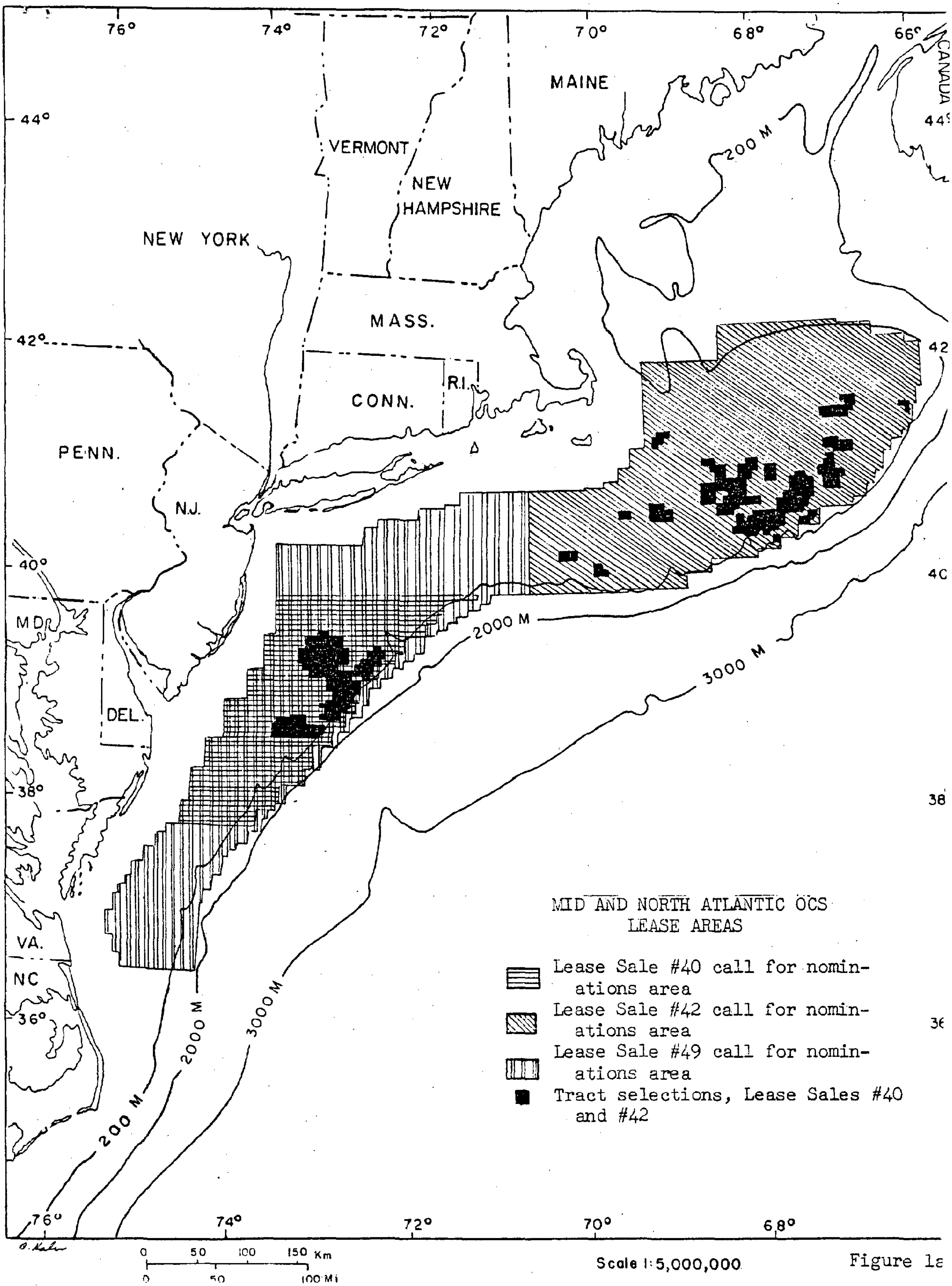

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Figure 1a

The purpose of Task 7.6, Identification of Critical Natural Resources Particularly Vulnerable to Oil Spills, is to provide fundamental resource data which will be used to determine management programs and legislation, to designate permissible and prohibitive uses and to define Geographical Areas of Particular Concern (GAPC). GAPC's have been defined, in the Coastal Zone Management Act of 1972, as areas of greater significance to the State than the remaining parts of the coastal zone. The GAPC's may face pressure, such as vulnerability to oil spills in the case of OCS development, which demand the attention of, or exceed the capabilities of the State's existing planning and regulatory powers. The critical natural resources identified in Task 7.6 may be designated as GAPC's based on a review of coastal zone resources and uses and upon consideration of certain factors included in the State-established criteria:

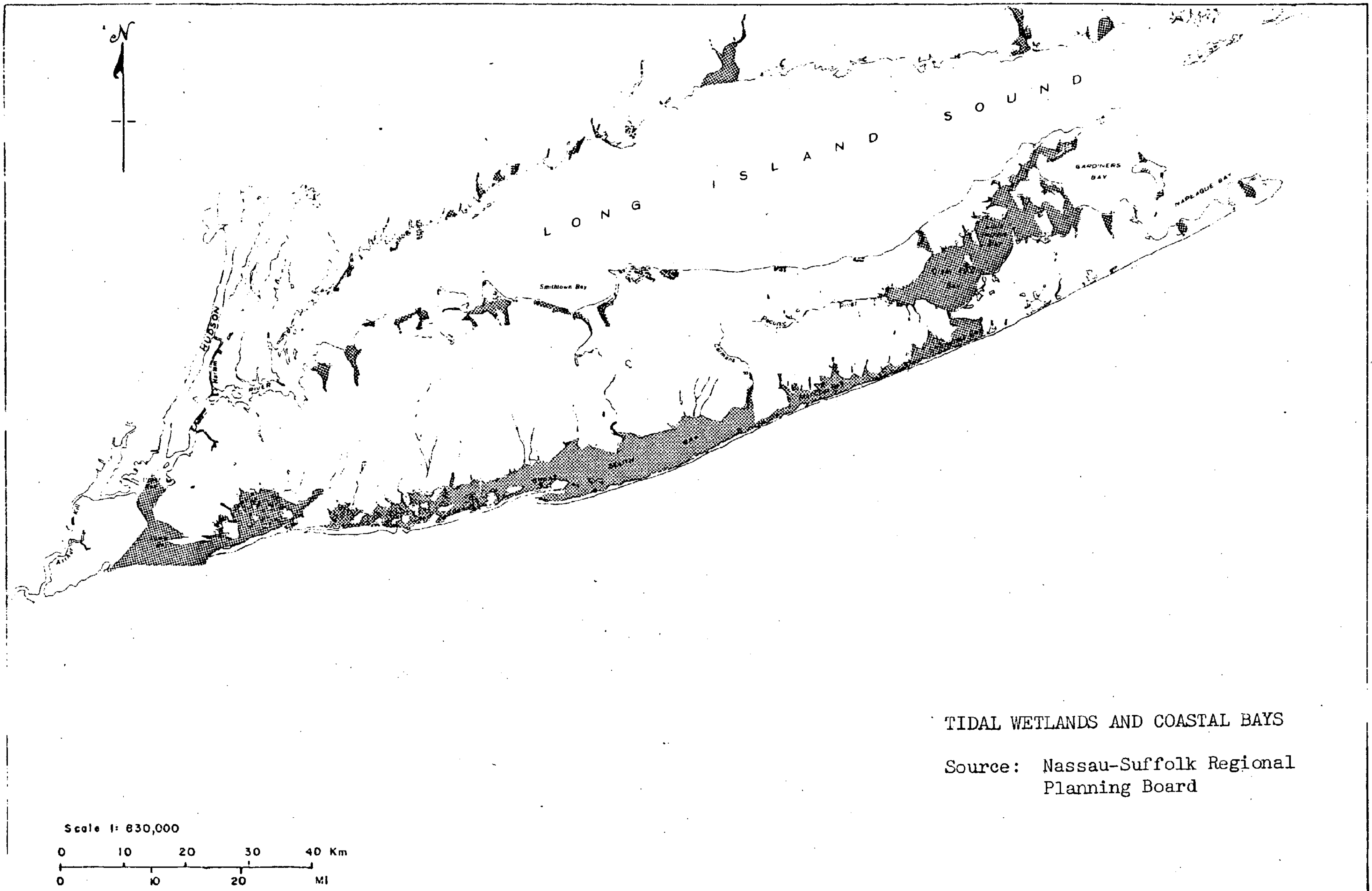
(1) areas of unique, scarce, fragile or vulnerable natural habitat, physical feature, historic significance, cultural value and scientific importance

(2) areas of high natural productivity or essential habitat for living resources, including fish, wildlife, and the various trophic levels in the food web, critical to their well being; and

(3) areas of substantial recreational value or opportunity.

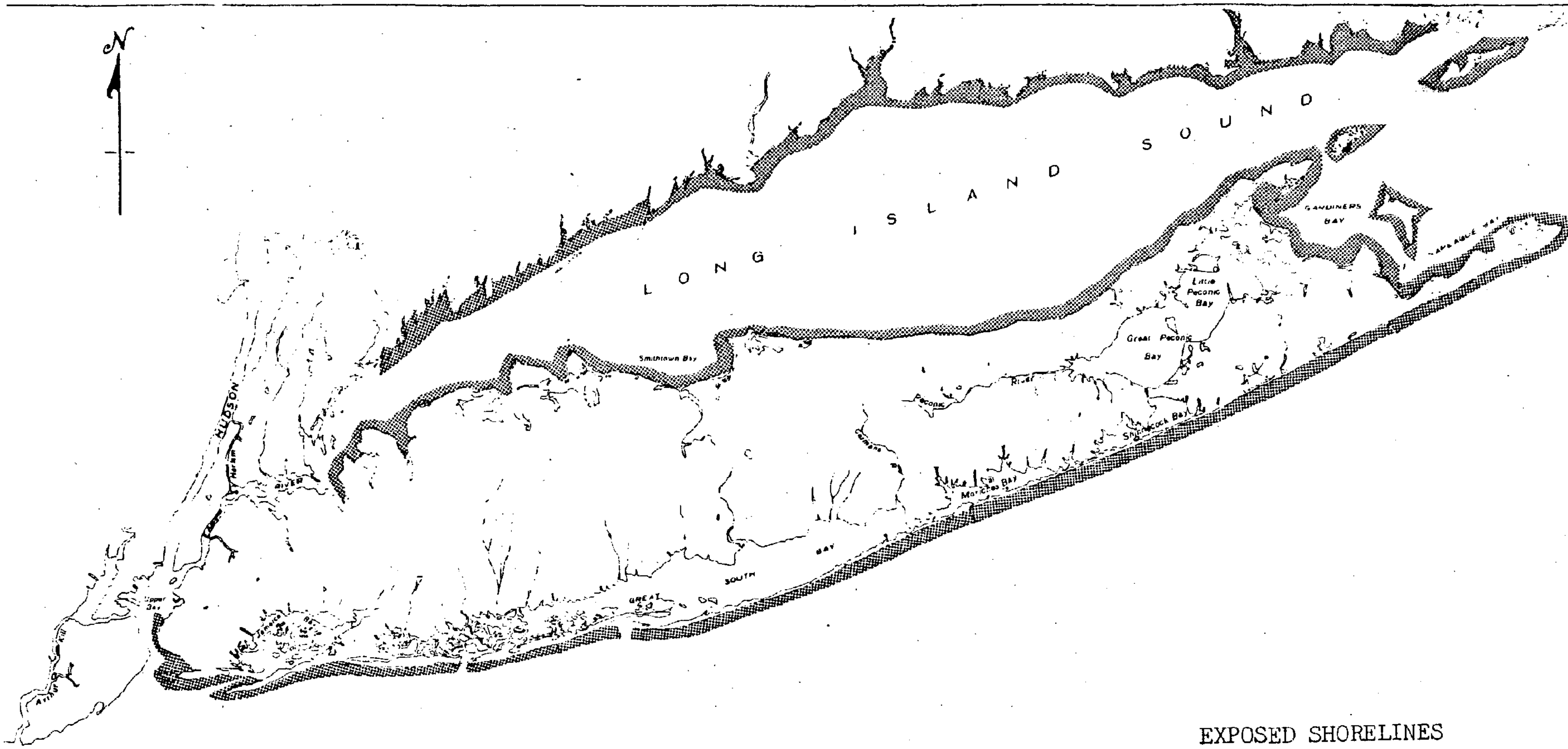
The critical natural resources in New York State, relevant to Outer Continental Shelf exploration and development, are located in three different habitats: tidal wetlands and coastal bays, exposed shorelines, and the offshore region (Figures 1b, 2 and 3). The life history characteristics of the key species in each of these habitats are summarized according to the following organization:

(1) distribution and niche preference
(2) reproduction
(3) fecundity and larval life
(4) growth and longevity
(5) migration characteristics
(6) food
(7) predation
(8) competition
(9) responses to the environment



TIDAL WETLANDS AND COASTAL BAYS

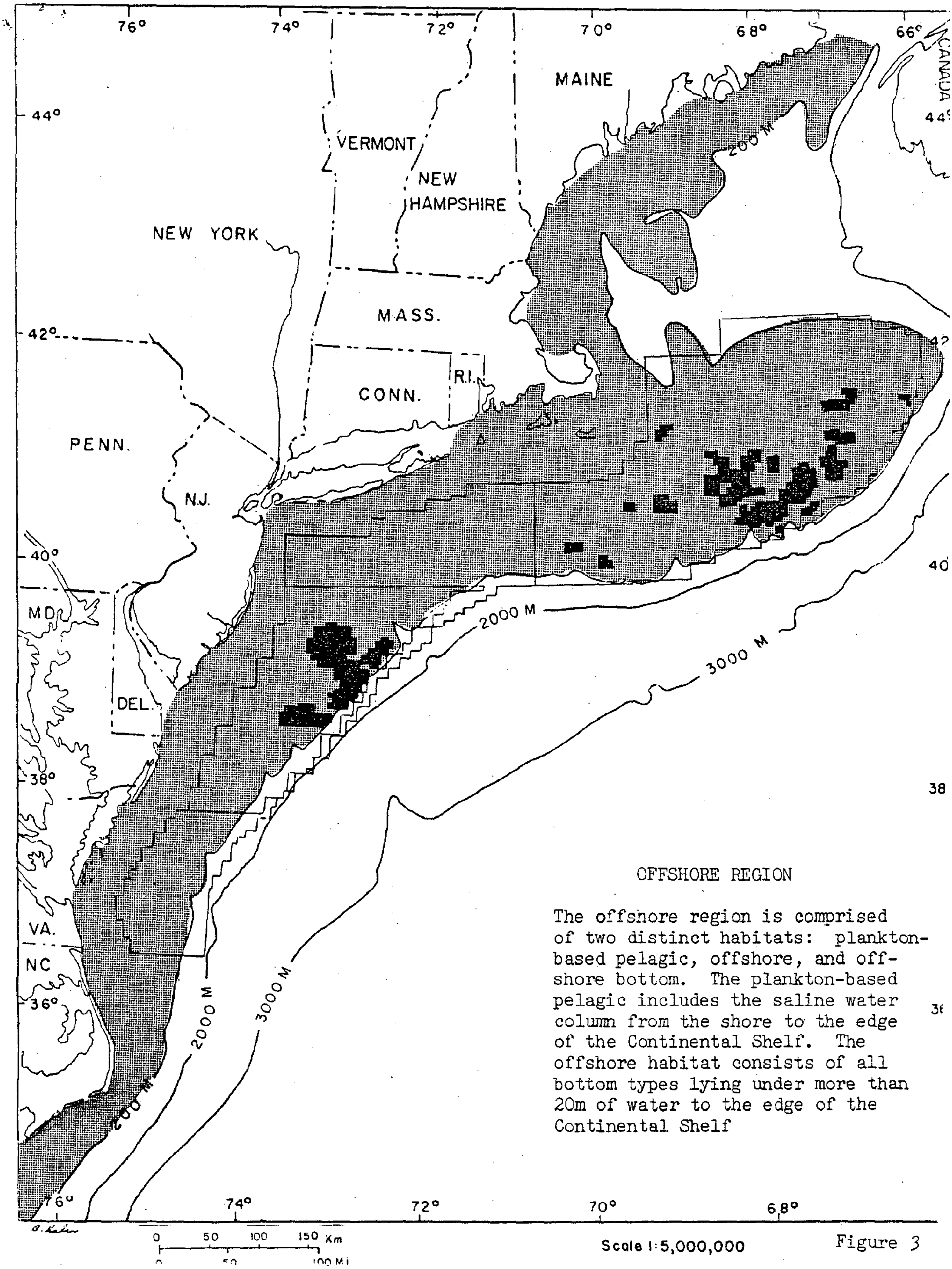
Source: Nassau-Suffolk Regional Planning Board



EXPOSED SHORELINES

This habitat is defined to extend from the intertidal area to a depth of 20 meters and includes two distinct habitats: sandy shores and rocky shores. The rocky shore habitat is not found in New York State coastal waters.

Source: The Research Institute of the Gulf of Maine



OFFSHORE REGION

The offshore region is comprised of two distinct habitats: plankton-based pelagic, offshore, and offshore bottom. The plankton-based pelagic includes the saline water column from the shore to the edge of the Continental Shelf. The offshore habitat consists of all bottom types lying under more than 20m of water to the edge of the Continental Shelf

Figure 3

The recreational and/or commercial harvests in both volume and value, are estimated for each species. The most significant component of Task 7.6 evaluates the biological sensitivity of the critical natural resources to petroleum contamination and estimates the sensitivity of the fishing industry to petroleum.

The major focus of this report is the resources found in the offshore region. As a sub-part of this task, the Nassau Suffolk Regional Planning Board undertook a similar study that focused primarily on the resources of the bays and the nearshore coastal zone. Much of the information contained in the NSRPB report will not be repeated here. A comprehensive assessment of the vulnerability of all the critical resources important to New York State should include both reports.

II. TIDAL WETLANDS AND COASTAL BAYS

Tidal wetlands should be viewed as highly developed, natural, productive living resources. The New York State Legislature recognized the values of wetlands in 1973 through passage of the Tidal Wetlands Act, which established a regulatory program to preserve and protect tidal wetlands. The law provides a broad definition of tidal wetlands that includes coastal salt marshes and regularly flooded salt marshes as well as coastal shoals, bars and mud flats. Coastal fresh marshes and the littoral zone (waters up to six feet deep) are also protected under the law.

Coastal wetlands have six natural functions:

1) They serve as storage areas for tidal surges and upland runoff.

2) They serve as a natural buffer, reducing the impact of storm tides and waves on the adjacent higher areas.

3) They have a sedimentation function - water moving across wetlands constantly stirs up the surface materials - vegetation acts as a filter causing sedimentation.

4) The marsh and shoal areas in particular may serve, beneficially, as a biological and chemical basin where deposited organic and inorganic materials are oxidized, decomposed, and digested while being converted into nutrients.

5) There is primary nutrient production from wetlands' vegetation with subsequent mechanical and chemical decomposition.

6) They serve as fish and wildlife habitat functions. This includes breeding nesting, resting, feeding, and predator-escape functions for various fish and wildlife species.

Human uses of the wetlands may or may not alter the wetland environment. No alteration uses include providing nursery areas for fisheries; offering unique and valued open space and aesthetic qualities; providing a wide range of active and passive recreation; and providing a wide range of opportunity as outdoor laboratories and living classrooms. Transportation, residential, commercial, industrial, resource extraction, and waste disposal uses would involve altering the wetland environment.

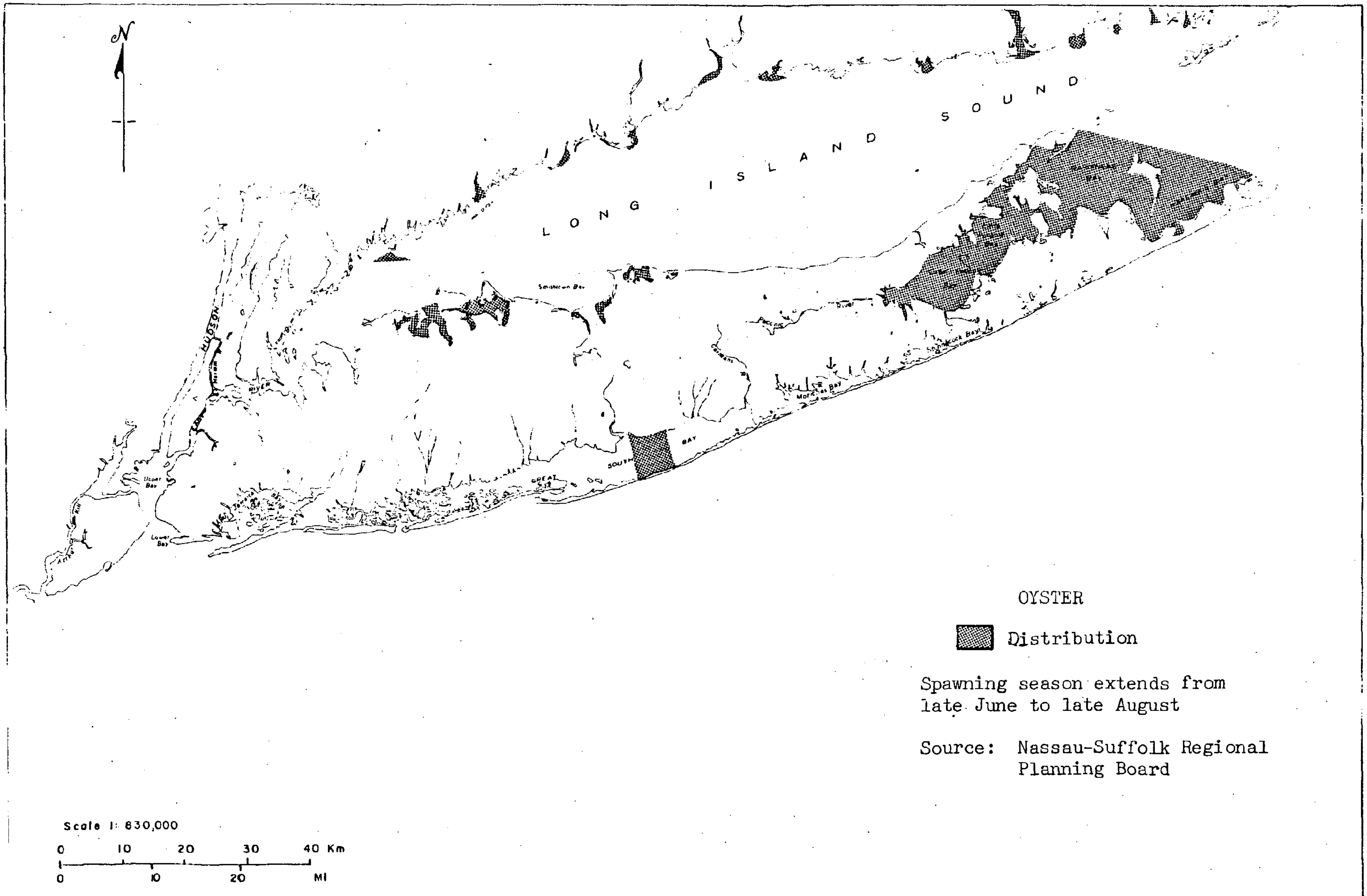
Coastal bays are influenced considerably by freshwater influxes from river outflow, groundwater seepage, or runoff. Consequently these bays are marked by a salinity gradient that fluctuates in position and steepness with season and freshwater runoff. The influence of freshwater runoff as well as the overall shallowness of estuarine waters also causes wide temperature fluctuations and often a down estuary gradient of decreasing temperature occurs in the spring and summer. The semi-enclosed nature of most estuarine waters combined with a constant renewal of nutrients from both fresh and sea water causes estuarine waters to be highly fertile.

The benthic invertebrates, fish and waterfowl considered regular inhabitants of tidal wetlands and coastal bays are oysters (Crassostrea virginica), hard-shell clams (Mercenaria mercenaria), soft-shell clams (Mya arenaria), bay scallops (Acquipecten irradians), winter flounder (Pseudo pleuronectes americanus), mallards (Anas platyrhynchos) and black ducks (Anas rubripes). The bay scallops, oysters, and clams occupy sandy and mud bottoms which are often exposed at low-tide. Winter flounder spawn in the shallow backwaters (2 to 5 meter water depths) of bays and estuaries, inhabiting inshore areas to water depths of 36 meters. The mallards and black ducks inhabit fresh and salt ponds, marshes and bays.

Oysters (Crassostrea virginica)

The American oyster (Crassostrea virginica) is one of the most important shellfish resources in the western hemisphere. The greatest abundance occurs in shallow water, frequently estuarine conditions, lower tidal zone to about 18 meters (Figure 4). Oysters inhabit areas with a wide annual range of temperature and salinity. Rocky or semi-hard bottoms and constantly renewed seawater are needed for flourishing communities. On Long Island the principal oyster fisheries are located in Long Island Sound, Great South Bay, and the Peconic Bays. In 1976, commercial landings of oysters in New York were 862 metric tons, worth $4.8 million at the dock.[1]

The oyster reproduces in summer spawning in response to seasonal changes, primarily in temperature. On Long Island the spawning season usually extends from late June to late August. The average female oyster releases over 50 million eggs per year, however less than a dozen of these reach maturity. Oyster



OYSTER

Distribution

Spawning season extends from
late June to late August

Source: Nassau-Suffolk Regional
Planning Board

eggs are shed in the water and are disseminated by currents. Behavioral responses to salinity and light allow larvae to return to their approximate area of origin by way of the currents. The actual length of larval life depends on the temperature, development proceeding faster at higher temperatures.

Oysters are a sedentary species, i.e. they do not display any type of migratory behavior. Oyster larvae and adults feed on microscopic diatoms, flagellates and other nannoplankton filtered from the water.

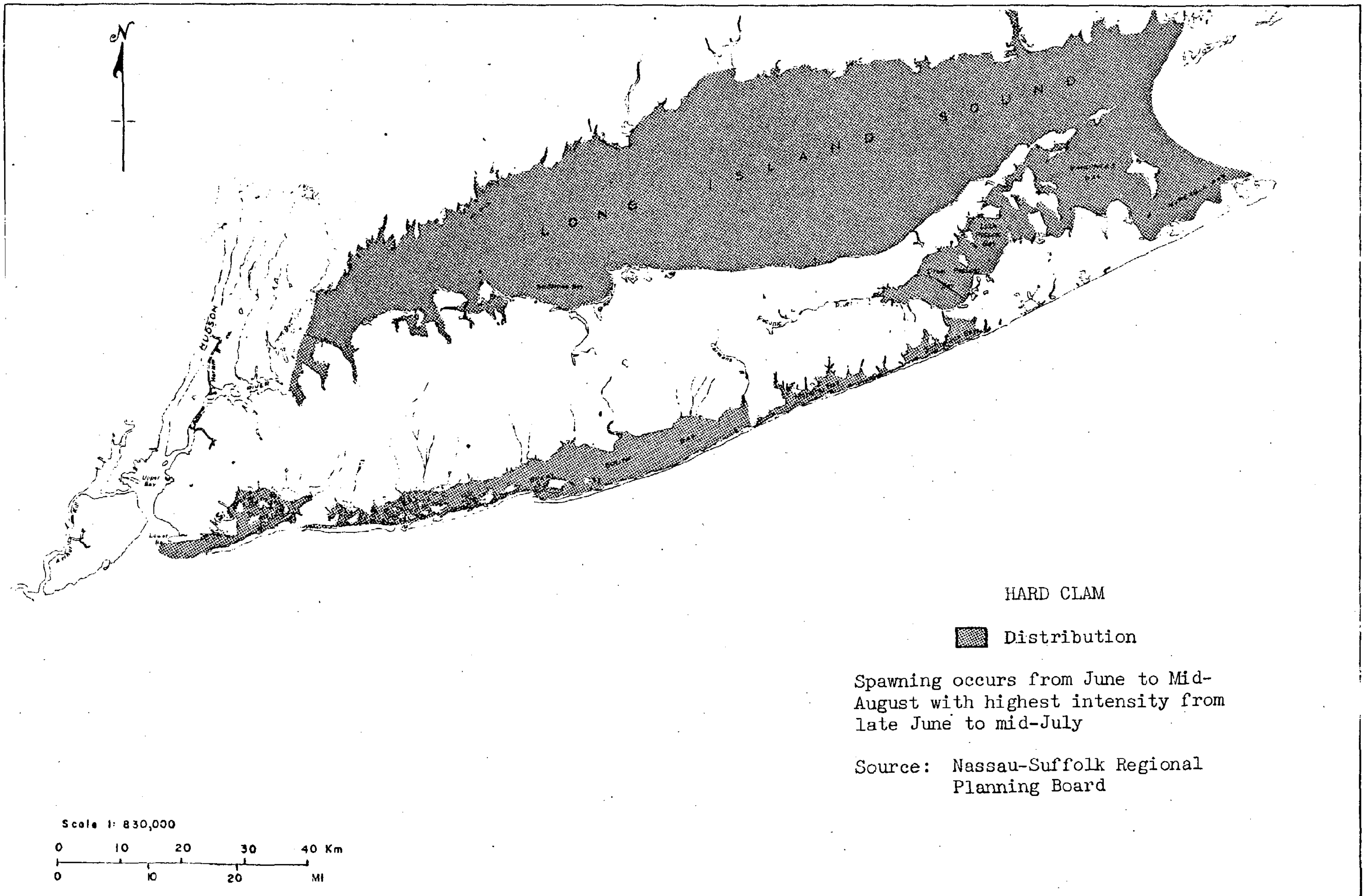
In high salinity areas oysters are plagued by a number of predators, mainly starfish and oyster drills. There are also many species which cohabit with oysters, a few of them can be harmful without feeding directly on them. Mud worms bore into oyster shells causing the oyster to expend energy in avoiding the predator that would otherwise go to growth.

As estuarine organisms, oysters must usually be tolerant to higher levels of turbidity than marine species. However it has been found that increased turbidity does have detrimental effects.[2] As little as 0.1 gram of silt per liter of seawater reduced the pumping rate, hence the feeding rate, of adult oysters by about 57 percent.[3] The effects of oil drilling fluids on adult oysters was tested in the Gulf of Mexico and they were found to have a profound effect on survival. Fluid concentrations over 200 ppm caused a 50 percent mortality in a week.[4] The oyster's economic value and sensitivity to pollution make inclusion of the oyster on the list of valued species mandatory.

B. <u>Hard-shell Clam (*Mercenaria mercenaria*)</u>

The hard clam is found from the Gulf of St. Lawrence to the Yucatan. It is abundant on sandy or muddy bottoms in estuaries and protected areas of the intertidal zones (Figure 5).

The hard clam fishery accounts for 50 percent of the value of all commercial fishery resources landed in New York State. Production from hard clam areas on Long Island has varied drastically over the years, peaking for several years,



HARD CLAM

Distribution

Spawning occurs from June to Mid-August with highest intensity from late June to mid-July

Source: Nassau-Suffolk Regional Planning Board

and then gradually declining to almost nothing. In 1975, the hard clam fishery accounted for 58.5 percent of all hard clams harvested in the United States. Commercial landings of hard clams in 1976, amounted to 3,628 metric tons valued at $18 million at the dock and an estimated $130 million retail.[5]

Spawning occurs from June to mid-August with the highest intensity occurring from late June to mid-July. Several million eggs are produced by each female, but the number fertilized is unknown. The hard clam has a pelagic larval stage called a veliger whose growth rate is greatly dependent on geographical location. Clams become sexually mature at different ages; maturity is a function of size rather than age. Growth occurs only during the summer months beginning around May 1 when the water temperature reaches 9.4°C.

The hard clam feeds on particulate matter consisting of detritus, bacteria, and plankton by means of ciliary mechanisms on the gills and labial palps. The hard clam is a sessile organism which does not exhibit population migration. Spawning takes place in the region of the adult habitat.

Adult clams are preyed upon by starfish, crabs, snails, striped bass, and black duck. The heaviest predation of clams occurs in the very early stages, in the pelagic and recently set clams. Clams live in competition with other burrowing ciliary feeding species which include bay scallops, surf clams, and soft-shell clams.

Clams may perish from a variety of physical and biological causes. Environmental factors such as changes in water temperature or salinity may retard growth or kill larvae. Water currents may carry larvae miles away from the beaches of origin to areas unsuitable for settlement. Plankton-feeding fish and other animals take a heavy toll of bivalve larvae.

Most waterborne pollutants are not toxic to hard clams although they will render them unmarketable. This is particularly true of the pathogens in domestic sewage. The feeding habits and physiology of hard clams cause them to retain a variety of materials and concentrate them. Clams also concentrate heavy metals, pesticides, organic compounds, and petroleum products. New York State has the authority to close shellfish waters to harvest because of pollution. Some of these substances are known to make clams unfit for human consumption. Petroleum would be easily detected by the consumer by tasting or smelling the clam meats. Petroleum products, even in low non-lethal concentrations may impair reproduction, alter physiology or induce a variety of tumors in clams.

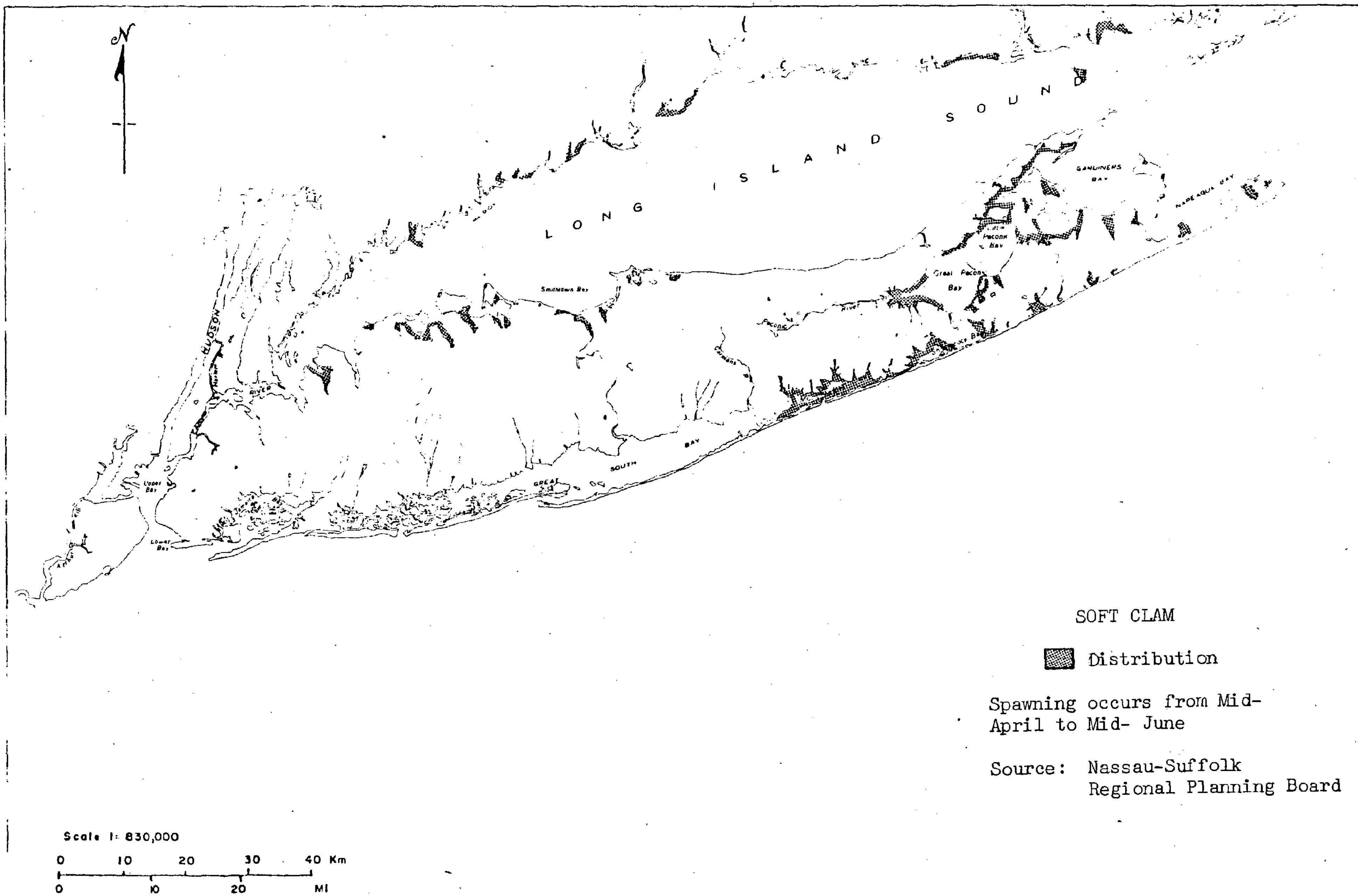
C. Soft-shell Clam (*Mya arenaria*)

The soft-shell clam is abundant throughout the New York region, living in nearly all kinds of cohesive sediments. Populations of greatest abundance occur in estuaries and protected areas of the intertidal zone (Figure 6). Stable bottom conditions, long daily inundation by tides, and rapid tidal currents are best suitable to the soft-shell clam's existence. In 1976, commercial landings of soft-shell clams in New York State were 21 metric tons, valued at $61,406 dockside.[6] However there is great potential for a larger harvest in the coastal bays of Long Island.

Spawning and fertilization take place in the water above or near the clam beds. The spawning season varies according to latitude and geographic differences in water temperatures, in the Long Island area it extends from mid-April to mid-June. The soft-shell clam is sexually mature and capable of spawning at one year of age. A 6 to 8 millimeter clam is capable of producing about three million eggs a year. Clam larvae are carried by currents, the free-swimming stage lasts 10 to 14 days depending on temperatures.

The soft-shell clam is a non-migratory species. The bulk of its food consists of microscopic plants and animals, clumps of bacteria and decomposing fragments of large organisms.

Predators include diving ducks, boring snails, horseshoe crabs, winter flounder, and other bottom feeding fish. The most serious competitor of the soft-shell clam is the blue mussel. There may also be some competition from



SOFT CLAM

Distribution

Spawning occurs from Mid-April to Mid- June

Source: Nassau-Suffolk Regional Planning Board

polychaetes because the soft-shell clam is frequently absent when polychaetes are present in great numbers.

Soft-shell clams, like hard clams, can be rendered unmarketable by waterborne pollutants specifically oil and dispersing agents. Tainting may occur with the ingestion of hydrocarbon compounds. Soft-shell clams are tolerant of changes in temperature and salinity, but changes in habitat such as shifting sands, smothering silt and too rapid currents are detrimental.

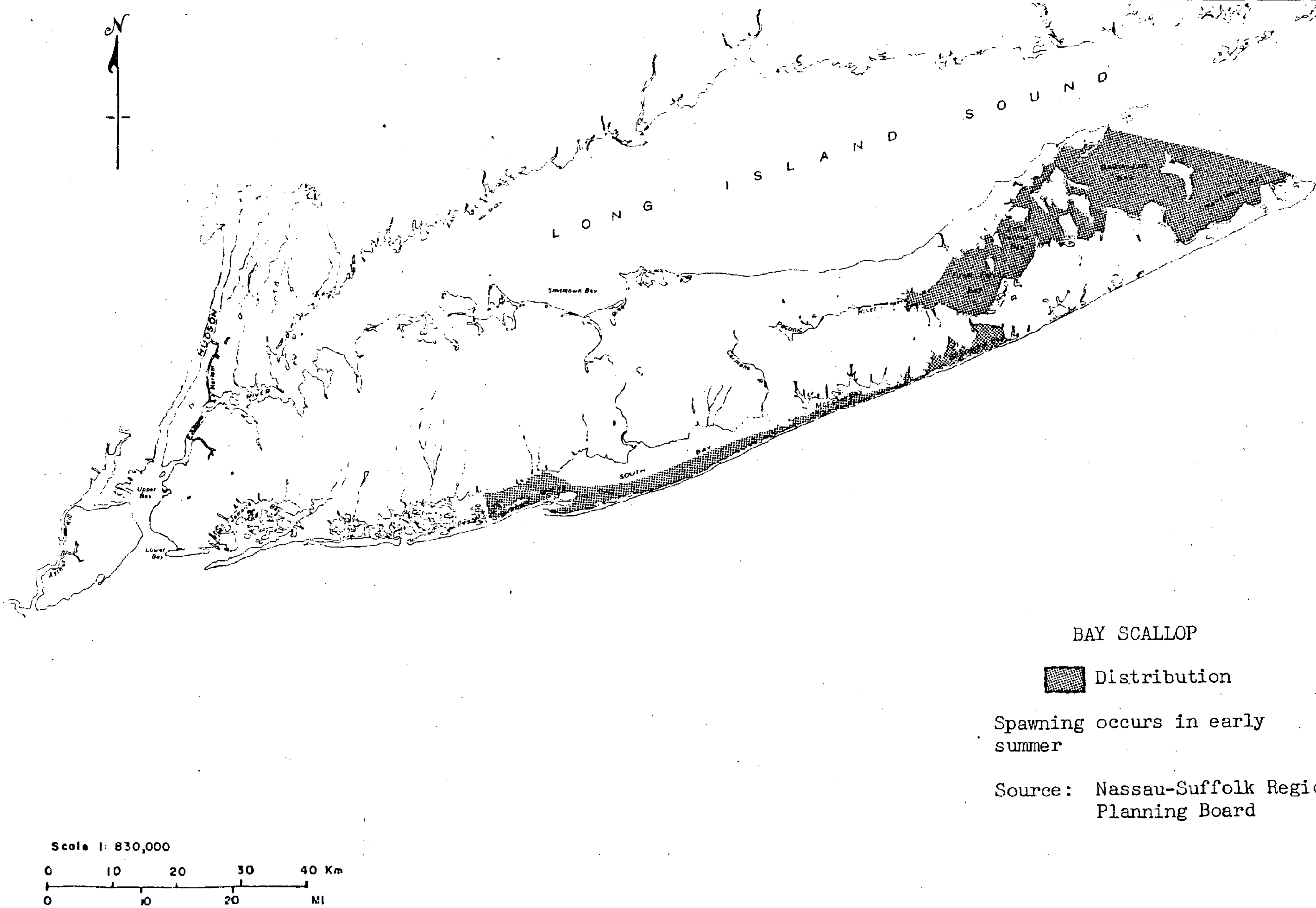
D. Bay Scallops (Aequipecten irradians)

Bay scallops inhabit a protected mud bottom which is only subject to low currents (Figure 7). It is both an intertidal and subtidal species. The current high production areas of bay scallops on Long Island occur in the Peconic Bays. There are potential high production areas located in Gardiners Bay, Shinnecock Bay, the outer edges of South Oyster Bay, Great South Bay and Moriches Bay. New York commercial landings of bay scallops in 1976 were 199 metric tons, valued at $816,000 dockside.[7]

The bay scallop spawns in early summer, spawning is usually initiated by a slight rise in temperature. Although there is no definite information on fecundity (fertility), as in other large bivalves with pelagic larvae, eggs probably number in the millions. Bay scallops mature at about two years of age, 50 to 90 mm in size.

Scallops do not migrate substantial distances despite an ability to move locally on the bottom. Bay scallops are filter feeders which feed chiefly on detritus.

Known predators of bay scallops are starfish, cod and wolf fish. Surf clams and ocean quahogs are often found in the same habitat as scallops and might be classed as competitors since they feed on the same food supply as bay scallops although there has been no evidence that such competition is serious. Sand dollars could also be considered serious competitors for both space and food.



BAY SCALLOP

Distribution

Spawning occurs in early summer

Source: Nassau-Suffolk Regional Planning Board

Bay scallops may also become tainted by large concentrations of hydrocarbons. The dependence of scallops on eelgrass (Zostera) during larval stages permits them only to recover from pollution after eelgrass does.

E. Winter Flounder (Pseudopleuronectes americanus)

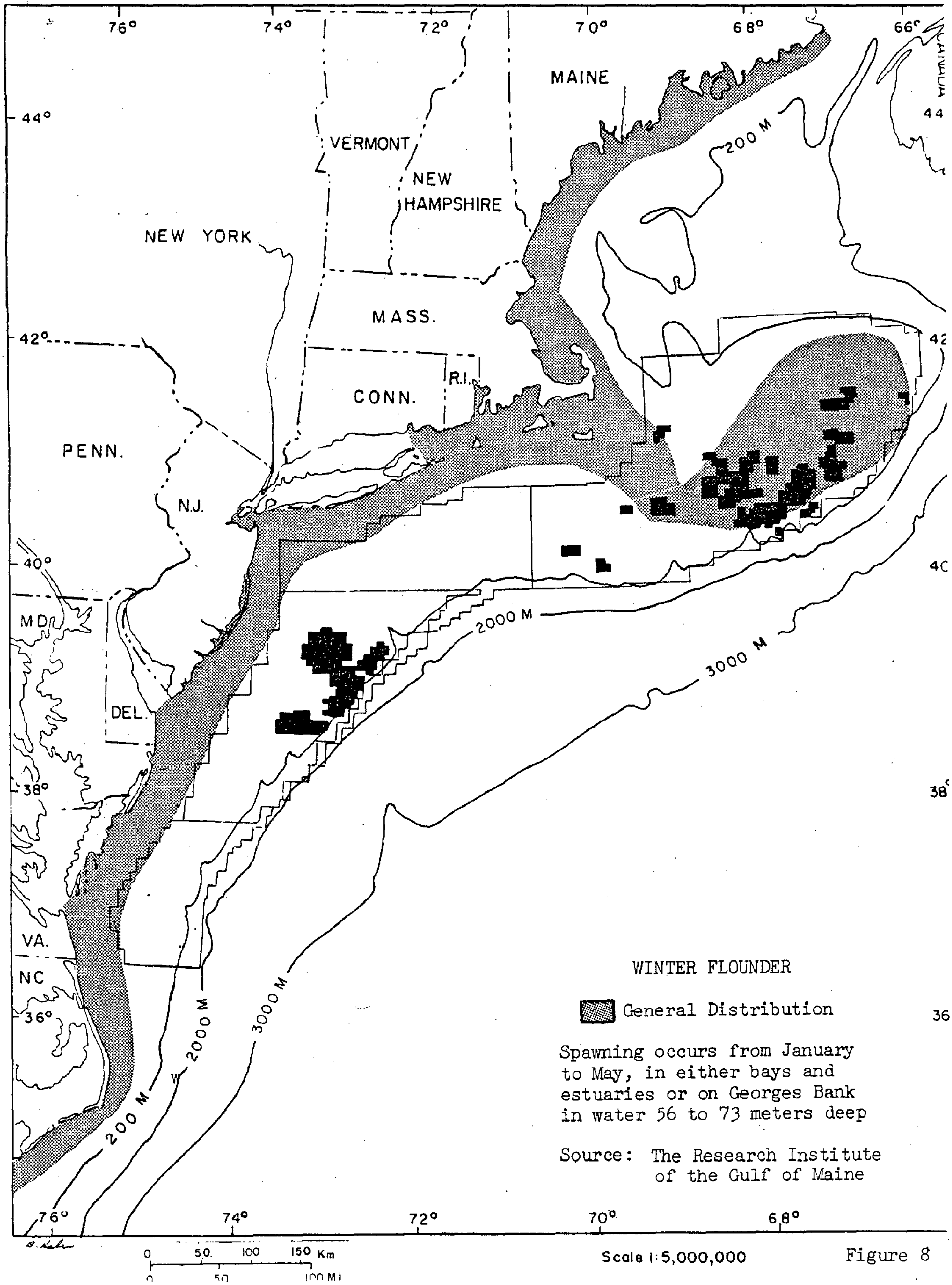
Winter flounder is a shallow water flatfish, which occurs in inshore fishing grounds to water depths of 36 meters, over soft, muddy to moderately hard bottoms. The winter flounder occurs abundantly where temperatures are 11.7-15.6°C, but can tolerate a much wider range (0°C-18°C). They are tolerant of lowered salinity and will penetrate into brackish water (Figure 8).

Winter flounder is an important commercial and recreational fish in New York State. In 1976, commercial landings of winter flounder were 323 metric tons, valued at $144,000 at the dock.[8] Data for recreational catches of winter flounder, Maine through New York, indicate recreational catches of winter flounder in the North Atlantic Region of 11,197 metric tons in 1970.[9]

Fish spawn in shallow waters from January to May, eggs sink to the bottom and adhere in clusters. Spawning often occurs in water as shallow as 2 to 5 meters. Individual females produce an average of 50,000 eggs annually. Young and larval stages of winter flounder occur in the inshore littoral zone during the spring and summer. The rate of larval growth is temperature dependent, fishes from different populations grow to different sizes.

Winter flounder is considered a nonmigratory species although low winter temperatures cause adults to shift to deeper water offshore. Young flounders, 2.5 to 11 cm long, feed chiefly on isopod crustaceans. The adult is limited by its small mouth to a diet of amphipods, isopods, marine worms, small clams, small eggs, shrimp and scavenged material.

The winter flounder is an important food item of the harbor seal, harp seal, and summer flounder. The little skate and ocean pont are competitors for food.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WINTER FLOUNDER
General Distribution
Spawning occurs from January to May, in either bays and estuaries or on Georges Bank in water 56 to 73 meters deep
Source: The Research Institute of the Gulf of Maine
0 50 100 150 Km
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Scale 1:5,000,000

Figure 8

The eggs and larvae of winter flounder are considered to be more sensitive to petroleum and petroleum products than adults. Some tainting of fish may also result. Winter flounder may sometimes perish by the thousands in very hot spills of summer weather, if they are trapped in shallow enclosed bays.

F. Mallards (Anas platyrhynchos)

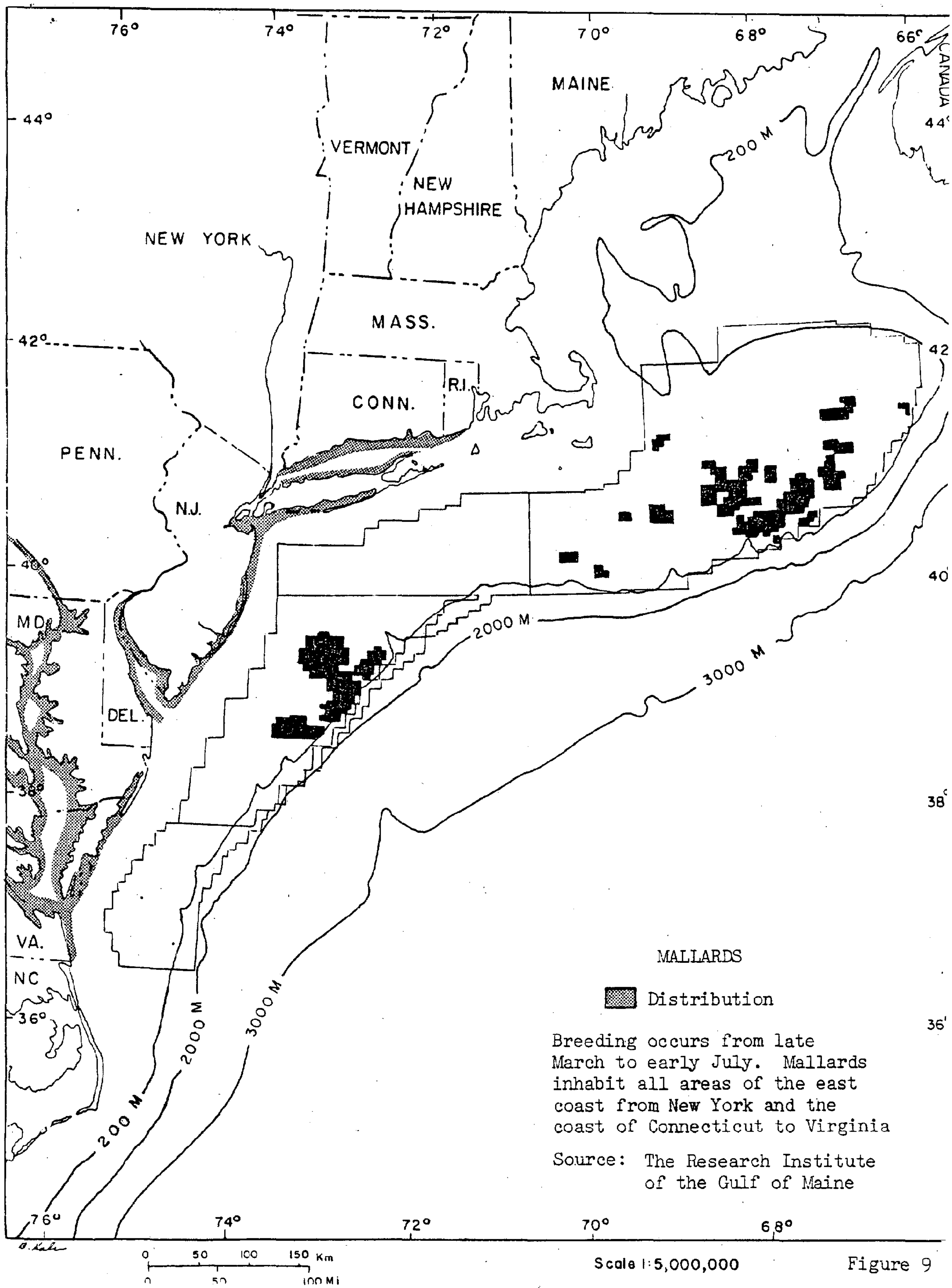
Mallards inhabit all types of freshwater as well as salt marshes and bays, feeding in shallow waters and along shores. In the New York area large populations of mallards are present in South Oyster Bay, Great South Bay, Hempstead Bay, Jamaica Bay, and Moriches Bay (Figure 9). Wintering population numbers of mallards, in the region from Northern New Jersey to Maine, were 9,491 in 1973.[10] However, populations of mallards have been increasing. It is a prime game species in New York State.

Mallards usually nest on the ground near water, well hidden among vegetation. Clutch size ranges from five to fourteen eggs. The incubation period usually lasts 26 days and the fledging period between 50 and 60 days.

The mallard exhibits a definite migration pattern in some areas of New York State. A mallard's diet is 90 percent vegetable, consisting of water plants, seeds, acorns, grains as well as insect grasshoppers, and small aquatic animals.

Predators include mammals, reptiles and human beings. Adult mortality can result from lead poisoning, disease, oiling, predation, and parasitism. Eggs are particularly vulnerable to oil spills, it can result in egg-shell thinning.

If a marsh or estuary were to be impacted by oil when large concentrations of migratory duck (mallards or black ducks) are present in spring and fall, the resulting mortalities could produce a noticeable population reduction for the species impacted. Mallards may cause additional problems when they move back into marshes which have been impacted.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MALLARDS
Distribution
Breeding occurs from late March to early July. Mallards inhabit all areas of the east coast from New York and the coast of Connecticut to Virginia
Source: The Research Institute of the Gulf of Maine
0 50 100 150 Km
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Figure 9

Black Duck (Anas rubripes)

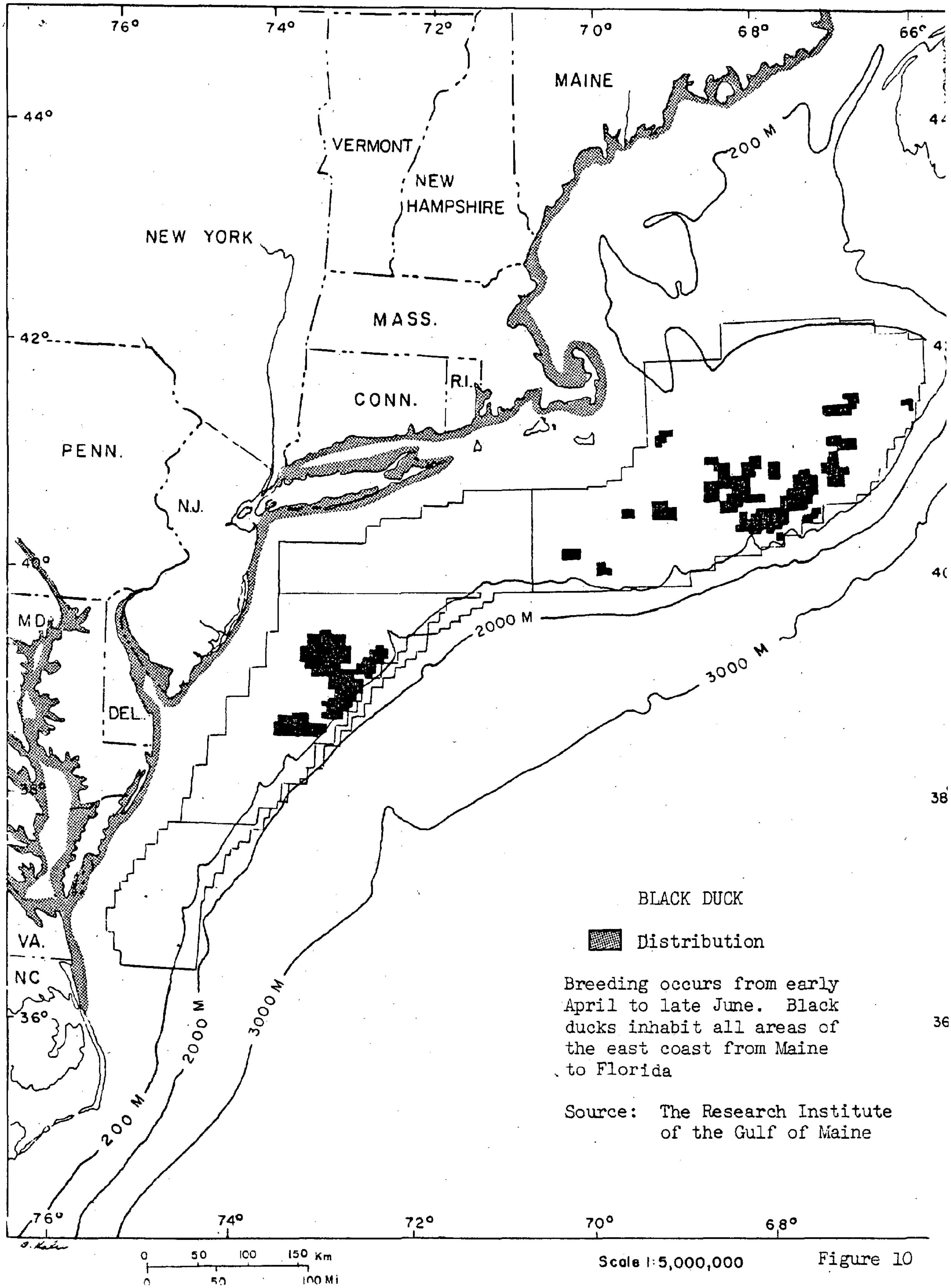
The black duck is the most common duck of Long Island's estuarine areas. It gathers in marshes, estuaries, mud flats and protected salt water (Figure 10). Wintering population numbers of black duck in the North Atlantic Region were 78,651 in 1973.[11]

The black duck nests at the edges of marshes, where eight to ten eggs are laid. The primary breeding grounds for black duck in New York State is Jamaica Bay. The black duck exhibits an incubation period of 27 days and a fledging period of between 55 and 60 days.

In New York State the black duck is an abundant migratory and mid-winter visitor, occurring in flocks even on the ocean in severe winter weather. The black diet is 75 percent vegetable and 25 percent animal, including pond weeds, grains, rice and even seaweed in winter. Black duck also feed on mussels, snails, barnacles, sand fleas, shrimp, crayfish and a few fish and their eggs.

The major predators of black duck are crows, mammals, snakes, turtles, and human beings. Adult mortality results from predation, disease, lead poisoning, oiling or parasitism.

The black duck is very vulnerable to oil spills because it spends must of its time in the water. The ducks are often found in small flocks; those flocks in an oil spill area would probably suffer a high mortality. Aquatic birds are among the most vulnerable to organisms to oil spills. Spilled petroleum and petroleum products can adversely affect aquatic birds through external exposure to surface films, internal exposure by feeding and preening, and loss of habitats or food supplies.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BLACK DUCK
Distribution
Breeding occurs from early April to late June. Black ducks inhabit all areas of the east coast from Maine to Florida
Source: The Research Institute of the Gulf of Maine
0 50 100 150 Km
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Scale 1:5,000,000

Figure 10

III. EXPOSED SHORELINES

Exposed shorelines can be considered the near-shore environment. An exposed shoreline is defined to extend from the intertidal area to a depth of 20 meters and includes two distinct habitats: sandy shores and rocky shores. The exposed, sandy shore habitat includes those areas of unconsolidated sediments ranging from cobbles through shingle to fine sand, found from the intertidal to a depth of 20 meters. The rocky shore habitat includes all shores washed by saline waters from the top of the zone wetted by spray to a depth of 20 meters with a rock substrate ranging from solid outcrops of bedrock to broken boulder beaches.

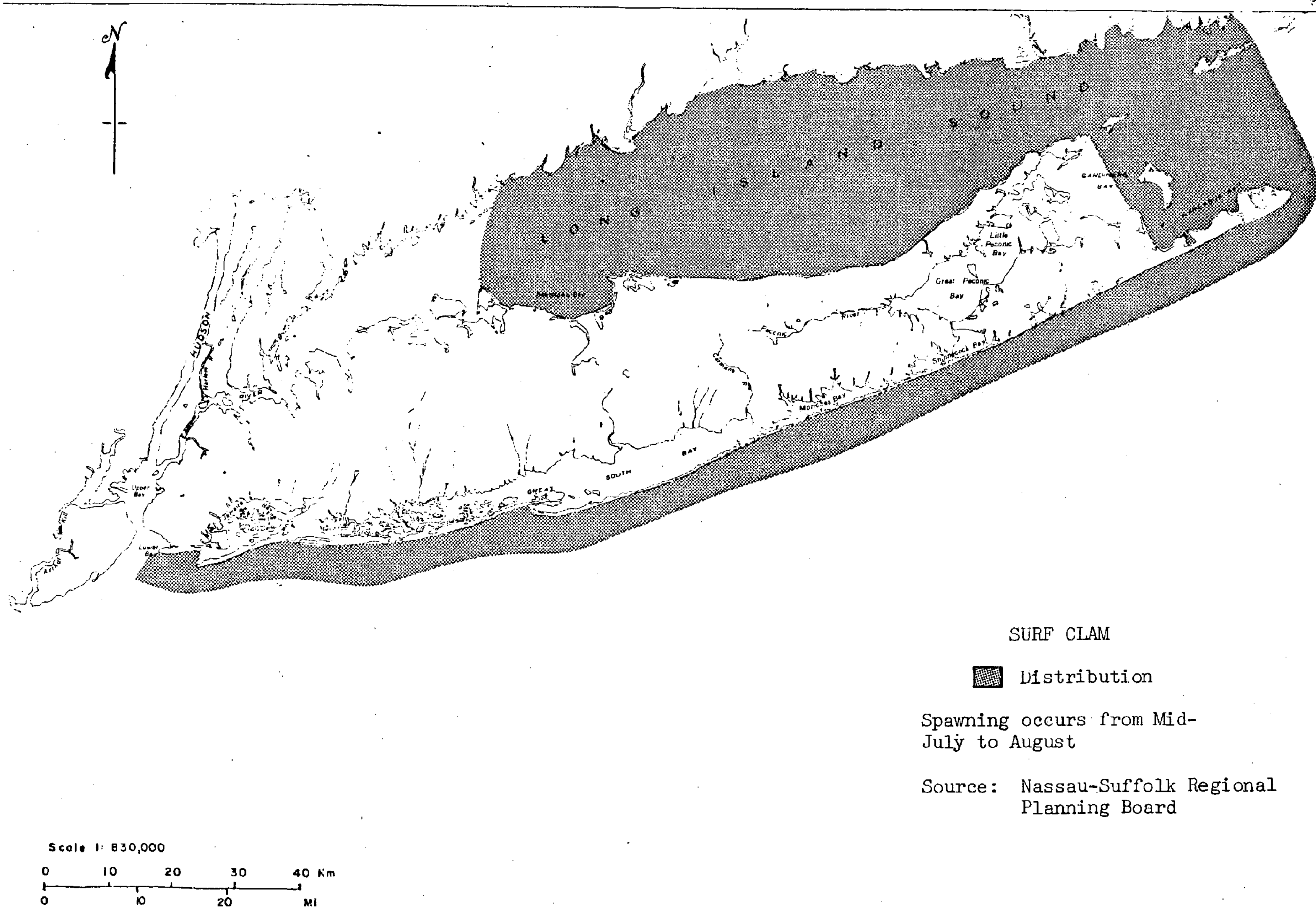
In New York State the sandy shore habitat occurs around the perimeter of Long Island and Staten Island in the ocean region. The rocky shore habitat is not found in New York State coastal waters. The benthic invertebrates and fishes considered major components of the sandy shore habitat are the surf clam (Spisula solidissima) and the striped bass (Morone saxatilis).

A. Surf Clam (Spisula solidissima)

The surf clam is an important shellfish resource occurring in Long Island Sound and Atlantic Ocean waters on sand bottoms from low water level to depths of 72 meters (Figure 11). Animals are usually found only in sand buried 2 to 20 cm below the surface. Surf clams may come to the surface and perform leaps of several feet when under stress of crowding or predator attack.

In 1976, commercial landings of surf clams in New York State were 1,567 metric tons, worth $1.1 million dockside.[12] The surf clam is second in volume landed among New York State shellfish resources. The volume of landings could be increased if water quality standards were improved enough to permit the harvest of clams off the Rockaways.

Surf clams occurring off Long Island spawn from May to late July when the temperatures reach about 15°C. The female releases about one million eggs annually. Larvae are pelagic, surf clams reach commercial size, 125 mm in about 5 to 6 years. Growth continues throughout the life span of a surf clam, they can attain a maximum size of 197 mm off Long Island.



SURF CLAM

Distribution

Spawning occurs from Mid-July to August

Source: Nassau-Suffolk Regional Planning Board

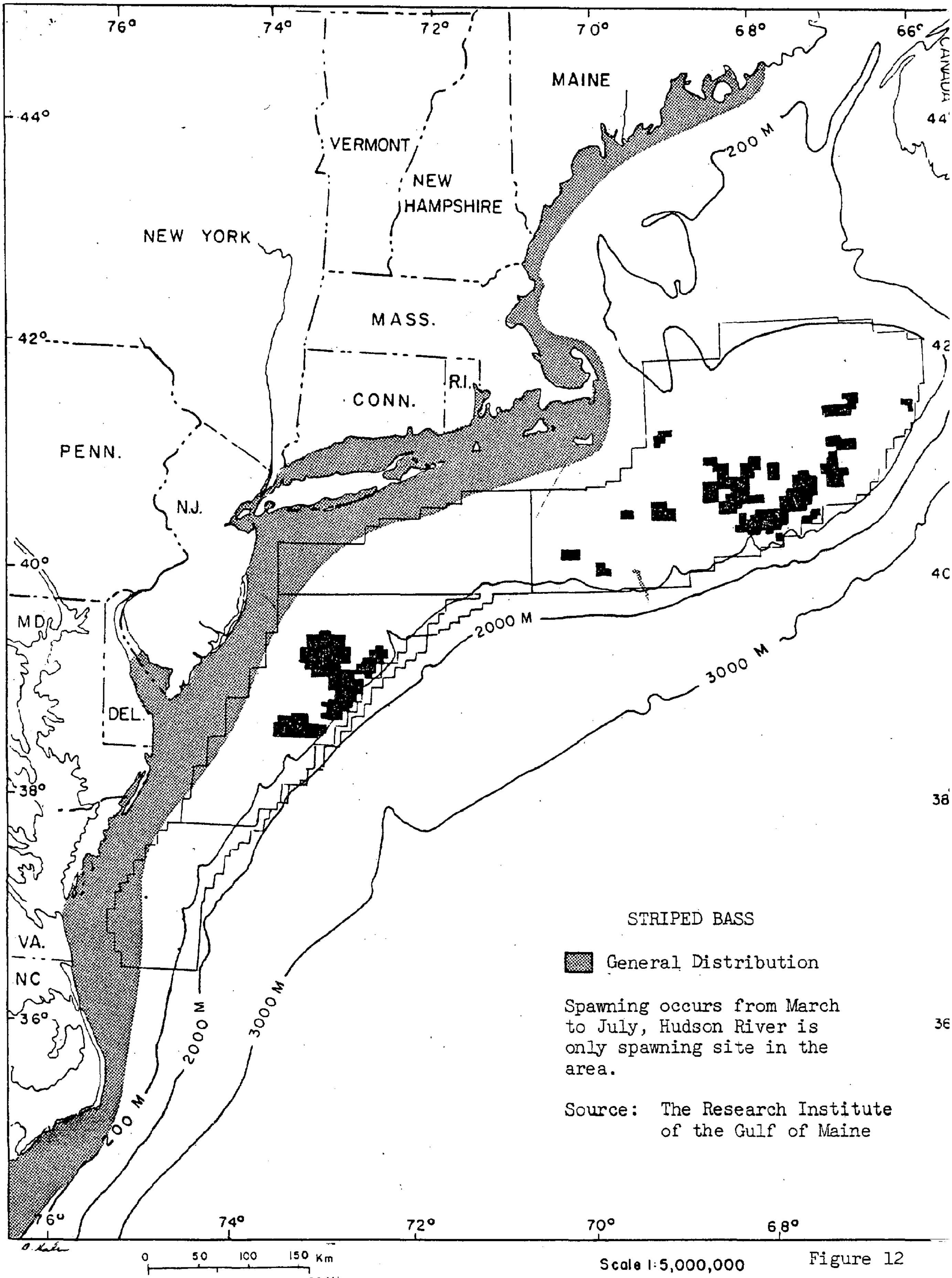
The surf clam is distributed by current dispersal of pelagic larvae. Large numbers of the surf clam sometimes appear on shore following storms. The surf clam is a filter feeder, lying near the sediment surface, extending short fused siphons into the water. Surf clams feed on suspended particulate matter and plankton.

Predators include moon snails, in shallow water and boring snails in deeper water. Smaller clams provide food for haddock, cod, and diving ducks. Competitors include the hard clam and the gem shell. The surf clam's association with the intertidal surf area of sandy beaches makes juveniles and adults vulnerable to oil pollution and cleaning agents.

B. <u>Striped Bass (Morone saxatilis)</u>

The striped bass is a large, anadromous, migrating fish which spends its entire life in coastal waters. In the New York area the striped bass prefers surf-swept beaches, or shallow bays and estuaries (Figure 12). Striped bass is a valuable commercial and sport fish. Recreational catches of striped bass in the North Atlantic Region (Maine through New York) were 20,795 metric tons in 1970.[13] In 1976, commercial landings of striped bass in New York State were 314 metric tons, valued at $422,000 at the docks.[14]

Striped bass spawn in estuaries near the head of the tide in the spring - late April and early May. The Hudson River is the primary striped bass spawning site in the North Atlantic Region. This site contributes to the essentially non-migratory stock of bass in Long Island Sound and the New York Bight. The fecundity (fertility) of a large bass is estimated at between 80,000 and 2,200,000 eggs. Eggs are semi-buoyant and sink in quiet water, but are readily spread by water currents. Fry (juveniles) reside in rivers and estuaries for about one year. All males are sexually mature by their third year, females by their sixth year. Striped bass grow to a great size, fish of 50 to 60 pounds (127-130 cm) are not exceptional.



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200 M
2000 M
3000 M
STRIPED BASS
General Distribution
Spawning occurs from March to July, Hudson River is only spawning site in the area.
Source: The Research Institute of the Gulf of Maine
0 50 100 150 Km
0 50 100 Mi
Scale 1:5,000,000

Figure 12

In the North Atlantic Region the striped bass population is migratory, except for some stock located in Long Island Sound and the New York Bight. Bass move up the coast in the spring when the water temperatures are about 8°C and return in the fall when the temperatures again reach 8°C. Striped bass are voracious feeders, eating principally fishes and invertebrates, both planktonic and benthic. Adults in the sea feed on small fish, squid, crab lobster, and sea worms. Fry feed on miscellaneous freshwater and marine invertebrates.

Man is probably the most serious predator of striped bass. Seals are also known to eat bass that are not too large. There is the potential for a very serious impact if an oil spill hit a migratory group during the spawning season. A minor threat exists during the rest of the year when the population is less densely congregated. Although relatively tolerant of temperature and salinity changes, eggs and young are susceptible to pollution in estuaries throughout the year.

IV. OFFSHORE REGION

The offshore region of New York State is comprised of two distinct habitats: plankton-based pelagic, offshore, and offshore bottom. The plankton-based pelagic habitat includes the saline water column from the shore to the edge of the Continental Shelf. The offshore bottom habitat consists of all bottom types lying under more than 20 m of water to the edge of the continental shelf.

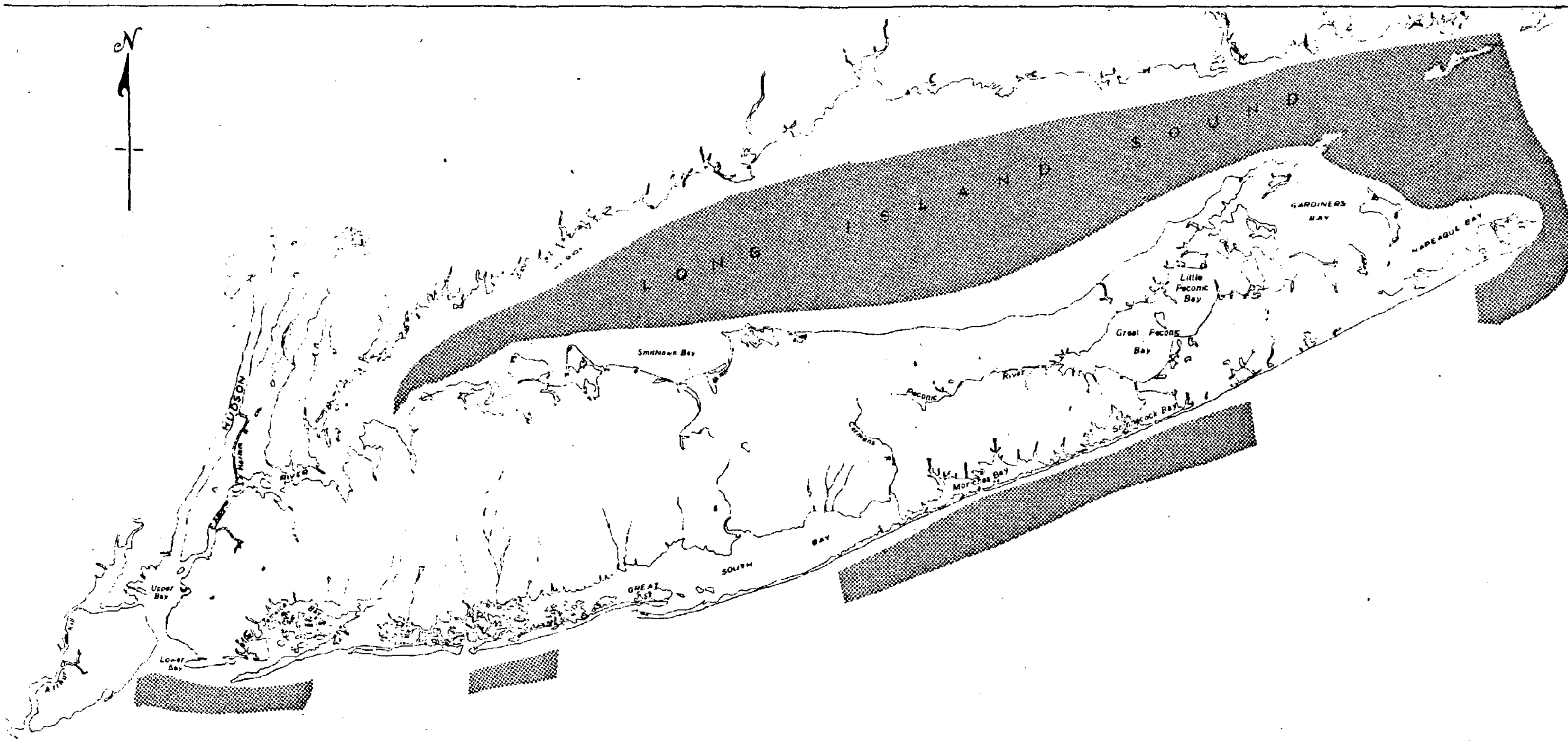
The biota of the plankton-based pelagic, offshore includes of American lobster (Homarus americanus), butterfish (Peprillus triacanthus), Atlantic menhaden (Brevoortia tyrannus), Atlantic mackeral (Scomber scombrus), and silver hake (Merluccuis bilinearis). Lobsters prefer a habitat with irregular bottoms which provide crevices in which to hide, although they frequently occur in sand or mud in which they make or find burrows. The fish species migrate from inshore to offshore areas depending on the season.

A. Plankton-Based Pelagic

1. American Lobster (Homarus americanus)

There are two major populations of lobsters: the inshore, or coastal lobsters, and the offshore Continental Shelf lobsters (figures 13a and b). In the New York area, the inshore lobsters support a commercial lobster fishery, and a sport fishery for lobster exists in some portions of Long Island Sound. Lobsters are found from Labrador to Cape Hatteras inhabiting a narrow band extending from the tide zone to a depth of 183 meters. Their entire life is spent in relatively shallow inshore areas. Commercial landings of lobsters in New York for 1976 were 270 metric tons. Landings were valued at $1.3 million at the dock, pound for pound the most valuable American fishery.[15]

The lobster breeds during July and August. The number of eggs produced by a single female depends on her age and size: a one-pound lobster produces about 10 thousand, a large 18-pound lobster about 130 thousand, about 35 percent of the eggs are lost during the incubation period. Larvae are cast into the sea when hatched and are temporarily pelagic. They swim near the



AMERICAN LOBSTER - INSHORE

Distribution

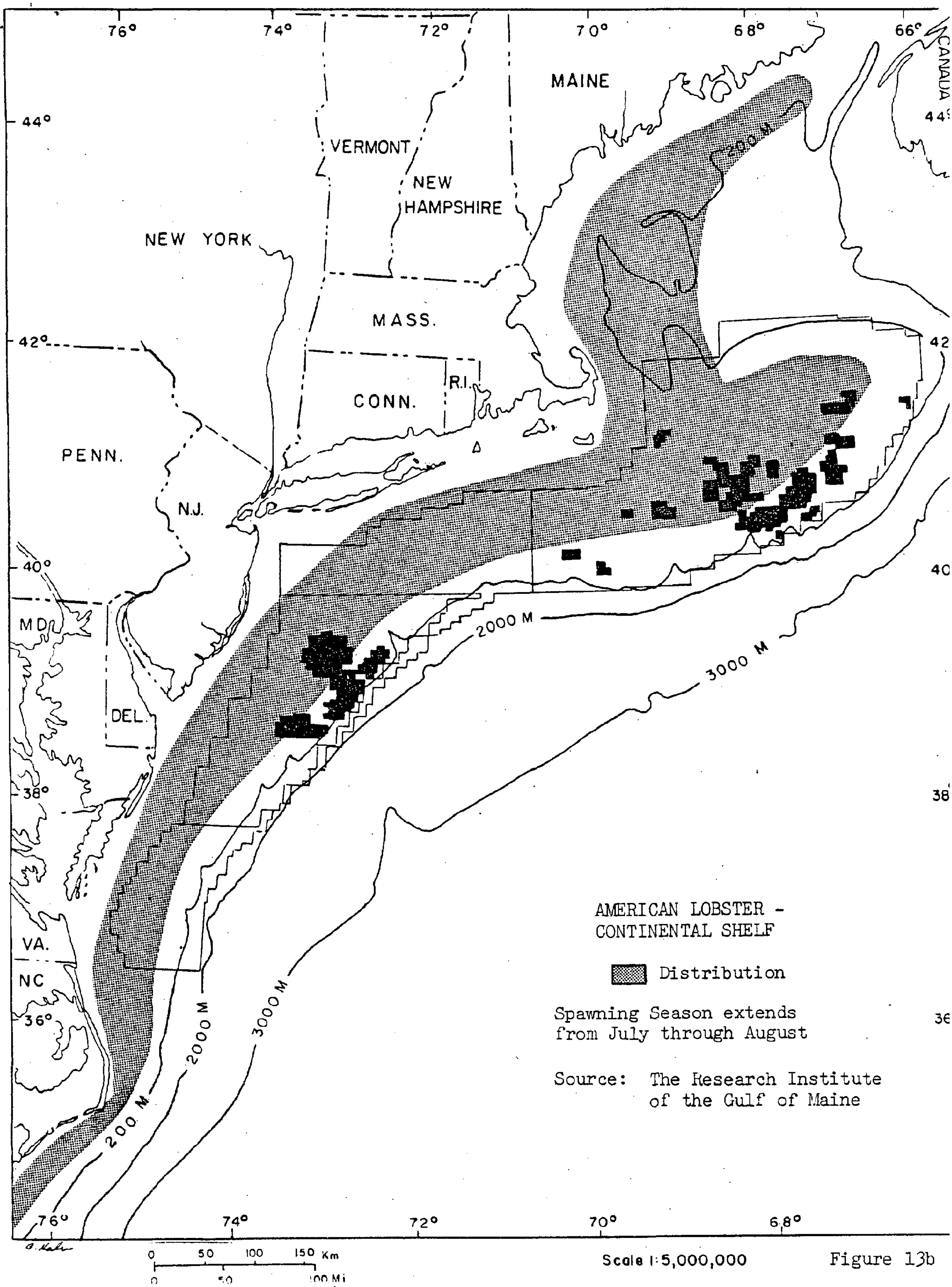
Spawning season extends from July through August

Source: Nassau-Suffolk Regional Planning Board

Scale 1: 830,000

0 10 20 30 40 Km

0 10 20 MI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200 M
2000 M
3000 M
AMERICAN LOBSTER - CONTINENTAL SHELF
Distribution
Spawning Season extends from July through August
Source: The Research Institute of the Gulf of Maine
Scale 1:5,000,000

Figure 13b

surface from 3 to 5 weeks, when they sink and are transformed into minature adults. Lobsters do not reach sexual maturity for at least 5 years. Inshore lobsters undergo limited migrations, moving randomly a few miles at the most. Continental Shelf lobsters travel greater distances, mean distances travelled varied from 28 to 80 miles. Migrations show a seasonal tendency, with onshore movements predominant in spring and early summer. Lobsters are generally scavengers feeding on fish, alive or dead, and invertebrates that come within their reach.

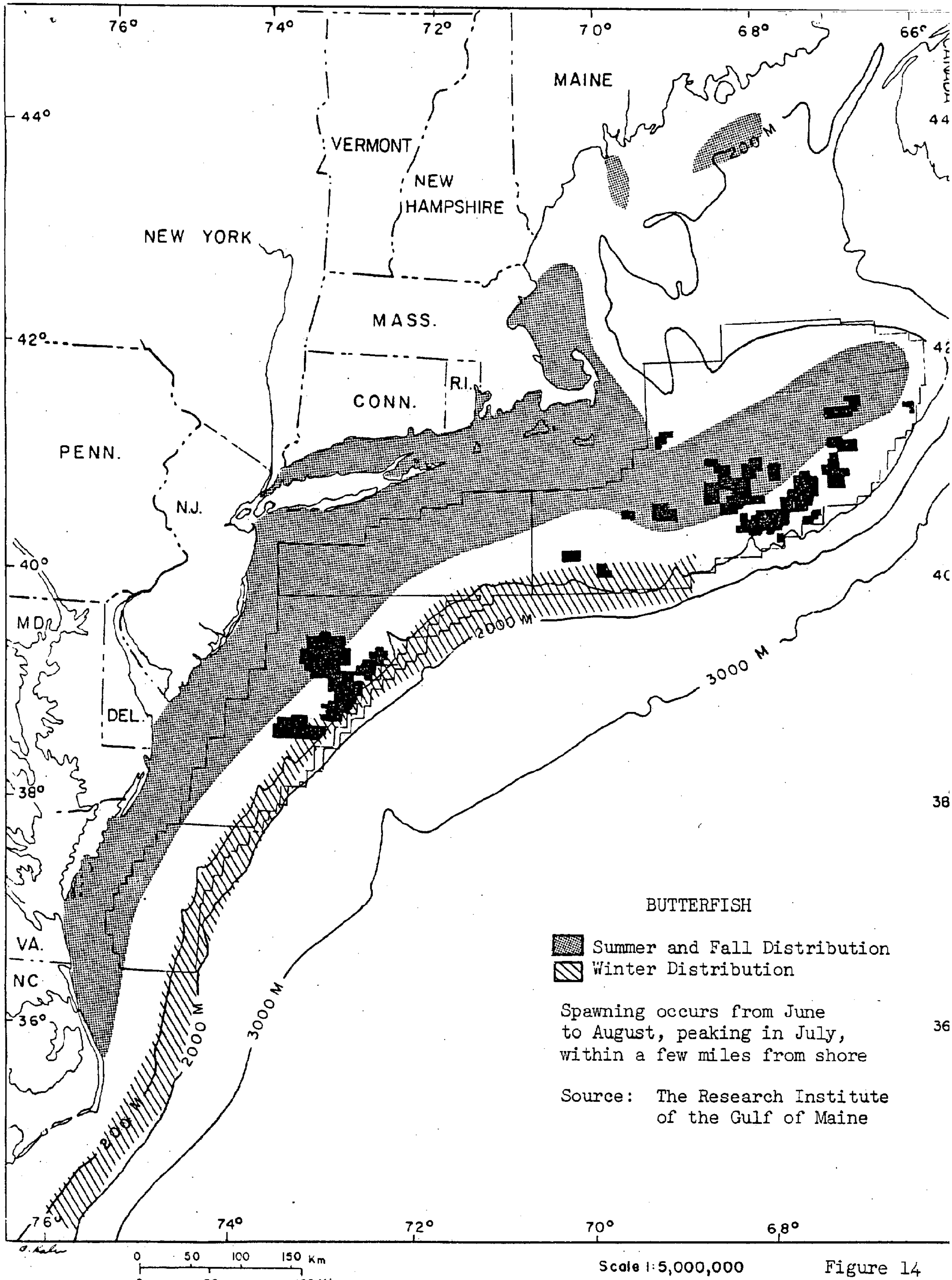
The lobster competes with other bottom carnivores and scavengers for food, and with certain burrowing crabs and fish for space. Lobsters are extremely territorial and aggressive intraspecific competition is significant. The cod, next to man, is a lobster's most destructive enemy.

Larvae, young and adults are vulnerable to oil pollution and cleaning agents along the shore. Lethal threshold concentrations for lobster larvae of crude oil emulsified in sea water ranged from .03 ml per liter to .002 ml per liter at 20-21°C. Concentrations of .01 ml per liter caused death in 9 days, and .006 ml per liter inhibited development.[16]

2. Butterfish (Peprillus triacanthus)

The butterfish is a small, pelagic which travels in small bands or loose schools. Butterfish are seldom found in waters deeper than 27 to 54 meters during the summer and prefer sandy bottoms. They often come inshore into sheltered bays and estuaries (Figure 14). In 1976, commercial landings of butterfish in New York State were 435 metric tons, worth $274,000 dockside.[17]

Butterfish spawn from June through August peaking in July. Spawning occurs a few miles from the shore, the fish return to coastal waters when they are spent. Both eggs and larvae are pelagic and it is probable that development can only proceed in comparatively warm water. At one year of age butterfish are approximately 119 millimeters in length and reach sexual maturity by age two.



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BUTTERFISH
Summer and Fall Distribution
Winter Distribution
Spawning occurs from June
to August, peaking in July,
within a few miles from shore
Source: The Research Institute
of the Gulf of Maine
0 50 100 150 Km
0 50 100 Mi
Scale 1:5,000,000

Figure 14

The butterfish exhibits a seasonal migration pattern, moving inshore in the spring and offshore in the fall to wintering grounds located at the edge of the Continental Shelf. Butterfish feed on small fish, squid, amphipods, shrimp and annelid worms.

Schools of small butterfish probably serve as forage for larger, predaceous fishes. An oil spill in butterfish spawning grounds could be fatal to eggs and larvae. Tainting of flesh could also result from exposure to petroleum products.

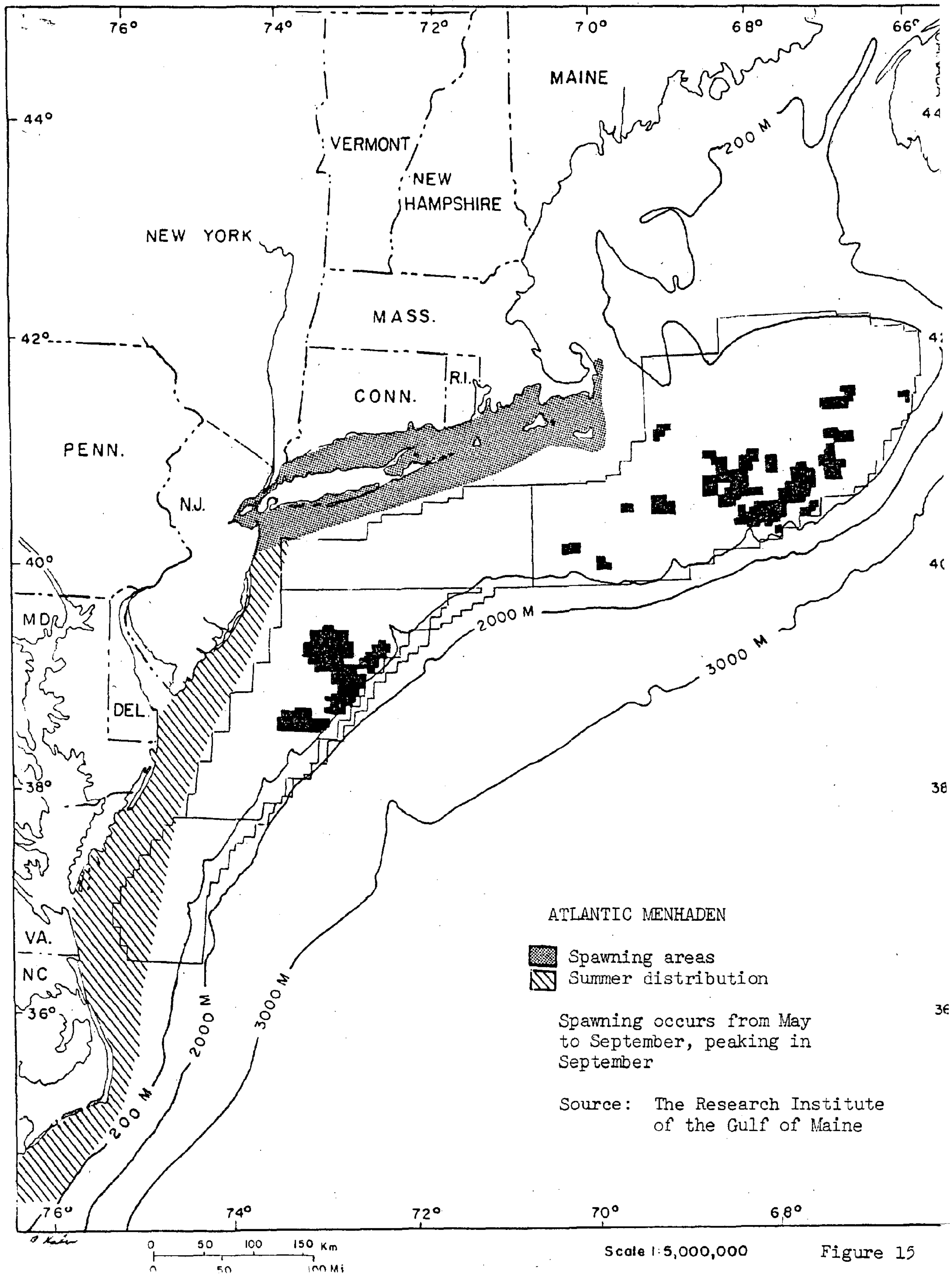
3. Atlantic Menhaden (*Brevoortia tyrannus*)

The Atlantic menhaden is a large schooling, pelagic fish generally occurring offshore. The menhaden is one of the most important commercial fishes of North America (Figure 15). In 1976, commercial landings of Atlantic menhaden in New York State totalled 460 metric tons, worth $43,000 at the dock.[18]

Spawning occurs at different times but is most intense in the ocean off New York from May to September. Depending upon length, fecundity has been estimated to range between 38,000 and 631,000 eggs per female. Eggs are pelagic and float. Shortly after hatching, juveniles congregate in estuarine nursery grounds where they stay for nearly a year before returning to the surface layers of the open ocean. Sexual maturity is reached in the third summer of life (about 9 inches long), and some fish attain an age of 8-9 years. Some may spawn twice annually.

Menhaden demonstrate a cyclical migration pattern, moving northward in the spring and early summer and southward in the fall. As the fish grow older they migrate farther northward. Menhaden are plankton feeders filtering microscopic organisms particularly diatoms from the water.

The Atlantic menhaden, swimming in schools of closely ranked individuals, helpless to protect itself, is the prey of every predaceous animal. They are preyed upon whales, porpoises, sharks, bluefish, cod and silver hake. Menhaden have little competition for food with other fishes because of its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ATLANTIC MENHADEN
Spawning areas
Summer distribution
Spawning occurs from May to September, peaking in September
Source: The Research Institute of the Gulf of Maine
0 50 100 150 Km
0 50 100 Mi
Scale 1:5,000,000

Figure 15

unique type of feeding. The prolonged (up to 1 year) estuarine life of the juveniles is the most susceptible stage to pollution.

4. Atlantic Mackerel (Scomber scombrus)

The Atlantic mackerel is a swift moving pelagic fish of the open sea, usually found in schools. The depth range of the mackerel is from the surface down to 180 meters. Mackerel are most abundant within the inner half of continental shelf during the fishing season, although their normal range does not extend oceanward beyond the upper part of the continental slope (Figure 16). New York commercial landings of mackerel totaled 109 tons in 1975, worth $40,000 at the dock.[19]

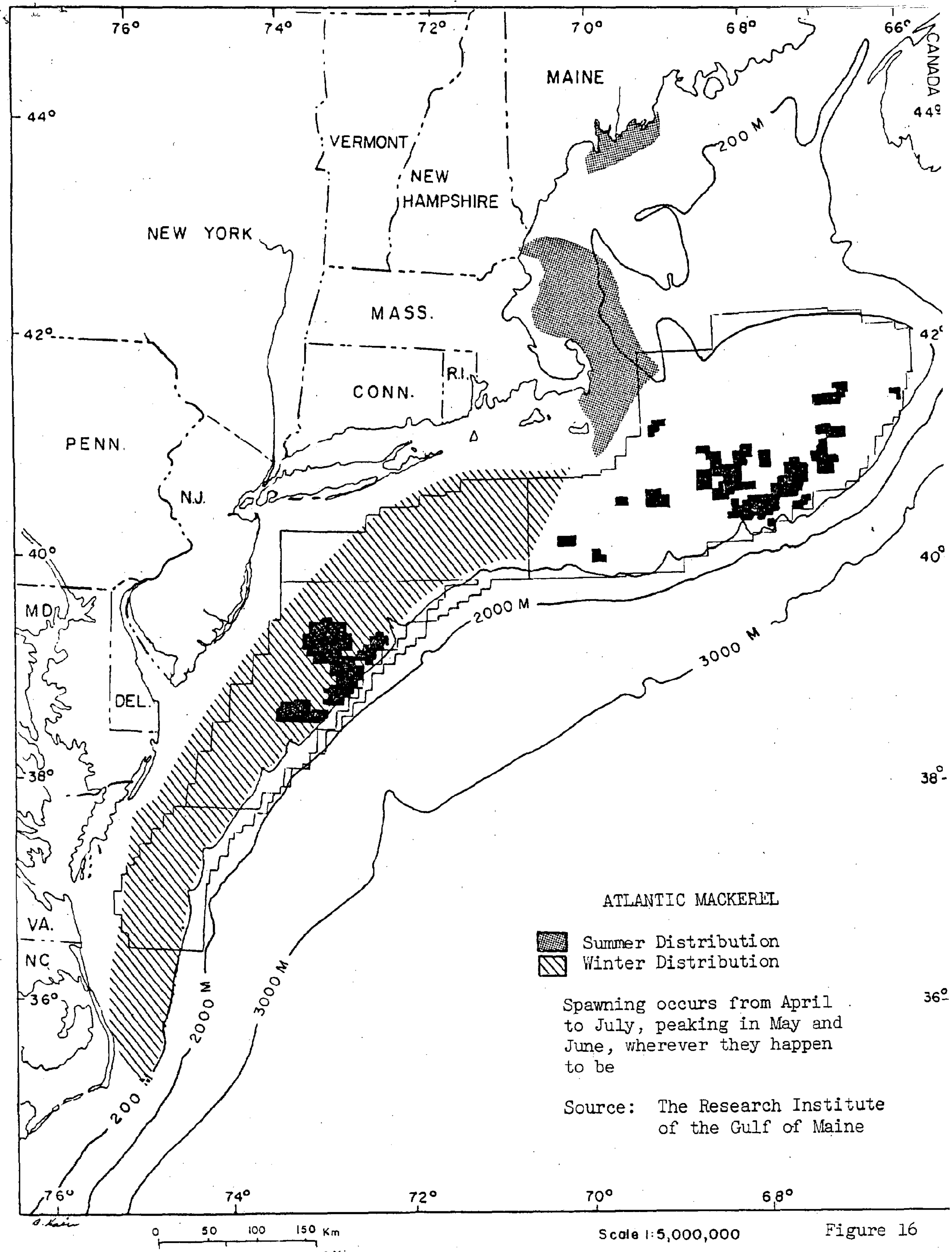
Mackerel spawn from April to July with peak spawning occurring between May and June. As schools are highly mobile and the eggs ripen in successive batches, spawning can occur over a wide area and over a long period of time. The Atlantic mackerel is moderately prolific, the average size female produces between 400,000 and 500,000 eggs. Both the eggs and larvae are planktonic (passively floating or weakly swimming). Growth is rapid until the third summer, when both sexes reach sexual maturity.

Mackerel migrations are tied in with the movements of the entire population in response to seasonal changes in water temperature. In the late fall they withdraw from the coast to spend the winter in the deeper, warmer water of the outer Continental Shelf. The diet of mackerel usually includes copepod eggs and larvae, various minute crustacea, and small fish larvae. They are capable of both selective feeding and filter feeding on plankton.

The mackerel falls easy prey to all the larger predaceous sea animals: whales, porpoises, sharks, striped bass and bluefish. Young mackerel are preyed on by squid, cod, and seabirds.

Silver Hake (Merluccius bilinearis)

The silver hake is a swift swimming, wandering fish, independent of depth within wide limits, and of the sea floor (Figure 17). Sometimes they swim



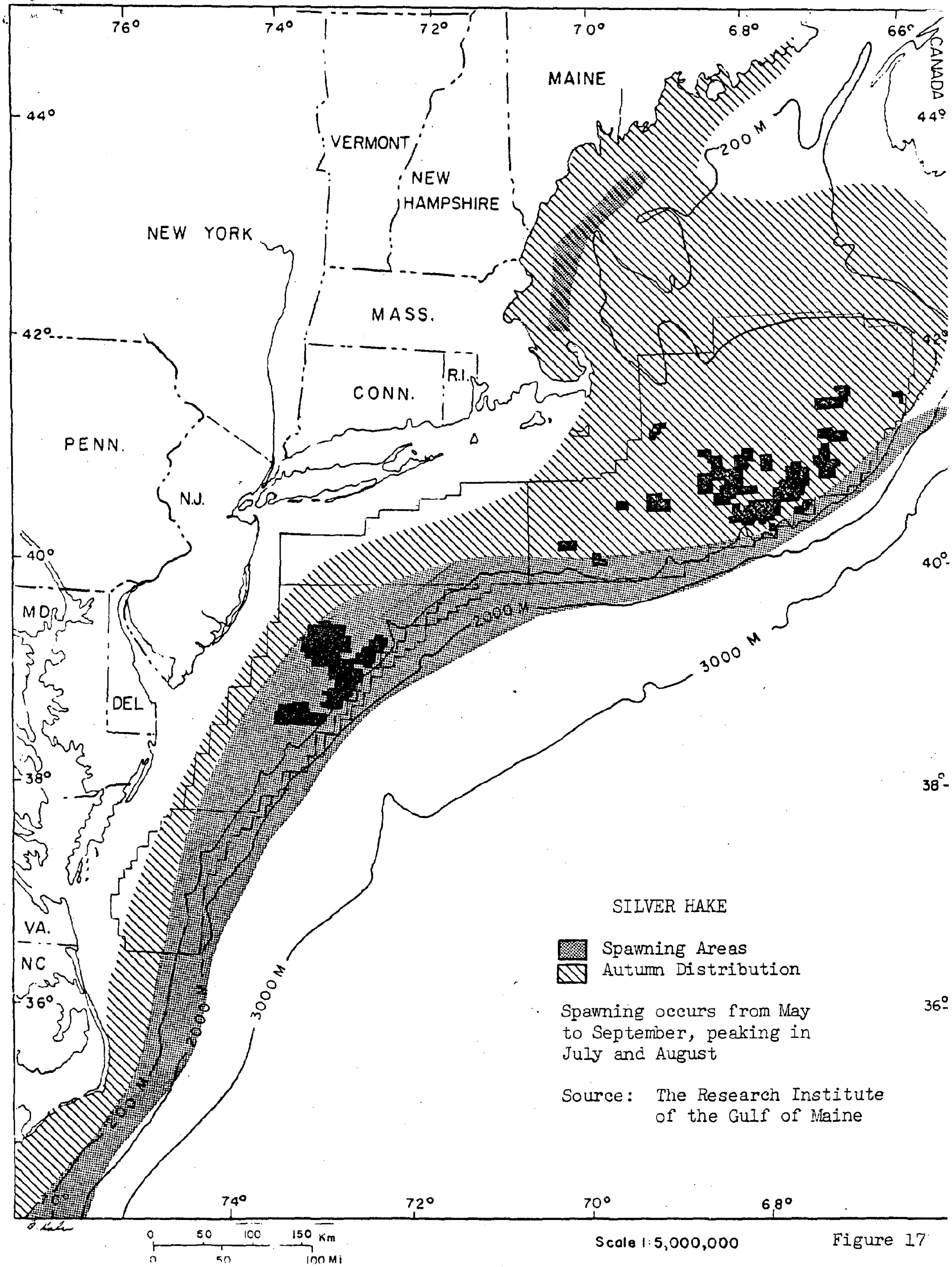
ATLANTIC MACKEREL

Summer Distribution
Winter Distribution

Spawning occurs from April to July, peaking in May and June, wherever they happen to be

Source: The Research Institute of the Gulf of Maine

Figure 16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200 M
SILVER HAKE
Spawning Areas
Autumn Distribution
Spawning occurs from May
to September, peaking in
July and August
Source: The Research Institute
of the Gulf of Maine
74°
72°
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0 50 100 150 Km
0 50 100 MI
Scale 1:5,000,000

Figure 17

close to the bottom, sometimes in the upper levels of the water, their vertical movements being governed chiefly by their pursuit of prey. In 1976, commercial landings of silver hake in New York State were 1,155 metric tons, worth $290,000 at the docks.[20]

The spawning season for silver hake extends from July through September, egg production is at its height in July and August. Spawning occurs anywhere between the surface and the bottom. Eggs of the silver hake may be spawned in low temperatures, although a comparatively warm surface layer is necessary for their later development. Both eggs and larvae are pelagic, drifting with the surface currents. Growth varies with location and females grow faster than males.

Most of the silver hake migrate from the inshore waters in the late autumn, presumably to warmer offshore wintering grounds, and return in the spring. Silver hake prey on herring and any of the other smaller schooling fish such as young mackerel, menhaden, alewives, and silversides. Juveniles feed on squid, shrimp, crabs, and clams.

Silver hake is preyed upon by larger fishes, particularly dogfish, and marine mammals. Red hake is a potential competitor of silver hake, although the diet of the red hake is different enough not to cause competition for food. Spilled oil or other hazardous substances could seriously injure the pelagic eggs, larvae, and adults when they are located in the surface waters.

B. Offshore Bottom

Many of the species present on the offshore bottom also exist in other habitats. The hard clams, soft shell clams, bay scallops, and winter flounder occupy both tidal wetlands and coastal bays, and the offshore bottom. However, these species are not significant components of the offshore bottom, they were described earlier as principal inhabitants of tidal wetlands and coastal bays. The principal biota of the offshore bottom consists of summer flounder (*Paralichthys dentatus*), scup (*Stenotomus chrysops*), and yellowtail flounder (*Limanda ferruginea*).

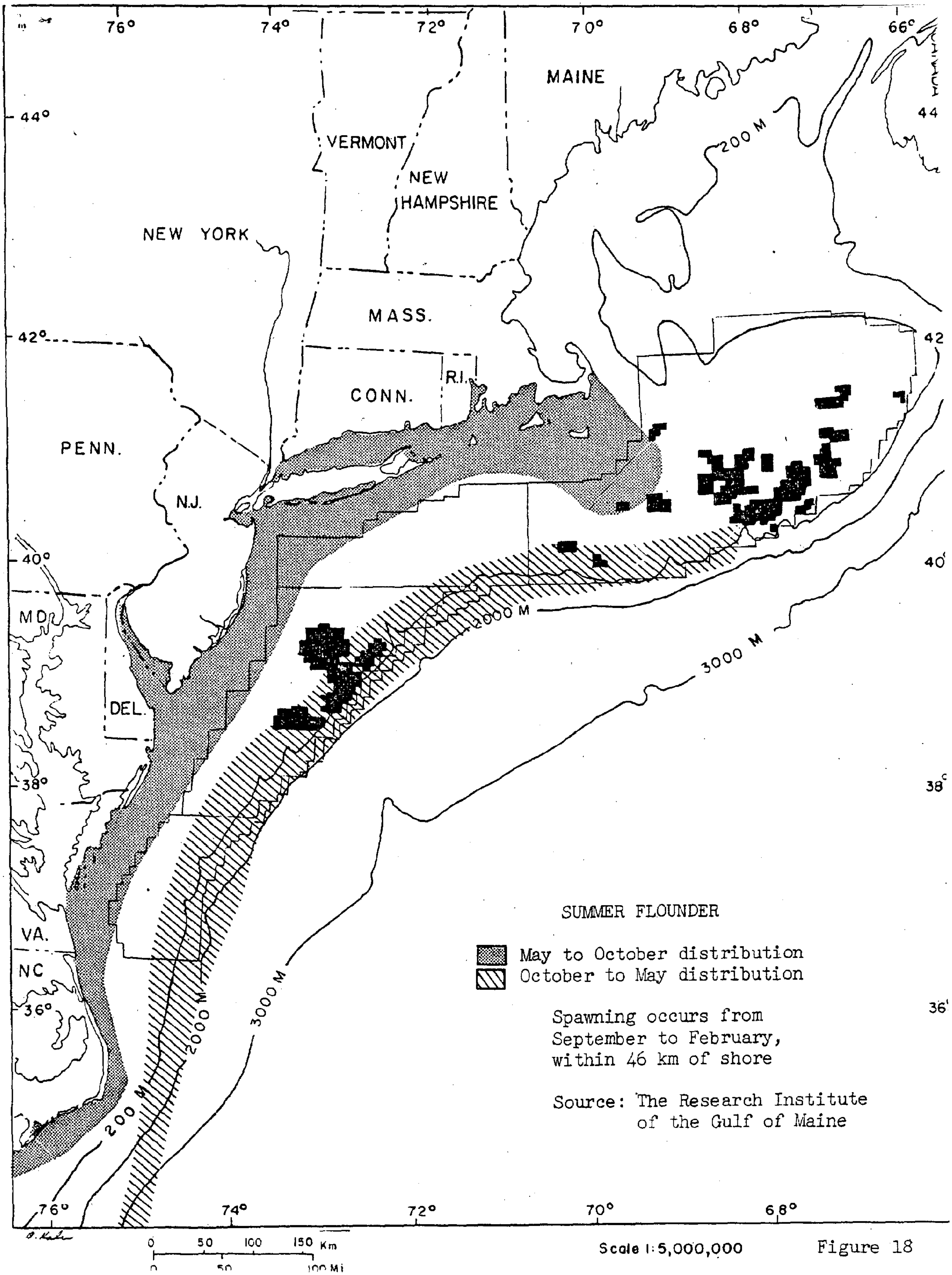
1. <u>Summer Flounder (Paralichthys dentatus)</u>

The summer flounder is a warm water flatfish that occurs most abundantly in moderate depths (18-32 meters) off New York during the summer, but winter in deeper waters off the Continental Shelf (Figure 18). During the summer months, summer flounder are common along the coast, off Sandy Hook, New Jersey and in Long Island bays, where they may be taken by sportsmen fishing from the shore. In 1976, commercial landings of summer flounder in New York State were 1,454 metric tons, valued at $1.5 million dockside.[21] Recreational catches of summer flounder for the North Atlantic Region (which includes New York) were 5,267 metric tons in 1970.[22]

Spawning occurs in late fall to early spring, normally in early September off New York. Year to year variations in the location of peaks in egg abundance suggest that bottom temperature may determine spawning ground locations. Summer flounder are dependent upon coastal bays (nearshore areas) as nursery areas. The small size and pelagic habitat of summer flounder eggs suggest that it is a high fecundity species, eggs per female probably number in the tens of thousands. First maturity for both sexes usually occurs at approximately one year of age. Juveniles attain lengths of 21-24 cm at the end of the first year.

The summer flounder exhibits a seasonal inshore-offshore migration, appearing inshore in May and moving to deeper, warmer waters in October. The summer flounder is a predaceous fish, very fierce and active in pursuit of prey. The diet of a summer flounder consists of various species of smaller fish, squid, crab, shrimp, small-shelled mollusks, worms and sand dollars. Summer flounder located in Great South Bay feed mainly on sand shrimp and winter flounder.

Summer flounder are preyed upon by marine mammals. Man can be considered a major predator since summer flounder catches contribute significantly to New York State recreational and commercial landings.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SUMMER FLOUNDER
May to October distribution
October to May distribution
Spawning occurs from September to February, within 46 km of shore
Source: The Research Institute of the Gulf of Maine
0 50 100 150 Km
0 50 100 Mi
Scale 1:5,000,000

Figure 18

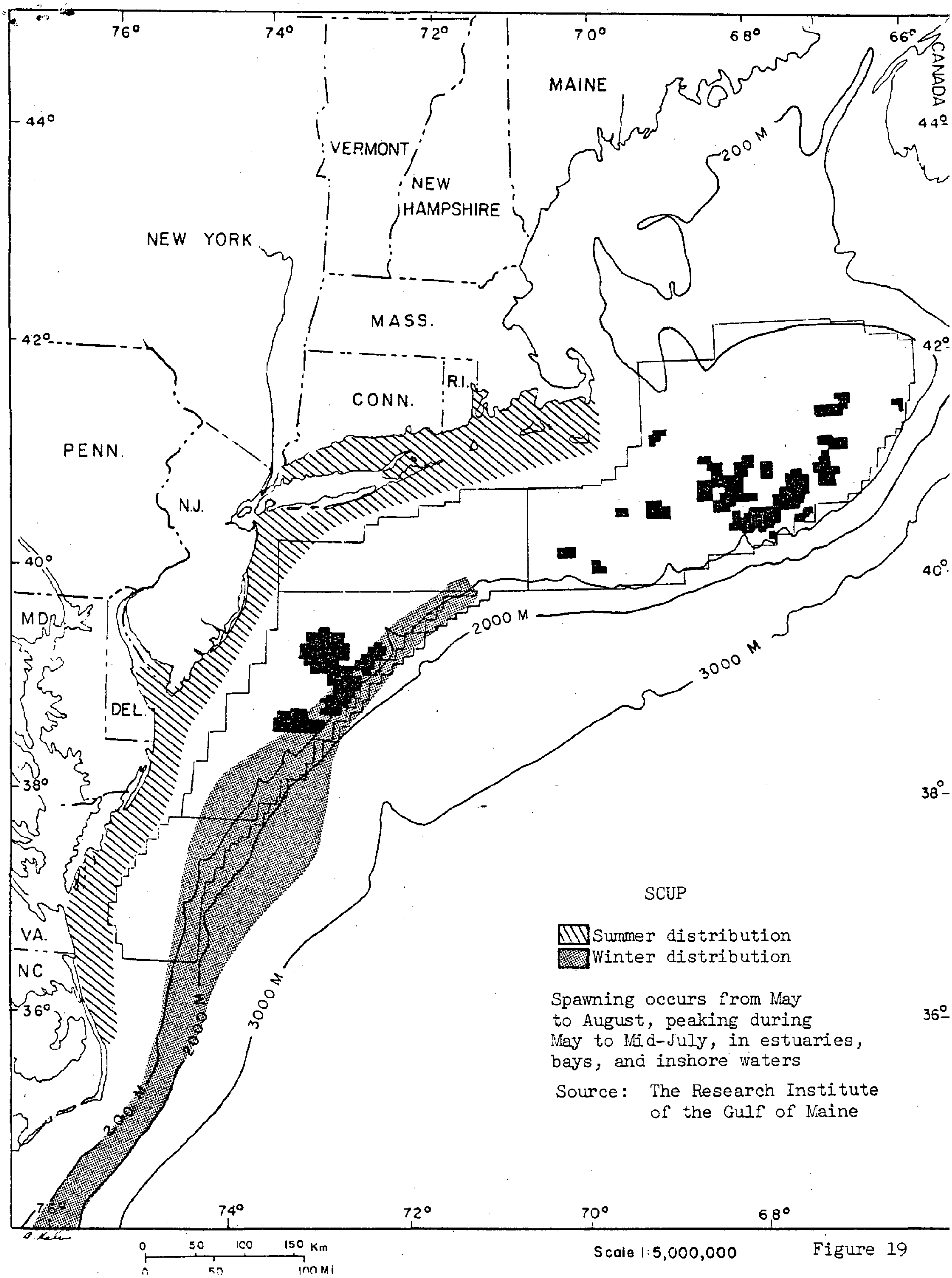
Juvenile flounders, occurring in inshore areas, are most susceptible to pollution from oil and dispersing agents. Growth in juvenile flounders is influenced by salinity, optimum growth occurring in the lower reaches of estuaries.

2. Scup (Stenotomus chrysops)

The scup occurs inshore in schools during the summer and offshore to depth of 126 meters during the winter. Scup are widely distributed along the Atlantic Coast although they prefer smooth or rocky bottoms and have relatively narrow temperature and salinity requirements (Figure 19). The scup is a valuable commercial and sport fish south of Cape Cod; the most important sport fish in tidal areas of New York. Recreational catches of scup in the North Atlantic Region for 1970 were 1,041 metric tons. Commercial landings of scup in New York State for 1976 were 1119 metric tons, worth $580,000 at the dock.[24] Data gathered by the New York State Department of Environmental Conservation indicates that the scup constitutes between 30 and 45 percent of the recreational catches in nearshore waters of eastern Long Island.[25]

Spawning takes place in inshore areas from May to August, peaking in June. They spawn in inshore areas: estuaries and bays, primarily south of Cape Cod. The shallow waters adjacent to wetlands serve as nursery areas. Scup eggs and larvae have been observed in Long Island Sound, Peconic Bay, and Gardiner's Bay. Eggs are buoyant and disseminated by current. Both sexes of scup reach sexual maturity at two years of age. Scup reach the minimum size limit required of a commercial catch, 17.8 centimeters, by 2½ years of age.

Scup exhibit a seasonal migration pattern. They winter depths of 82 to 137 meters offshore, returning in May to inshore areas (from shore to 37 meters). Scup are largely bottom feeders, preying upon invertebrates such as amphipods, marine worms and young squid.



SCUP

Summer distribution
Winter distribution

Spawning occurs from May
to August, peaking during
May to Mid-July, in estuaries,
bays, and inshore waters

Source: The Research Institute
of the Gulf of Maine

Figure 19

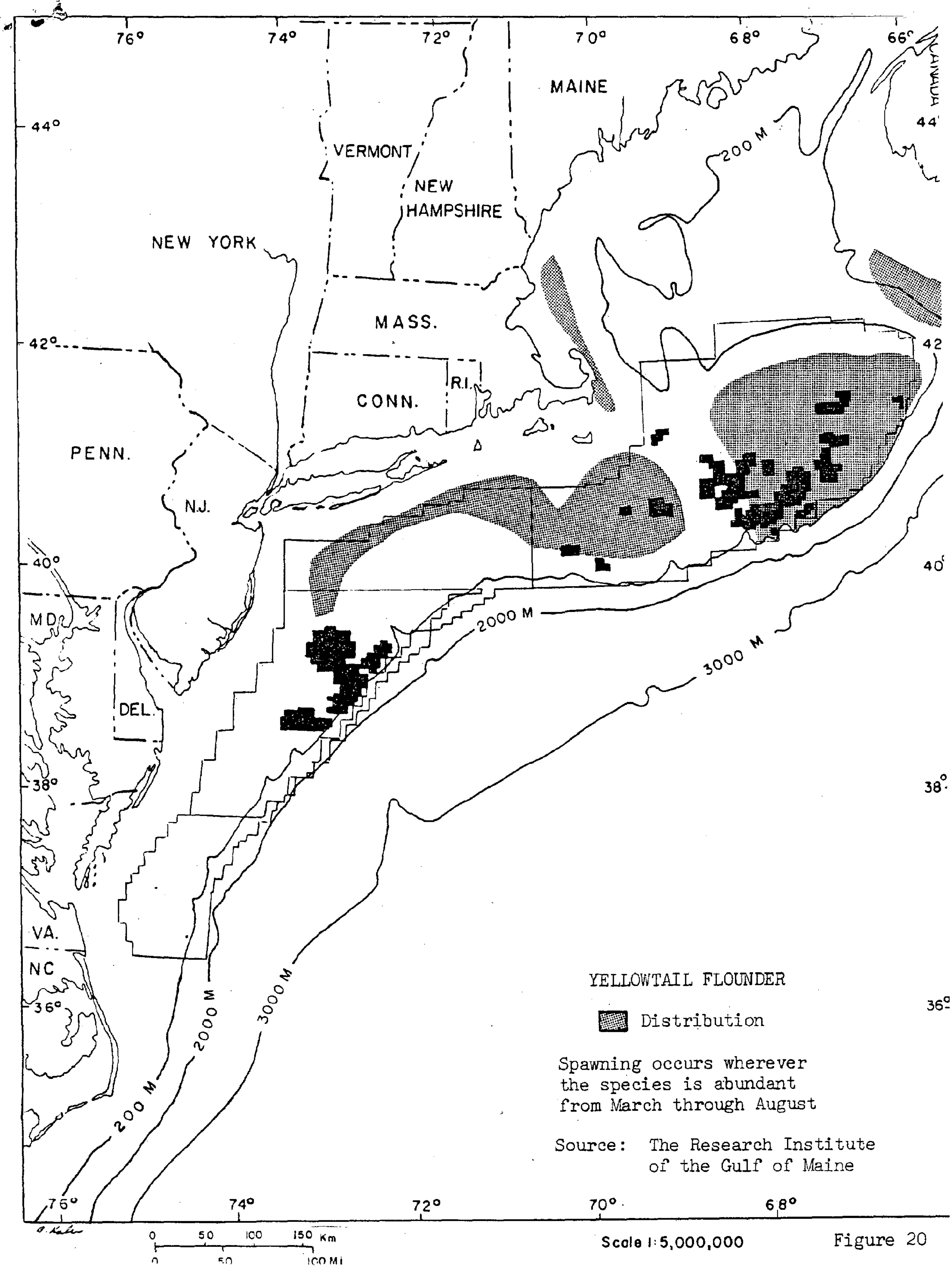
The major predators of scup are marine mammals and man. The species availability of scup fluctuates widely due to natural causes, therefore scup would be most vulnerable to detrimental environmental changes and heavy fishing pressure during years when general populations have already been reduced to low levels by natural causes. The low population levels have probably been a result of poor spawning success.

3. Yellowtail Flounder (*Limanda ferruginea*)

The yellowtail flounder is a shallow water flatfish which occurs on the continental shelf. The center of distribution of yellowtail flounder extends from Montauk Point to southern Massachusetts Bay and Georges Bank, in water between 10 and 72 meters deep. Almost any sandy bottom or mixture of sand and mud suits them (Figure 20). Commercial concentrations of yellowtail flounder usually occur in water between 46 to 64 meters deep. During 1976, New York State commercial landings of yellowtail flounder totaled 279 metric tons, valued at $168,000 dockside.[26]

The yellowtail flounder has a protracted spawning seasoning, spawning wherever it is abundant from March through August. The onset of spawning activities in any population is probably loosely associated with spring warming of shelf waters, yellowtail spawning is relatively insensitive to temperature between 1 and 12°C. In any mature female (3 or 4 years old) not all eggs ripen simultaneously, rather small batches of eggs ripen throughout the spawning season. Both eggs and larvae of yellowtail flounder are pelagic, drifting with the currents. The yellowtail grows to a length of about 12 centimeters by the time it is one year old.

The yellowtail flounder is a stationary species, there is no reason to suppose that it travels about much after it once takes to the bottom. However, yellowtail flounder have been described, in Massachusetts Bay, as inhabiting the deep water in summer, and approaching the shores in winter, as do various other ground fishes that tend to avoid high temperatures.



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YELLOWTAIL FLOUNDER
Distribution
Spawning occurs wherever the species is abundant from March through August
Source: The Research Institute of the Gulf of Maine
0 50 100 150 Km
0 50 100 Mi
Scale 1:5,000,000

Figure 20

Yellowtail flounder are a stationary species, spending the entire year on their normal grounds. The yellowtail flounder feeds chiefly on the smaller crustaceans such as amphipods, shrimps and mysids, small shellfish, and worms. Yellowtail are also known to eat small fish, but as one of the more sluggish flatfishes they probably do not catch fish too often.

Predators of yellowtail flounder include the larger predaceous fish, marine mammals, and man. Toxic effects on yellowtail flounder may result through the incorporation of petroleum derived hydrocarbons into the food chain.

V. BIOLOGICAL SENSITIVITY OF CRITICAL NATURAL RESOURCES TO PETROLEUM CONTAMINATION

Pollution of the marine environment by oil is a worldwide problem of growing concern to many nations. The impact of oil on the marine environment is governed by physical, chemical, and biological factors in addition to the inherent complexity of crude oil and refined products. Biological damage caused by a spill is affected by the type of oil spilled (Table 1), dose of oil, physiography of the spill area, weather conditions at the time of the spill, biota of the area, season of the spill, previous exposure of the area to oil, exposure to other pollutants, and treatment of the spill.

The effects of oil pollution on different organisms in various habitats may vary from no effect to responses of avoidance and decreased activity and nonadaptive responses of physiological stress and panic (Table 2). Lethal toxicity can occur when hydrocarbons interfere directly with cellular and subcellular processes, particularly membrane activities. Sublethal effects may also involve cellular and physiological effects, although these effects do not produce immediate death. They can however, ultimately affect survival of individual organisms, local population dynamics, and the dynamic equilibrium of biotic communities. Sublethal effects could also include disrupted or abnormal behavior, higher susceptibility to disease, reduced photosynthesis, and reduced fertility.

What kills one species may have little or no effect on another. Individuals within a species may also be affected differently, certain life stages i.e. eggs, hatches larvae, and newly molted individuals may have varying sensitivity to similar pollution levels (Table 3).

The potential damage, which could occur to benthic invertebrates, fish and waterfowl, resulting from pollution by crude oil and oil fractions include:

(1) Direct lethal toxicity of organisms through coating and asphyxiation.

(2) Direct lethal toxicity through contact poisoning of organisms.

(3) Direct lethal toxicity through exposure to the water-soluble toxic components of oil at same distance in space and time from the accident.

Table 1

Toxicity of Soluble Aromatics*

Class of Organisms	Estimated Concentration (ppm) of Soluble Aromatics Causing Toxicity	Estimated Amount (ppm) of Petroleum Substances Containing Equivalent Amount of Soluble Aromatics	
		#2 Fuel Oil	Fresh Crude
Finfish	5-50	25-250	10^4-10^5
Larvae (all species)	0.1-1.0	0.5-5	10^2-10^3
Pelagic crustaceans	1-10	5-50	10^3-10^4
Bivalves (clams, scallops, oysters)	5-50	25-250	10^4-10^5
Benthic crustaceans (lobsters)	1-10	0.1-10	10^3-10^4
Other benthic invertebrates (worms, etc.)	1-10	5-50	10^3-10^4
Flora	10-100	50-500	10^4-10^5

*United States Congress, Office of Technology Assessment, Coastal Effects of Offshore Energy Systems, Volume II: Working Papers

Table 2

Effects of Oil on Organisms

Oil Fraction Causing Response	Effect	Response: Cellular	Physiological	Behavior
Lower boiling aromatics	direct lethal toxicity	X	X	
Lower boiling aromatics	sublethal effects		X	X
Residual	coating with oil		X	X
Possibly all fractions	Incorporation of oil into food webs	X	X	
Residual	Changes in Habitat		X	X

Moore, S.F. "Towards a model of the effects of oil on marine organisms," Background papers for a workshop on inputs, fates, and effects of petroleum in the marine environment (Airlie, Virginia: May 21-23, 1973) pp. 635-653.

Table 3
Effects of Oil on Selected Species

Major Species	Location	Life Cycle Sensitivity	Time of Year Most Vulnerable	Nature of Effects Caused by Oil Spills
American oyster	estuaries, lower tidal zone to about 18 meters	larvae stages, disrupts feeding, vulnerable in all stages as a sedentary species	late June to late August	turbidity (0.1 gram of silt per liter of seawater) reduced the feeding rate in adults by 47%; 5-50ppm oil toxic, 200ppm has caused a 50% mortality in one week
Hard-shell clam	estuaries, protected areas of intertidal zone	vulnerable in all stages as a sedentary species	entire year	tainting of flesh, 10 to 100 ppm lethal, disruption of habitat
Soft-shell clam	estuaries and protected areas of the intertidal zone	vulnerable in all stages as a sedentary species	entire year	changes in habitat such as shifting sands, smothering silt and too rapid currents are detrimental; tainting can occur, 10-100 ppm lethal
Bay scallops	intertidal and subtidal	vulnerable in all stages as a sedentary species	entire year	oil concentrations reduces respiration, 10-100 ppm lethal, tainting
Surf clam	on sand bottoms from low water level to 72 meter water depths	Juveniles and adults	entire year	10-100 ppm lethal, tainting can occur, cleansing agents and could concentrate oil through food chain as a filter feeder
American lobster	relatively shallow inshore areas from tide zone to depths of 183 meters	larvae young and adults are vulnerable to oil pollution and cleaning agents along the shore	July and August	concentrations of .01 ml per liter caused death in 9 days and .006 ml per liter inhibited development; 100 ppm lethal to all larval stages
Butterfish	seldom found in waters deeper than 27 to 54 m, often come inshore into sheltered bays and estuaries	eggs and larvae	June through August	concentrations in excess of 0.1 ppm lethal to eggs and larvae, tainting of flesh
Winter Flounder	inshore fishing grounds to water depths of 36m	eggs and larvae	January to May	tainting, concentrations in excess of 0.1 ppm could be lethal to eggs and larvae, may perish in the thousands if trapped in shallow enclosed bays during hot weather

Major Species	Location	Life Cycle Sensitivity	Time of Year	Nature of Effects Caused by OCS Operations
Striped Bass	surf swept beaches, or shallow bays and estuaries	eggs and young migratory group during spawning season	late April and early May	concentrations in excess of 0.1 ppm in estuaries would be lethal to eggs, a year class could be wiped out if a spill hit a migratory group during spawning season
Atlantic menhaden	offshore, estuarine nursery grounds	juveniles up to one year of age	May to September	concentrate oil through food supply, possible tainting of flesh, concentration of 500 ppb or higher delay embryonic development
Atlantic mackerel	inner half of continental shelf, depth range from surface down to 180m	eggs and larvae, feeding behavior	April to July	through food supply, can cause tainting of flesh, concentrations in excess of 0.1 ppm lethal to larvae
Silver hake	coastal waters, wide depth limits	eggs, larvae, adults	July through September	concentrations in excess of 0.1 ppm would be lethal to eggs and larvae located in surface waters tainting of flesh
Summer flounder	most abundant in moderate depths (18-32 meters)	juveniles	early September	larvae are extremely vulnerable to oil spills - concentrations in excess of 0.1 ppm are lethal, disrupts physiological activity
Scup	inshore in schools in summer, offshore to 126 meter depths in winter	entire life cycle, most vulnerable as eggs and larvae	May to August	concentrations in excess of 0.1 ppm lethal to larvae and young, tainting of flesh
Yellowtail flounder	water between 10 and 72m deep	eggs and larvae, feeding behavior	March through August	disruption of physiological activity depressed respiration rates, tainting of flesh, incorporation of petroleum derived hydrocarbons into food chain
Mallard	on the ground and near marshes and along ponds and streams	entire life cycle, feeding behavior	Late March to early July	incorporation of petroleum derived hydrocarbons into food chain, loss of bouyancy, overexposure
Black Duck	fresh-water marshes, coastal salt marshes, and along the shores of lakes, ponds, and streams	entire life cycle, feeding behavior	early April to late June	loss of bouyancy, overexposure, incorporation of petroleum derived hydrocarbons into food chain

(4) Destruction of the generally more sensitive juvenile forms of organisms. (Table 4)

(5) Destruction of the food source of higher species.

(6) Incorporation of sublethal amounts of oil and oil products into organisms (resulting in reduced resistance to infection and other stresses - the principal cause of death in birds surviving immediate exposure to oil).

(7) Incorporation of carcinogenic and potentially mutagenic chemicals into marine organisms.

(8) Low-level effects that may interrupt any of numerous events (such as prey location, predator avoidance, mate location or sexual stimuli and homing behavior) necessary for the propagation of marine species and for the survival of those species higher in the marine food web.

Benthic Invertebrates

Benthic invertebrates are the group of organisms most directly affected by spilled oil. The extreme vulnerability of the benthic community is due to the fact that a large fraction of its inhabitants are sessile. For this reason, such organisms are often used as indicator species. Oil and oil derivatives can affect benthic invertebrates directly by internal or external exposure, or indirectly by habitat alteration. Direct external exposure occurs either when oil is deposited upon the substrate by sinking (as a result of tidal or wave action) or when soluble oil fractions go into solution. Direct internal exposure occurs when oil is ingested, and oil soaked sediments would affect filter feeders and detritus feeders. Habitat feeders could alter the community structure by favoring certain species and discriminating against others.

The concentrations of soluble aromatics which cause toxicity have been estimated by the Massachusetts Institute of Technology. The acute toxicity sensitivity for the larvae of all benthic invertebrates is 0.1 to 1 part per million (ppm), 1 to 10 ppm for lobsters, and 5-50 ppm for mollusks (scallops, oysters, clams).[27]

The American lobster (Homarus americanus) would be most sensitive to oil during the larval stages. A larvae exposed to 1.0 ppm of unweathered crude

Table

SPAWNING BEHAVIOR

Species	Spawning Season	Spawning Peak	Spawning Location
Shellfish			
American oyster	June to Late August	Late June - Mid-July	Intertidal or estuarine areas
Hard clam	June to Mid-August	Late June - Mid-July	Sandy or muddy bottoms between tides and in shallow water
Soft clam	Mid-April to Mid-June	May	In water above clam beds (intertidal or subtidal areas)
Bay scallops	Early summer	July	Protected mud bottom, subtidal and intertidal areas
Surf clam	May to Late July	Mid-July	On sand bottoms from low water level to depths of 72 meters
American lobster	July and August	July	Relatively shallow inshore areas
Finfish			
Striped bass	March to July	Late April to Early May	Estuaries
Butterfish	June through August	July	Few miles from shore
Atlantic menhaden	May to September	September	Ocean waters
Atlantic mackerel	April to July	May and June	Wherever fish happen to be when eggs are ripe
Silver hake	July through September	July and August	Water shallower than 90 m
Summer flounder	September to November	October	At the bottom in deeper water
Scup	May to August	June	Inshore areas: estuaries and bays south of Cape Cod
Yellowtail flounder	March through August	April and May	Wherever species is abundant, 46 to 64 m deep over sand bottom
Winter flounder	January to May	March	Backwaters of bays and estuaries, Georges Bank in water 46 to 73 m

Species	Spawning Season	Spawning Peak	Spawning Location
Birds			
Black Duck	Early April to Late June	May	Marshland, lakes, ponds, streams, scrub fields, and open woodland
Mallard	Late March to Early July	Late April through May	On the ground in and near marshes and along ponds and streams

oil in seawater, appears generally lethargic, active motions are minimal, feeding depressed and animals often appear dead. Exposure to crude oil causes larval lobsters normally blue to turn a red color. This sharply reddened coloration makes the larvae visually apparent and easy prey to other foraging carnivores.

One possible long term effect of oil pollution is that shellfish of commercial value will incorporate hydrocarbons into their body tissues, either by direct ingestion or by consumption of plankton exposed to the pollutant. The major adverse effect is that the animal becomes tainted with an objectionable taste or smell. In general, the detectable levels of petroleum hydrocarbons are retained for only short periods of time, with the possible exception of oysters and mussels.

Oysters that had been transferred to clean sea water after an oil spill still contained oil concentrations more than six months later. Oil contaminated sediments are a source of further tainting of future generations of shellfish.

Large concentrations of oil, 10 to 100 parts per million, are lethal to shellfish. Death would occur either by smothering or by the growth of tumors on the gonads. Petroleum also interferes with pheremones, the chemicals by which animals communicate, by either interfering with their reception or by mimicking them directly.

Fish

Fish are probably less vulnerable to oil spills than other marine organisms because they simply move away from the areas contaminated by oil. However most laboratory evidence indicates that fish are susceptible to the toxic effects of oil and to many of the chemical dispersants used to clean-up after oil spills.

The exact effects of oil activities on fish populations are not clear at this point, but will undoubtedly vary from species to species. Light, refined petroleum products in shallow confined areas, are potentially more damaging to crude oil or heavy oil in deeper, open areas. Potential adverse impacts on fish populations include:

(1) Eggs and larvae die in spawning and nursery areas from exposure to concentrations of hydrocarbons in excess of 0.1 ppm.

(2) Adults die or fail to reach spawning grounds if the spill occurs in a critical, narrow or shallow waterway. Anadromous fish homing to an estuary are particularly vulnerable to this situation.

(3) A local breeding population is lost due to contaminated spawning grounds or nursery areas.

(4) Fecundity and spawning behavior is changed.

(5) Local food species of adults, juveniles, fry, or larvae are affected.

The most harmful effects of oil spills on fish fauna seem to occur during the egg and larval stages. They are extremely sensitive to high boiling point hydrocarbons and are the least mobile stages in the life cycle of any fish species. There has been concern that larval fishes, which often concentrate at the ocean surface, may be adversely affected by floating oil, either through toxicity or entrapment. Numerous deaths among the egg and larval stages could cause serious consequences for adult populations over the long run, and such consequences may be difficult to detect. The finfish resources most potentially vulnerable to oil spills are striped bass, summer and winter flounder.

The sublethal effects from oil pollution, especially from the chronic low-level discharge of oil into the marine environment, are the least known and potentially the most dangerous to fish. Sublethal effects are often subtle and may not be known until damage to the population is widespread.

Feeding, reproduction, and social behavior have been shown to be disrupted by soluble aromatic derivatives as low as 10-100 parts per billion. Interference with predator detection of prey is also possible. Fish nutrition may be altered by physiological/behavioral effects, blocking taste receptors, and mimicking natural chemical messengers which attract predators to their prey. The tainting of fish flesh is an important problem for commercial and recreational fish species.

Birds

The effects of oil on birds, especially pelagic seabirds, has been the foruc of numerous research efforts during the last forty years. A number of relevant conclusions can be drawn for the purpose of impact assessment from these efforts:

(1) Seabirds constitute one of our most abundant, widely distributed but least understood biological resource. Their populations range in the hundred of millions.

(2) In general, seabirds are: long-lived; have a very low reproductive potential; are geographically isolated from man and most predators (requiring only a low level of annual replacements); have relatively restricted ranges; nest in colonies along the coast or on islands; frequently concentrate in hugh flocks during various seasons, and take a long time to recover from severe population depletion.

(3) Losses of birds to oil spills are highest during the winter months when the species are abundant along the coast and concentrated on wintering grounds.

The damage to bird populations is the most direct and obvious effect of oil spills. Oil spills pose a considerable potential threat to bird populations in Baltimore Canyon and Georges Bank. Atlantic coastal habitats support thousands of species of birds providing wintering, breeding, and feeding grounds.

Spilled oil or petroleum products can adversely affect aquatic birds through external exposure to surface oil films, internal exposure by feeding and preening and loss of habitats or food supplies. The primary effect of direct contact of avifauna with oil is the destruction of the water repellancy and insulation properties of the plumage. In lightly oiled birds, buoyancy is lost and insulation is reduced. Many of these birds die of exposure or starvation, others are suspected of drowning at sea. Death by exposure is a result of the loss of vital body heat through oil-impregnated feathers. Starvation results from the oil-induced mortality of food items or the inability of oiled birds to search for food.

Waterfowl mortality, due to oil spills, can also occur during nesting season. Brooding adult birds can transfer oil from their feathers to the surfaces of their eggs. Oil does not allow respiratory gases to pass through pores in the egg, and subsequent hatching success may be significantly reduced.

Internal exposure of aquatic birds to oil occurs when the oil is ingested, either with contaminated food or during preening (cleaning of the plumage with the bill). Indirect effects of spilled oil on birds are those induced by habitat alteration, especially the loss of food supply. Spilled oil may destroy vegetation or invertebrates in traditional feeding grounds. This loss of potential food organisms may reduce survival of wintering, nesting or migrating populations long after most oil has been removed.

The habitat preferences and behavior of certain species increases or decreases its relative susceptibility to fouling by oil. A brief and general ranking in order of susceptibility is:

(1) diving ducks -- auks, some ducks, grebes, loons, pelicans and comorants,
(2) geese, some ducks, and pelagic phalaropes
(3) shore birds
(4) gulls, terns, cranes, and herons

It should be noted that the main damage caused by oil to birds occurs in the early stages of the spill, while oil is still on the surface and before it comes ashore. It is thus, urgent that action be taken as quickly as possible to assess the situation and initiate preventive efforts to (1) protect unoiled bird concentrations by the strategic placement of booms, dispersal of slicks and deterrent techniques; (2) birds censuses by species in the area, including the number oiled (live and dead) and unoiled. Quick action can often reduce mortality by directing attention to nesting, feeding or roosting areas, sanctuaries and bird concentrations so that priority may be given to protecting them.

VI. ESTIMATES OF SPILLS THAT MAY IMPACT CRITICAL NATURAL RESOURCES

Perhaps the most detrimental aspect of OCS development is the potential for oil spills both in the offshore region and, more importantly, the probability for spills reaching shore and impacting the environmental and economic resources of the State. Again, the major focus of this report is on the offshore region. The NSRPB study should be utilized to determine oil spill effects on the nearshore resources.

Since 1969 and the Santa Barbara incident, there has been an increasing awareness of oil spills and their detrimental effects. In fact, much of the technology for oil spill cleanup was developed after 1969.[31]

However, the recent rash of tanker accidents including the Argo Merchant have highlighted the fact that oil spill containment equipment cannot operate under various adverse weather conditions such as increased wave heights (greater than five feet), high winds, and strong currents. Thus, oil spills on the high seas in hazardous waters must run the course of nature. Efforts to contain and clean-up spills in these areas can be considered to achieve minimal results.

A. Oil Spill Statistics

To accurately assess the range and frequency of oil spills in the Mid-Atlantic and the North Atlantic, there must be a base on which to make projections.

The best known oil spill statistics are compiled by the U.S. Coast Guard although other individual agencies compile their own statistics. Offshore oil pipeline data, for example, is compiled by the U.S. Geological Survey of the Department of the Interior. Additionally, the Office of Pipeline Safety and Operation of the Department of Transportation also keeps its own statistics.

Unfortunately, the records of these three agencies do not agree, leading to the inescapable conclusion that either reporting or investigation of these incidents is faulty.[32]

It should be noted, however, that the statistics compiled by these and other agencies are based on reporting. Thus, if an operator does not report a spill, the incident may not be recorded. Secondly, the statistics, especially for offshore operations, are obviously historical and are compiled from the experiences of other U.S. leasing areas. These experiences, where climatic conditions are much less severe, may not be relevant to the harsh weather conditions to be encountered in the frontier OCS areas of the Mid-Atlantic and North Atlantic.

Further, to predict the numbers and volumes of spills, many researchers have utilized volume production figures as averages to determine the kinds and extent of spills. However, the size and probability of spills is a much more accurate way to describe spills rather than volume production.[33]

B. Oil Spill Models

In the past few years, at least seven oil spill models that pertain to Long Islan have been developed to predict where an oil spill will travel given a hypothetical spill location. Most notable of these are the United States Coast Guard Model and the U.S. Geological Survey oil spill risk model, both developed to provide a basis for determining where spills would go in the event of spills both near to shore and on the Continental Shelf where drilling will occur. The USGS model has been extensively utilized by the Bureau of Land Management in writing the environmental impact statements for the Baltimore Canyon and the Georges Bank.[34,35]

Other models and drift card studies have been developed to illustrate more succinctly the relationship between oil spills in the lease areas and possible impacts on Long Island. Most significant of these works are a series of reports done for the Nassau-Suffolk Regional Planning Board by Devanney and Stewart.[36,37,38]

Taken together, these models and drift card studies provide tools which can be used to reach hypothetical conclusions about spills. There are extensive limitations to these models, and total reliance on them is unwarranted. It should be remembered that the models (seven in all: MIT, (1) Stewart, Devanney, and Briggs, 1974, and (2) Devanney and Stewart, 1974; Coast Guard, (1) Lessauer and Bacon, 1975 and (2) Miller, Bacon and Lessauer, 1975, Hardy et al. 1975; Brookhaven National Laboratory Model; U.S.G.S., Smith, Slack and Davis, 1976) are theoretical mathematical models. All these models are simplified, one dimensional, wind-driven systems. They assume that the water column is homogeneous and do not consider other important oceanographic factors such as mixing, long shore pressure gradients, long shore drift, density differences, upwelling, or settling out in the water column. These factors are important to predict the fate of oil spills close to shore and the impacts of spills on the upwelling system.[39]

At present, the most extensively used is the USGS model that is the basis for prediction and transport of spills and environmental impacts for the Department of Interior (Bureau of Land Management), environmental impact statements. However, the analyses that are utilized consider the amount of undiscovered economically recoverable resources in the specific lease sale only. For example, the Mid-Atlantic analyses which appeared in the Final Environmental Impact Statement[40] were based on a resource find of 1.4 billion barrels over the life of the field. For the North Atlantic area, a maximum find of 650 million barrels of oil was used as the basis for analysis. The analyses also dealt with spills within the lease areas only. Thus, a pipeline spill or a tanker spill closer to shore was not included in the analyses.

To accurately assess the potential for oil spills and possible impact upon the resources of New York State, a combination of the forementioned studies must be utilized to predict (1) spills originating and transported from the lease areas and (2) spills originating and transported outside of the lease areas.

C. Size and Distribution of Oil Spills that May Impact New York State

Reliance on historical, reported data may not be applicable to the frontier Atlantic OCS regions. Because of the differing estimates of the size and distribution of spills based on both historical and mathematical probabilities for a given resource find, a statement of the absolute numbers and distributions of future spills is not feasible.

For purposes of evaluating environmental impacts of possible spills, a high find scenario would dictate the worst environmental conditions, assuming that there is oil found in the Mid-Atlantic and further assuming that tankers would be utilized in the North Atlantic to transport oil from the Georges Bank to refineries in the New York/New Jersey Port Area:

	High Find
Mid Atlantic	2.6 billion barrels[a]
North Atlantic	0.9 billion barrels[b]

[a]assumes pipelines for transport to shore
[b]assumes tankers from platforms to Port of New York and New Jersey

The scenario numbers under discussion are greater than those estimated by the Bureau of Land Management for the individual lease sales for Sale 40 and 42. The individual lease sale figures are based on somewhat lower resource finds, and the statistics and impacts derived for the environmental impact statement reflect these lower finds. In this analysis of impacts, the derivation of new spill probability statistics for the scenario figures did not seem productive given the hypothetical nature of existing spill models, the descrepancies of various spill data, and the time required for reevaluating and hypothesizing new data for these purposes. Consequently a wide variety of already available data have been employed as conservative estimates of the numbers and distribution of spills that could result given OCS development.

Based on the Mid-Atlantic and North Atlantic USGS oil spill risk analyses,[41,42] the following tables will be used as the basis for discussion:

Table 5

Mid-Atlantic[(a)]
Oil Spill Frequency Statistics by Potential Sources

	Expected number of spills during the production life of the lease area (mean)	Probability of at least one spill occurrence
A. Spills greater than 1,000 bbls in size		
Platforms	2.3	.9
Pipelines	2.5	.92
Tankers	3.3	.96
Platforms and Pipelines	4.8	.99
Platforms and Tankers	5.6	.99
B. Spills 50 to 1,000 bbls in size		
Platforms and Pipelines	17.8	.99
Platforms and Tankers	Not Available	

(a)Figures based on estimated economically recoverable resources of 1.4 billion bbls.

Table 6

North Atlantic[(b)]
Oil Spill Frequency Statistics by Potential Source

	Expected number of spills during the production life of the lease area (mean)	Probability of at least one spill occurrence
A. Spills greater than 1,000 bbls in size		
Platforms	1.14	.65
Pipelines	1.26	.69
Tankers	1.69	.81
Platforms and Pipelines	2.40	.91
Platforms and Tankers	2.83	.93
B. Spills 50-1000 bbls in size		
Platforms and Pipelines	8.93	.99
Platforms and Tankers	13.2	.99

(b)Figures based on estimated economically recoverable resources of 0.65 billion bbls.

The expected number of spills is given as the mean or 50% value. Based on the statistical distribution, the following are derived:

Mid-Atlantic

- 70% chance that there will be between 2 and 7 spills greater than 1,000 bbls given platforms and pipelines
- 50% change that there will be 18 spills of 50-1,000 bbls

North Atlantic

- 81% chance that there will be between 1 and 4 spills
- 50% chance that there will be 13 spills of 50-1,000 bbls.

Because the find scenario is larger than the recoverable resources on which the statistics are based (2.6 vs. 1.4 billion and 0.9 vs. 0.65 billion), the high numbers for spills greater than 1,000 bbls will be chosen for discussion purposes; i.e., seven spills in the Mid-Atlantic and four spills in the North Atlantic.

D. Predicting Where Oil Spills Will be Transported

Assuming that there will be a number of large spills on the Atlantic OCS in the Georges Bank and the Baltimore Canyon, the obvious question is what will be the impact of these spills? Although there will be a number of smaller spills, the spills greater than 1,000 barrels will produce the greatest problems. These smaller spills should not be discounted, but they will occur on the Continental Shelf in deep water where they can be actively dispersed by wave and wind action.

From the numerous studies and models developed to date, it appears that the probability of New York State's coasts being adversely impacted by a large spill from the present leasing area is small. However, it should be noted that these purely hypothetical mathematical models are based primarily on wind direction. If spills occur outside the lease area, for example in the Nantucket to Ambrose traffic lane, the chances of a spill reaching Long Island are greatly increased.

The following table is a synopsis of data and impacts on Long Island on the seven previously mentioned oil spill trajectory models and studies:

Table 7
Probability of Impacting Long Island Shore

Stewart, Devanney, and Briggs, 1974	25% - spring 8% other seasons
Lessauer and Bacon, 1975	Spill impacts the shore in 4-8 days
Miller, Bacon and Lessauer, 1975	When summer high pressure remains stationary for 4-5 days then spill comes ashore When winter storm stalls and becomes stationary south of spill sites, there is a high chance of spill impacting shore
Devanney and Stewart, 1974	Spills south of 40° N latitude: less than 10% probability of impact in winter; less than 50% probability of impact in summer
Hardy et al. 1975	In winter months, 0% probability of a spill stranding on Long Island if more than 10 miles offshore In summer there is greater than 0% probability of a spill stranding on Long Island within 60 days if the spill is within 30 miles offshore
Brookhaven National Laboratory	Probability of impact is very low if the spill is greater than 15 miles offshore
Smith, Slack and Davis, 1976	70% probability of 7 major spills 10% probability of spill impacting shore 90% probability of pipeline spill impacting Mid-Atlantic shore

The reason for the presentation of this data is to highlight the discrepancies between and among the various studies and the problems in comparing and constrasting the results of each. Different researchers used different release points or points of discharges. Thus a truly accurate description of the time and distance to shore is not feasible.

E. Limitations

Based on the previous discussion and the extent of oil spill data, OCS operations can be expected to result in both major and minor spills that will affect both the offshore and the nearshore regions.

According to the statistics, one could expect seven large spills (greater than 1,000 barrels) from the Mid-Atlantic lease area and four from the North Atlantic.

Previous discussions by coastal zone managers of oil spill dangers center on the impacts should oil reach shore. Obviously, this is where the worst environmental and economic effects will occur. However, one must not discount the fact that major spills in the offshore regions could devastate a year class of finfish resulting in losses to New York fisherman.

As discussed previously, the oil spill models are two dimensional and, therefore, do not take into account the mixing phenomenon and gradual introduction of oil into sediments and perhaps the food chain. Thus an accurate appraisal of the quantitative and qualitative effects of a major spill in the ocean cannot be made. While recognizing that spills may not be transported to shore, one cannot assume that because a spill has "disappeared" from the surface, it no longer poses a threat to the marine environment.

Catastrophic occurrences such as the Argo Merchant can provide first class environmental laboratories on both the effects of spills and transport. Presently, the USGS is still tracking the Argo Merchant spill by satellite giving scientists real time data on the movement and transport of oil in the Atlantic OCS. Thus the real time data can be utilized as a correlation with the theoretical data on which the model is based.

In providing this test, the model may be substantially improved to enhance its predictive capability.

VII. ESTIMATE OF THE SENSITIVITY OF THE SHELLFISH AND FISHING INDUSTRIES TO PETROLEUM CONTAMINATION

The fishing industry could be adversely affected by a major oil spill. An oil spill, whether from a tanker, pipeline or platform, could have a devastating impact on fish, shellfish, and the entire marine environment. Damages to the marine environment could include:

(1) death of organisms through coating and asphyxiation;

(2) death of organisms through poisoning and long-term exposure to toxic materials;

(3) destruction of food sources for species higher in the food chain;

(4) incorporation of small amounts of oil and oil products into organisms which could result in reduced resistance to infection and other stresses; and

(5) introduction of carcinogenic chemicals into marine organisms.

In addition to killing some organisms outright, oil pollution could cause tainting of commercial species of fish and shellfish (Table 8), and could foul fishing gear. Adult finfish, not killed outright, may suffer long-term declines if food webs are interrupted or resistance to disease and environmental stress lowered. Larval and juvenile fish killed in great numbers would result in greatly reduced yields several years after the spill, particularly for species which are currently overfished. Oil spills may also impact selected species through genetic damage, disruption of normal physiological processes, and pathobiological conditions.

Several of the commercial fish species important to New York State are schooling fish which exhibit seasonal migration patterns. If an oil spill occurred during these migrations, be it an oil or tanker spill or even a platform spill, an entire year class of a fish species could be eliminated. Butterfish, scup and Atlantic menhaden could be adversely affected as they are schooling fish that exhibit seasonal migration patterns, moving inshore in the spring and offshore in the fall to wintering grounds located at the edge of the Continental Shelf.

Table 8
New York Commercial Landings, 1976*

Species	Landings Rank	Landings Tons	Wholesale Value Rank	Wholesale Value Dollars
Finfish				
Summer flounder	1	1,603	1	$ 1,499,781
Silver hake	2	1,273	4	289,655
Scup	3	1,238	2	579,588
Butterfish	4	480	5	273,954
Striped bass	5	347	3	422,136
Yellowtail flounder	6	295	6	168,068
Atlantic mackeral	7	225	8	39,517
Winter flounder	8	178	7	143,941
Shellfish				
Hard clam	1	4,515	1	18,120,265
Surf clam	2	1,728	4	1,089,204
American oyster	3	951	2	4,763,957
American lobster	4	297	3	1,338,484
Bay scallop	5	219	5	816,372
Soft clam	6	24	6	$ 61,406

*National Marine Fisheries Service, New York Landings, Annual Summary 1976, Current Fisheries Statistics No. 7212, Washington, D.C.: U.S. Department of Commerce, NOAA, NMFS, April 21, 1977.

The tainting of commercial species of fish, clams, and oysters by oil has frequently been reported, resulting in unsaleable catches. Tainting may be quite persistent, the noticeable taint lasting several months.

A short term impact on sport-fishing opportunities could be caused by a spill affecting shoreline piers, jetties, groins, and nearshore artificial fishing reefs. The loss of opportunities would primarily be caused by the dispersion of the fish population concentrations, leading to lower success rates which could discourage participation. The most severe impacts would occur if the artificial reefs along the western end of Long Island were affected. Thirty-three percent of the more than eight million persons who participated in salt-water fishing in the Mid-Atlantic region in 1973-1974 were residents of New York State. Additionally, participation may decrease as a result of a boat fisherman's reluctance to use his vessel in areas that might potentially soil the craft and gear.

One observation that emerges from examination of oil spills and fisheries is that while there is reasonable evidence for localized effects, there is as yet little specific evidence of widespread damage to major fisheries resource populations resulting from oil spills. There is some evidence that other factors, such as long-term shifts in geographic distribution, repeated year class successes or failures, and overfishing, may cause pronounced changes in fisheries.

Footnotes

[1]National Marine Fisheries Service (NMFS), New York Landings, Annual Summary 1976, Current Fisheries Statistics No. 7212 (Washington: U.S. Dept. of Commerce, NOAA, NMFS, April 21, 1977) p. 2.

[2]The Research Institute of the Gulf of Maine, (TRIGOM), A Socio-Economic and Environmental Inventory of the North Atlantic Region, Vol. I, Book 3 (South Portland, Maine: The Research Institute of the Gulf of Maine, November, 1974), p. 10-58.

[3]Ibid., p. 10-58.

[4]Ibid., p. 10-59.

[5]NMFS, New York Landings, Annual Summary 1976, p. 2.

[6]Ibid., p. 2.

[7]Ibid., p. 2.

[8]Ibid., p. 2.

[9]J.L. McHugh and Anne D. Williams, Historical Statistics of the Fisheries of the New York Bight Area (Albany, New York: New York Sea Grant Institute, July, 1976), p. 54.

[10]TRIGOM, A Socio-Economic and Environmental Inventory of the North Atlantic Region, p. 13-53.

[11]Ibid., p. 13-53.

[12]NMFS, New York Landings, Annual Summary 1976, p. 2.

[13]McHugh and Williams, Historical Statistics of the Fisheries of the New York Bight Area, p. 54.

[14]NMFS, New York Landings, Annual Summary 1976, p. 2.

[15]Ibid., p. 2.

[16]Congress for the United States, Office of Technology Assessment, Working Papers for Coastal Effects of Offshore Energy Systems, Vol. II (Washington: Superintendent of Documents, November, 1976), p. C-10.

[17]NMFS, New York Landings, Annual Summary 1976, p. 2,

[18]Ibid., p. 2.

[19]Ibid., p. 2.

[20]Ibid., p. 2

[21]Ibid., p. 2.

[22]McHugh and Williams, Historical Statistics of the Fisheries of the New York Bight Area, p. 54.

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[24]NMFS, New York Landings, Annual Summary 1976, p. 2.

[25]Division of Marine and Coastal Resources, New York State Department of Environmental Conservation (Stony Brook, New York: Region I Office New York State Department of Environmental Conservation).

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[28]American Petroleum Institute, Proceedings, 1977 Oil Spill Conference (Washington, D.C.: American Petroleum Institute, March 8-10, 1977), p. 573.

[29]United States Congress, Office of Technology Assessment, Coastal Effects of Offshore Energy Systems, Volume II: Working Papers (Washington, D.C.: U.S. Government Printing Office, November, 1976), Table C-7.

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[31]Don E. Kash and Irvin L. White, Energy Under the Oceans, (Norman, OK; Oklahoma Press, 1973) pp. 128-129.

[32]American Petroleum Institute, Proceedings 1977 Oil Spill Conference, p. 95.

[33]Council on Environmental Quality, OCS Oil and Gas - An Environmental Assessment, Volume 1 (Washington, D.C.: U.S. Government Printing Office, April, 1974), pp. 87-98.

[34]Richard A. Smith, James R. Slack, and Robert K. Davis, An Oil Spill Risk Analysis for the Mid-Atlantic Outer Continental Shelf Lease Area, (Reston, Va.: U.S. Geological Survey, June 1976).

[35]Richard A. Smith, James R. Slack, and Robert K. Davis, An Oil Spill Risk Analysis for the North Atlantic Outer Continental Shelf Lease Area, (Reston, Va.: U.S. Geological Survey, 1976).

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