U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
National Marine Fisheries Service

NATIONAL MARINE FISHERIES SERVICE
BIOLOGICAL LABORATORY, BOOTHBAY HARBOR, MAINE

FISHERY
LEAFLET
640

Cover:

The dory, a graceful symbol of New England's fisheries, is still used as a platform for pursing nets, and, in the unwritten law of Maine fishermen, as a mark for a selected fishing ground.

UNITED STATES DEPARTMENT OF COMMERCE
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NATIONAL MARINE FISHERIES SERVICE BIOLOGICAL LABORATORY, BOOTHBAY HARBOR, MAINE

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ABSTRACT

This report describes the activities of the National Marine Fisheries Service Biological Laboratory at Boothbay Harbor, Maine, the northernmost marine research facility maintained by the U.S. Government on the Atlantic Coast.

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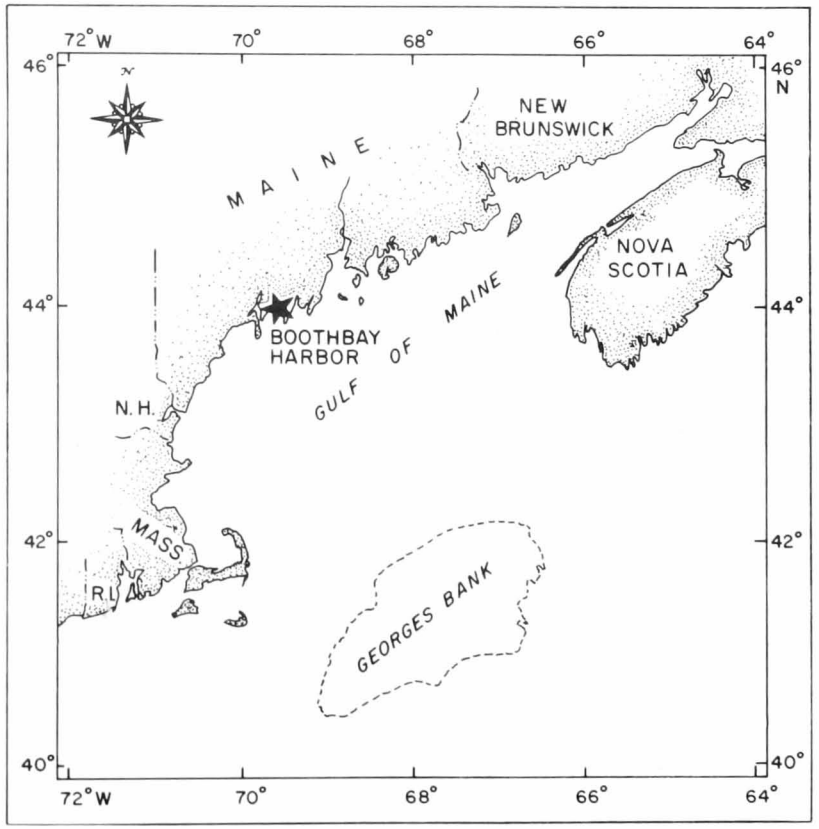
INTRODUCTION

The Marine Laboratory at Boothbay Harbor is operated by the Federal Government to study and maintain the living resources of the North Atlantic. It is the only Federal laboratory in the truly cold-water zone of the eastern United States, the northern environment that favors lobsters, herring, and the valuable ground fisheries for haddock and cod. An outstanding research facility is the Laboratory's constant and controlled flow of unusually clean natural seawater for year-round studies ashore.

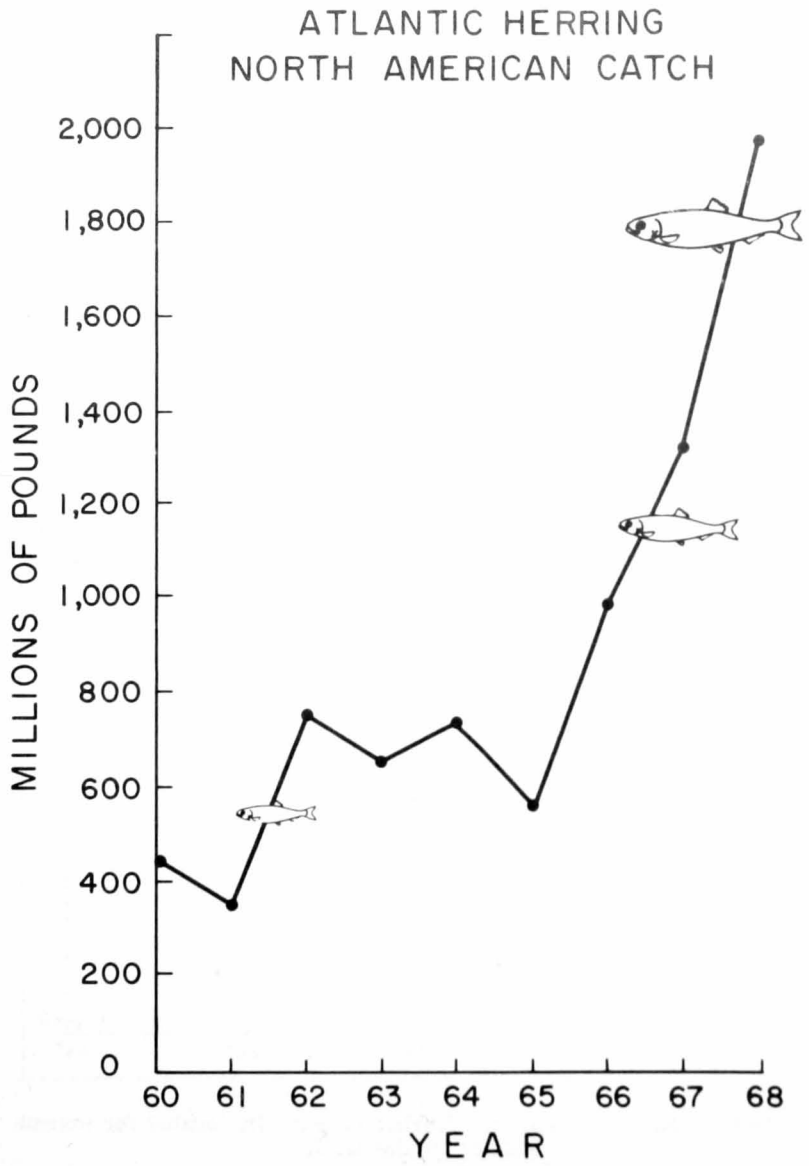
The Laboratory occupies a 10-acre site which was first used as a lobster hatchery in 1905. After World War II the Government replaced the hatchery operations with marine research, and Boothbay Harbor became a base for studies of herring in the Gulf of Maine. Research on clams, European oysters, and Atlantic salmon was begun and completed in the 1950's. Lobster research was added in 1965. Since its beginning the Laboratory has been modified and improved to meet the changing needs of the fisheries it serves. During the 1960's the demand for herring and lobster gave rise to large offshore fisheries on the continental shelf. Inshore, the herring have been fished for a century by the United States and Canada to support a valuable sardine industry. Offshore, especially on Georges Bank, large herring are fished by Russia, Germany, Poland, and other European nations. International shortages of fish meal combined with the decline of fisheries in Europe that provided herring for food have intensified the demand, forcing the Northwest Atlantic herring catch up to 2 billion pounds annually, a fivefold increase in less than 10 years.

Lobsters are also fished intensively by the United States, both on its Atlantic coast and in the canyons of the continental shelf. Although the total production of lobsters is fairly stable at about 30 million pounds a year, the offshore portion of the fishery has grown steadily since 1960 and now forms about 20 percent of the U.S. catch.

The various parts of these two great fisheries have been placed in delicate balance by heavy fishing pressure. Exten-



The Gulf of Maine. Boothbay Harbor is centrally located for marine studies in the Gulf.



The herring catch by all nations, 1960-68. The demand for herring soared in the sixties. Canadian fishermen took more than one-half of the 2 billion pounds in 1969; at the same time, catches by U.S. fishermen declined.

sive knowledge is required to maintain full production without destroying the two resources through overfishing. To produce such knowledge is the purpose of the Laboratory at Boothbay Harbor.

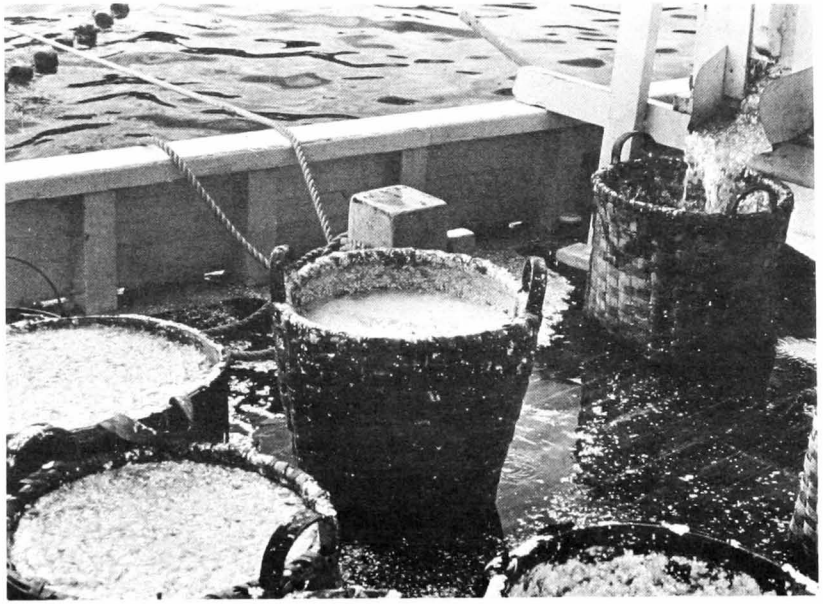
Russian fishing vessels on Georges Bank. Russia opened up the herring fishery on Georges Bank in 1961. The smaller fishing vessels supply the large factory ship, and the catch is processed at sea.

The Laboratory is staffed by 40 people who plan and administer the biological and biochemical research on the lobster and herring and the oceanographic studies of the inshore Gulf of Maine. The biological studies are enhanced by the availability of cold, clean seawater, an advantage that has also been used by visiting scientists from warmer areas who required a cold marine environment for their research. In addition to standard research equipment, the Laboratory has two vessels for coastal and estuarine studies. Deep-water research is pursued on large vessels chartered from other Service laboratories. Studies of the ocean environment form an essential part of the programs; data on conditions of sea and air that were once gathered manually are now recorded continuously and automatically. International conservation of the resources is sought through regular meetings with scientists from Canada and the European nations who fish the Northwest Atlantic; the organization (International Commission for Northwest Atlantic Fisheries) is called ICNAF.

THE HERRING RESOURCE

In the United States herring are used for sardines, fish meal, and lobster bait. A valuable by-product is pearl essence, the silvery substance of the herring's body that is used in the paint, textile, and cosmetic trades.

The herring is an abundant fish, but its availability to fishermen undergoes puzzling fluctuations. One of the goals of our research is to learn the cause of fluctuations and to predict when and where changes will occur. Since 1960 the sardine fishery of Maine has declined, while the offshore fishery in international waters has expanded; the 1960 catch by Maine and Canada, made almost exclusively in coastal waters, was about 400 million pounds compared with the 1969 catch of 2 billion pounds, a fivefold increase attributable to the offshore catches by a half-dozen foreign nations today. About half of the herring used by the United States are imported from Canada.



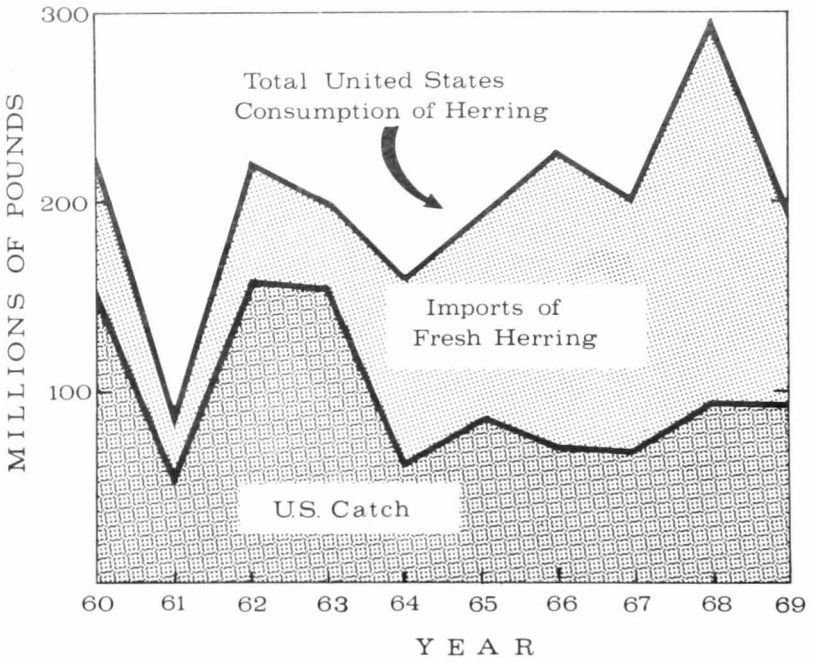
Herring scales. Pearl essence, the silvery substance of the herring, is a costly ingredient of paints, ceramics, costume jewelry, and even lipstick.

Life History

The herring range from Labrador to Virginia in the Northwest Atlantic, but are most abundant in Maine and Canada. Large schools of mature fish spawn in the autumn, usually over a rocky bottom at depths of 12 or more feet. A large female may carry over 100,000 eggs. The eggs, when extruded and fertilized, collect on the bottom in clumps; hatch-

ing requires about 15 days. Newly hatched herring are slender and nearly transparent during a larval stage that lasts about 6 months. They grow rapidly during the summer; as 2-year-olds they reach 7 inches, a size preferred by sardine processors. During their 4th or 5th summer they reach adulthood at a length of 10 to 12 inches.

The herring is a plankton feeder. By converting plankton, the minute plant and animal life adrift in the ocean, into usable protein, the herring plays a vital role in the ocean's food chain. Besides its direct contribution to man, the herring is forage for haddock, cod, silver hake, mackerel, tuna, and other predaceous fishes.



U.S. herring catch and imports, 1960-69. The decline in catch in the sixties increased our dependence on imports from Canada.

Fishing Methods

On the offshore banks, herring fishermen use trawlers, vessels of 80 feet or more. Closer to shore, the purse seine is favored, and it now accounts for half the Maine catch and about 70 percent of the Canadian catch. Fishermen use stop seines and weirs to trap sardines a few hundred feet from land, because these less mobile types of gear enable them to hold their catches several days while the fish cleanse their intestines prior to being processed.

Larval herring. This assortment of plankton fits on a dime. The slender dark-eyed animals of 6 and 10 o'clock on the circle are newly hatched herring. A portion of another larva lies at 3 o'clock. Except for their eyes, the larvae are almost transparent. Fishermen refer to young herring as "eyeballs."

A herring weir. The weir is made of brush, stakes, and netting. Schools of herring are guided by the leader, left center, into the weir. The opening is closed and the fish trapped. By diverting the fish into the pound at left, the fisherman can operate his weir continuously. The use of weirs has declined in favor of the more aggressive methods of stop seining and purse seining. The photograph was made at low water.

The weir is a circular trap of stakes and netting set permanently in an area frequented by herring. Barriers guide the fish into the weir where they are trapped. The stop seine is a long sweep of netting that can be stretched across a cove to trap herring. Stop seines can be moved from place to place, but are limited to the shallow coastline. The purse seine is a long band of netting that is drawn full-circle about a school of herring and then closed at the bottom in the manner of a drawstring purse. The purse seiner searches for schools of herring with echo sounders in coastal areas and in the open ocean. The trawl is a bag-shaped net that is drawn through the water to gather up fish lying in its path. Kitelike vanes, called otter boards, combine with floats and weights to keep the net open. Trawls can be adapted to fish either the ocean bed or the middle depths.

Herring Research

The goals of herring research in the Laboratory are to predict the year-to-year changes in abundance of herring and to determine the effect of offshore fishing by foreign nations upon our domestic catches. The year-to-year variation is especially critical for the sardine industry, whose greatest need is a method for predicting good and bad years so that it can inventory against scarcity and maintain a stable market.

The first step in prediction is to identify the stocks that supply the young herring. The spawning adults may form separate groups along the coast, each group varying from year to year in its contribution to the fishery; or they may intermingle, seeking only a suitable environment for their progeny. In any year the success of spawning and the survival of the young will subsequently influence the sardine catch, and later, the replenishment of the fishery through spawning by those that survive to adulthood.

To develop a method for predicting the success of the herring fishery is a composite undertaking for which we:

1. Compile records of the catches. A well kept history is vital to understanding the future. The record-keeping that began in 1947 was the precursor of the electronic processing and computer analysis in use today.
2. Sample herring from the catches for studies of age, growth, bone structure, tissues, and food habits. These facts help us to identify groups of fishes and to determine their source.
3. Determine the survival rate of young herring from the time they hatch until they enter the sardine fishery. Our purpose is to find crucial periods in the herring's life cycle that can be measured to indicate the strength of an oncoming year class.
4. Examine the planktonic food of the herring. By means of fine-meshed nets we determine the kinds, amounts, and locations of the herring's food. We wish to know

if the presence of food controls the movements of herring to a fishing area.

5. Study the herring in offshore waters. Biological evidence supports our belief that the Georges Bank and inshore fisheries are based on separate stocks. We wish to know the potential of the offshore fisheries for future use by American fishermen.
6. Determine the physical oceanography of the Gulf of Maine. Changes in temperature and currents and the interaction of sea and weather may profoundly affect the catch of herring.
7. Study the herring's behavior. Under controlled laboratory conditions we are learning the herring's preferences for temperature, dissolved gases, salinity, and light; from these studies we seek to know the kind of environment that herring prefer.

Since 1963 we have examined over 100,000 herring from the catches in both inshore and offshore waters and have found evidence that two major groups of herring exist: a Maine group and a Georges Bank group, which have a number of differences. The separate identities of the two stocks are supported by differences in growth rate and in numbers of vertebrae and fin rays. The difference between the two stocks is further confirmed by biochemical methods which seek characters that vary among individuals but are genetically controlled and differ in their frequency of occurrence in different stocks. Such variable characters, although detectable only by specialized methods, are comparable to color of eyes, hair, and skin that we so readily use to distinguish the races of man and breeds of domestic animals. Research now proceeds on each stock separately.

Many of the herring that hatch in the autumn die in a few months; thus the number that will ultimately enter the fishery is established while the herring are in the larval stage. Our research has shown that some of the newly hatched herring enter estuaries and remain there until the following spring. A study of this estuarine habit shows that midwinter

A sardine carrier. The herring — 2 years old and 7 inches long — are pumped into the carrier and lightly salted for the 6-hour trip to the factory. The ash-splint baskets beside the wheelhouse are used for collecting scales.

mortalities are highest and are the most important influence in controlling the number of herring that the estuaries will contribute to the sardine fishery. The highest mortality that we have measured was in February 1965 when the condition of the larvae was the poorest in 4 years.

We have published descriptions of the seasonal and annual distributions of plankton in the coastal areas of Maine; these, joined with studies of the sardines' diet, show that western Maine is richest in the animal plankton preferred by young herring. The greater abundance of food confirms our finding that young herring grow fastest in western Maine. In view of these findings, we look to the behavior and environmental requirements of the fish to account for the decline of the fishery in that area.

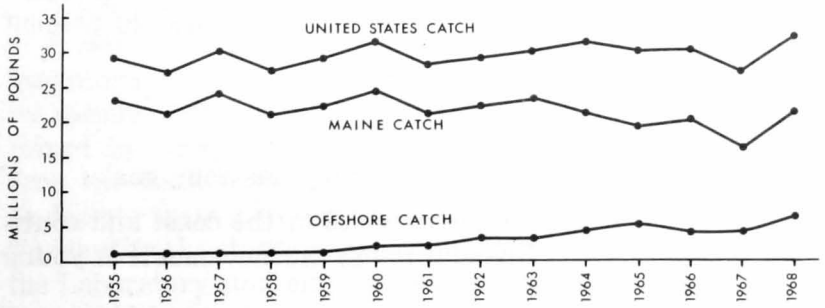
In our studies of plankton, we have found that sardines feed heavily upon larval barnacles which swarm as plankton during early spring. This diet causes the sardines to break

apart when they are transported; such fish are useless for canning. As an aid to the industry, we report the distribution of planktonic barnacles when they swarm each spring.

Our purpose in studying the herring's behavior is to learn what conditions in the environment attract or repel sardines. We have found that temperature and salinity are important influences.

THE LOBSTER RESOURCE

In the United States, New England, led by Maine, has always been the chief producer of lobsters. The development of a canning process at Eastport, Maine, in 1843 gave rise to an organized lobster fishery, and by 1880 Maine had 23 factories which produced 2 million pounds of canned lobster meat. A century ago, the lobster was common enough to be ground up and scattered in the ocean as a lure for mackerel. In 1880, U.S. lobstermen caught 20 million pounds of lobster and sold them for 2 cents a pound, whereas in 1968, they caught 32 million pounds, a record, and by 1971 some fishermen received $1.45 a pound at dockside. Despite the U.S. record for 1968, elements within the North American lobster fishery have known difficulty during the past 10 years. In that period Maine's coastal catches have fluctuated between 16 million and 24 million pounds. Canada's catches have declined; meanwhile a fishery has been opened on the continental shelf to provide an estimated 20 percent of the U.S. catch. Whether the coastal and continental shelf fisheries make their harvest from the same or different stocks of lobsters constitutes a major problem to be solved for management of the two fisheries.



Lobster catches. Compared with herring, the U.S. lobster catch is rather stable at about 30 million pounds. Offshore catches and imports from Canada help to supply the U.S. market.

Life History

Although the lobster inhabits the colder waters of the Atlantic, its growth, mating, and hatching depend largely on summer's warmth. Lobsters maintain the salt in their blood to match their seawater environment and are most often found in water of high salinity; fresh water is lethal. The lobster extracts dissolved oxygen from seawater with its gills and, like all gillbreathers, requires moisture to survive. It can live out of water for several days if the air is cool and damp, a faculty that aids the producer in supplying his market, which demands lively lobsters. Lobsters frequent all types of ocean bottom, but most of them inhabit rocky areas where they construct burrows and live in crevices.

Lobsters mate just after the female has molted, usually in late spring or early summer, and she extrudes the eggs a year later. The extruded eggs adhere to her abdomen and incubate for a year; they hatch about 2 years after the adults have mated. Breeding females molt but once every 2 years and are thus smaller than males of the same age that molt annually. Lobstermen are required by law to remove the egg-bearing, or "berried," lobsters from their catches and return them to the ocean. A small female carries 15,000 eggs; a large one, 60,000.

Fourth stage lobsters. The fourth stage is critical. The lobsters, about a month old, are ready to leave the surface and spend their lives on the bottom of the ocean. They have molted three times. If they survive, they will molt about 25 times to reach market size in 5 to 7 years.

Lobsters grow by molting and require between 20 and 30 molts and 5 to 7 years to reach a market size of 1 pound. Cold summers and late springs may delay or inhibit the molting of some lobsters; older lobsters may not molt every summer, whereas a juvenile may molt twice or more.

Fishing Methods

In the coastal fishery, lobsters are caught with box-shaped traps made of oak laths. The traps are 3 feet long and are ballasted to fish the ocean bottom on rocky grounds from 10 to 300 feet deep. Redfish cuttings, herring, and alewives are the preferred baits.

Some lobstermen are part-time fishermen and set only a few dozen traps, but a two-man team working full time may fish over a thousand. The catches are usually sold to dealers, who store them in pounds, live-cars, or tanks. The fishery is most productive in summer and autumn. The lobsters are packed alive in iced containers and shipped to all parts of the country.

The fishery for lobsters on the continental shelf ranges out to 200 miles from shore. The catches are made in depths of 150 to 1500 feet by ships about 80 feet long that carry tanks for storing the catches. The major part of the catch is made with otter trawls; but in recent years the deep-water trap has gained favor, and now provides 20 percent of the offshore catch.

Lobster Research

Lobster research in the Laboratory has four goals:

1. To learn if the lobster fisheries of the coast and continental shelf are linked through the movements of young or adult lobsters.
2. To assess the abundance and distribution of the offshore stock that in recent years has made an increasingly important contribution to the domestic fishery.

Maine lobstermen

in the 1890's . . .

by a stainless steel toggle in the back muscle between the carapace and abdomen, the area where the old shell opens at the beginning of a molt. Tank and field tests have both proved that the tag is retained by a molting lobster.

Since 1966 nine thousand lobsters have been tagged and released in the fishing areas of the coast and the continental shelf. Recaptures show that coastal lobsters remain in their chosen territories; offshore lobsters, however, moved considerable distances, one-third of them having been recaptured over 50 miles from the tagging sites. The varying depths of recapture indicate that some offshore lobsters move into the coastal waters of southern New England in the spring and return to deep water in the fall.

The use of biochemical methods for separating stocks is based on the knowledge that the structure of proteins is under genetic control. Nearly all living species are highly

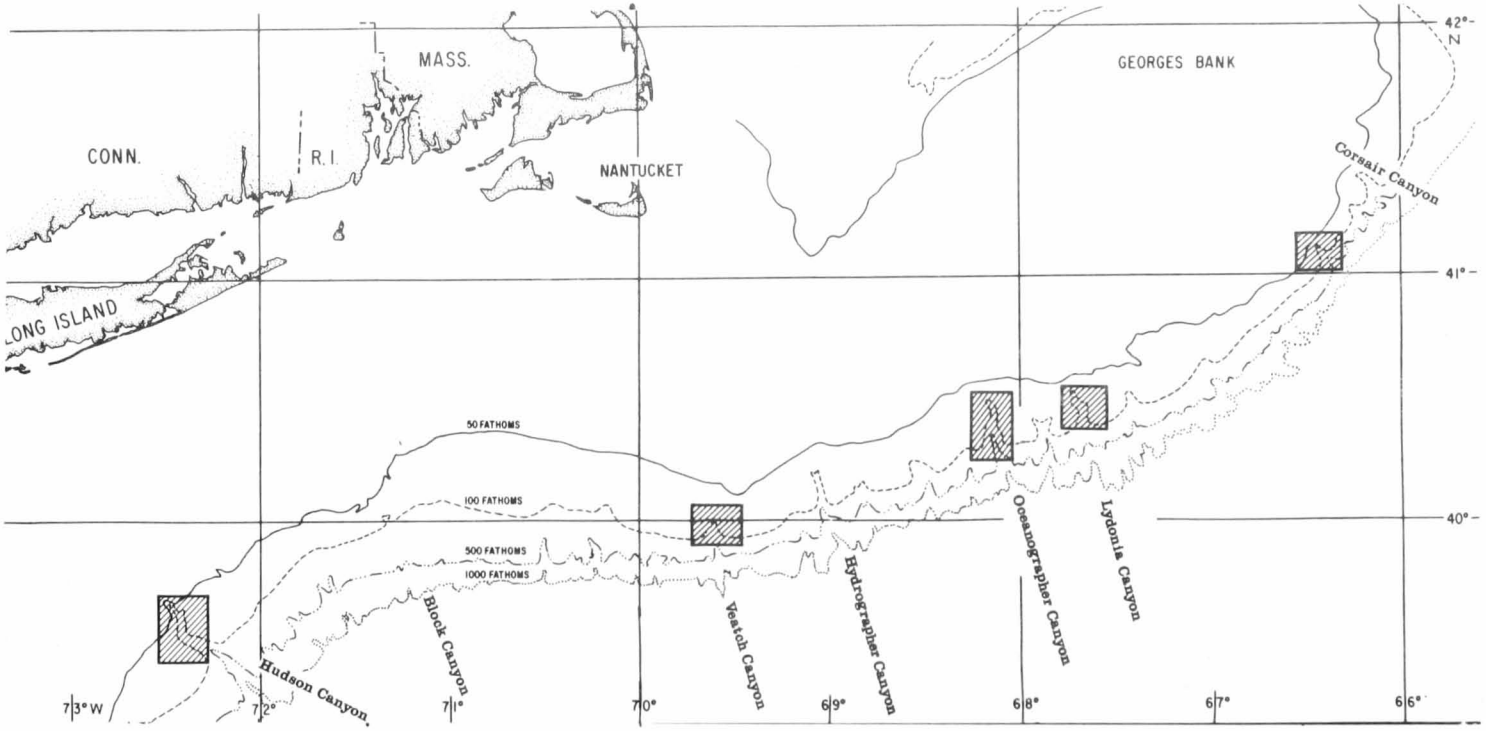
. . . and . . .

3. To obtain an understanding of the lobster's life history and environment necessary for management of the resource.
4. To develop methods of lobster farming that will help the industry to meet the demands of a growing population.

A self-contained group of lobsters is called a stock; it maintains itself in its own area by feeding and reproducing; its members do not emigrate from the stock, nor are they joined by immigrants from other stocks. Fishermen may crop one stock without affecting another, even though they so deplete their own area that fishing becomes unprofitable. To identify the stocks which supply United States fishermen, the Laboratory staff employs tagging, parasitology, biostatistics, and biochemistry.

Tagging is a direct, positive method for tracking a lobster's movements. A numbered sleeve of plastic is anchored

. . . in the 1970's. Everything has changed but the traps.



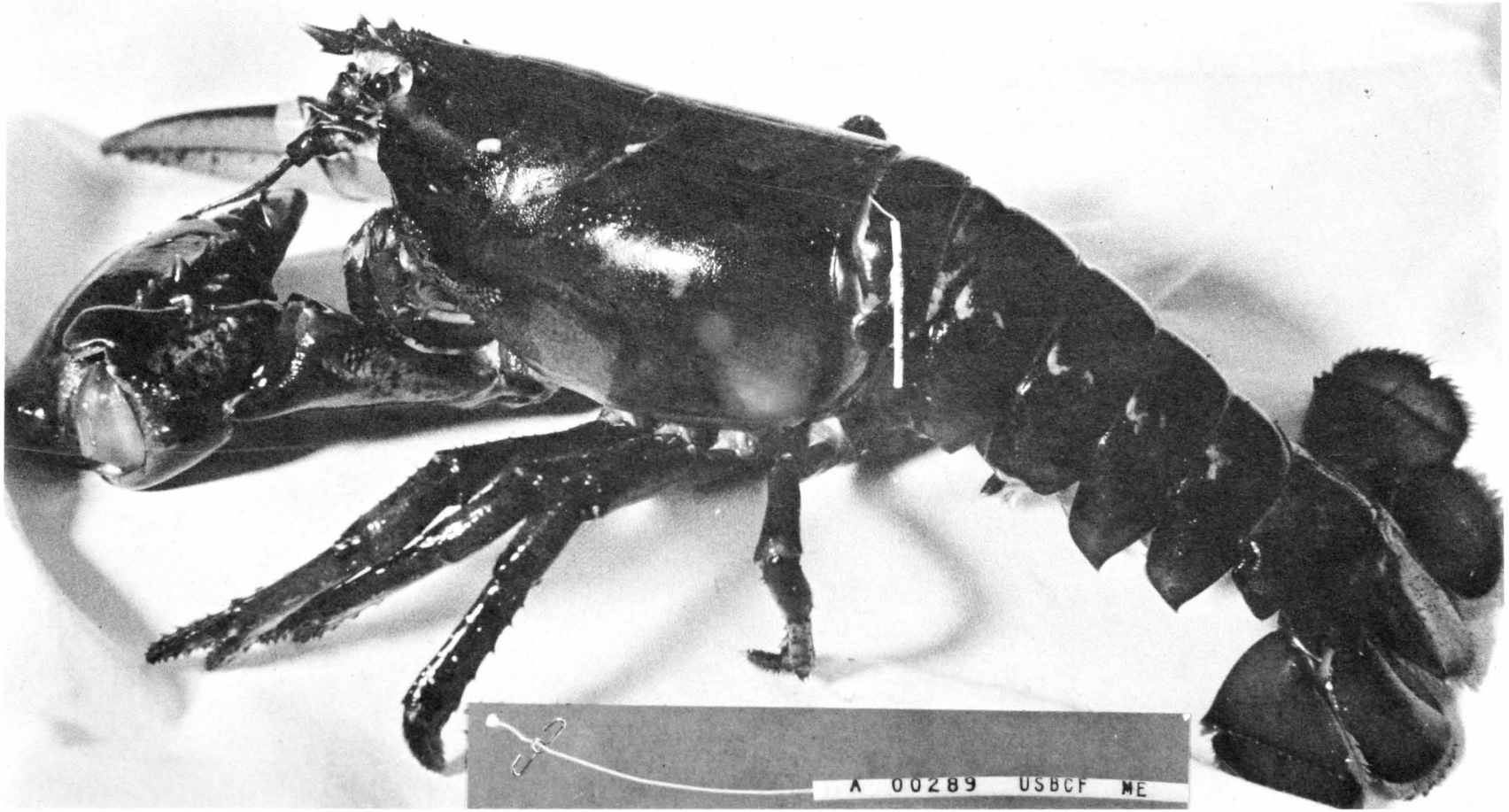
Offshore lobster grounds. The continental shelf is serrated by canyons lying 70 to 200 miles offshore. Here, particularly in the shaded areas, lobsters are caught in deepwater trawls.

variable for a variety of genetically-controlled forms of proteins and enzymes. Separate stocks differ in the frequencies of occurrence of these variant forms. The studies at the Laboratory show that lobsters are biochemically variable, and the forms are being studied to find differences which might tell whether separate stocks exist.

The offshore group of lobsters now supplies 20 percent of the domestic catch. To assess the abundance and distribution of lobsters, we are measuring catch, fishing effort, size, and sex distribution of the offshore harvest. Records are obtained through port samples and research cruises. Evidence of stock identity is sought in the catches from major canyon areas along a 300-mile range of the continental shelf.

Lobster farming offers hope for augmenting the fishermen's catches, which cannot meet the demands of expanding markets. We are studying the effect of temperature and diet upon growth of the lobster. We must learn how to reduce the growing time of 5 to 7 years now required for a lobster to grow from egg to market size. The problems of disease, cannibalism, and failure to molt successfully must be solved before lobster culture is practicable.

The distribution and abundance of lobsters in coastal areas



A tagged lobster. The tag (inset), based on a Canadian design, consists of a stainless steel toggle attached by nylon filament to the numbered sleeve. The toggle is embedded with a hypodermic needle in the back muscle at the point where the shell first opens at molting. Most of the tags are retained when the new shell forms.

according to size, sex, and molting condition have been studied by the Laboratory's scuba divers to learn the effects of seasonal change, water temperature, depth, predators, and types of habitat.

In 1966 several barge-loads of granite were placed in the ocean near Boothbay Harbor. The stones formed an artificial reef 50 to 80 feet deep that was colonized by about 50 lobsters and a variety of fish, crabs, and scallops. Studies of the reef by scuba divers have provided new insights to the behavior and requirements of the lobster and its relation to other marine life.