ARTICLES

GROUNDFISH SURVEY PROGRAM OF BCF WOODS HOLE

Marvin D. Grosslein

Otter trawl surveys of groundfish populations in New England waters have been conducted from time to time over the last 20 years by BCF's Biological Laboratory at Woods Hole, Massachusetts. The frequency and scope of these surveys increased markedly after acquisition of the new research vessel 'Albatross IV' in 1963. Nine surveys in 1963-65 represented 3 seasons each year and covered the Continental Shelf out to a depth of 360 meters (200 fathoms), from Long Island to western Nova Scotia. This was about 60,000 square miles. In 1967, the survey area was extended south to Cape Hatteras, N. C., in response to increasing concern over foreign exploitation of the stocks of fish in the Middle Atlantic Bight (Fig. 1). The total survey area now covers nearly 75,000 square miles. It is being covered twice a year, one cruise each spring and fall.

Principal objectives of the survey program are:

1. To monitor fluctuations in structure and size of fish populations--to provide a measure of the effects of fishing that is independent of commercial fishery statistics.

2. To assess the fish production potential of Atlantic coastal waters.

3. To determine environmental factors controlling fish distribution and abundance.

4. To provide basic ecological data on fishes (e.g., growth rates and food) necessary to understand interrelationships between fish and their environment.

METHODS

Routine Data Collected

Routine data recorded for each survey trawl haul include length frequency and total weight of every fish species in the catch--and invertebrates such as lobsters, shrimp, scallops, and squid. Scales or otoliths are also collected routinely for several important groundfish species to estimate age composition, and from this information, mortality rates. Water temperature profiles from surface to bottom are taken routinely throughout the region. Since 1968, fish eggs and larvae have been sampled with plankton nets down to 50 meters simultaneously with otter-trawl hauls. A wide variety of other kinds of data is also collected. This depends on available personnel and needs of individual investigators within and outside BCF.

Machine Processing Methods Developed

So far, only preliminary analysis of part of the survey data has been possible. The minimum routine information collected on a single cruise represents a formidable quantity of data, and comprehensive analysis requires automatic data processing (ADP) methods. Development of ADP capability at the Woods Hole Laboratory has now reached a point where, for the first time, it is feasible to begin an adequate analysis of the basic survey data--past and present.

Sampling Design Tailored to Objectives

One prerequisite for successful monitoring of changes in fish abundance is an objective measure of the precision of the abundance index: that is, the sampling error of the average catch per haul of the research trawl. This requirement, plus consideration of the nature of groundfish distribution, led us to adopt a stratified random sampling design for the surveys. The entire area from Cape Hatteras to western Nova Scotia is now subdivided into 58 sampling strata; their boundaries were selected chiefly on the basis of depth--which is known to be correlated with groundfish distribution (Fig. 2). Trawl stations are

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Note: Figs. 5, 7, 8, 9, and 10 are in the appendix in reprint (Sep. No. 846) of this article. For a free copy of the Separate, write to Division of Publications, U.S. Department of the Interior, Fish and Wildlife Service, BCF, 1801 N. Moore St., Arlington, Va. 22209.

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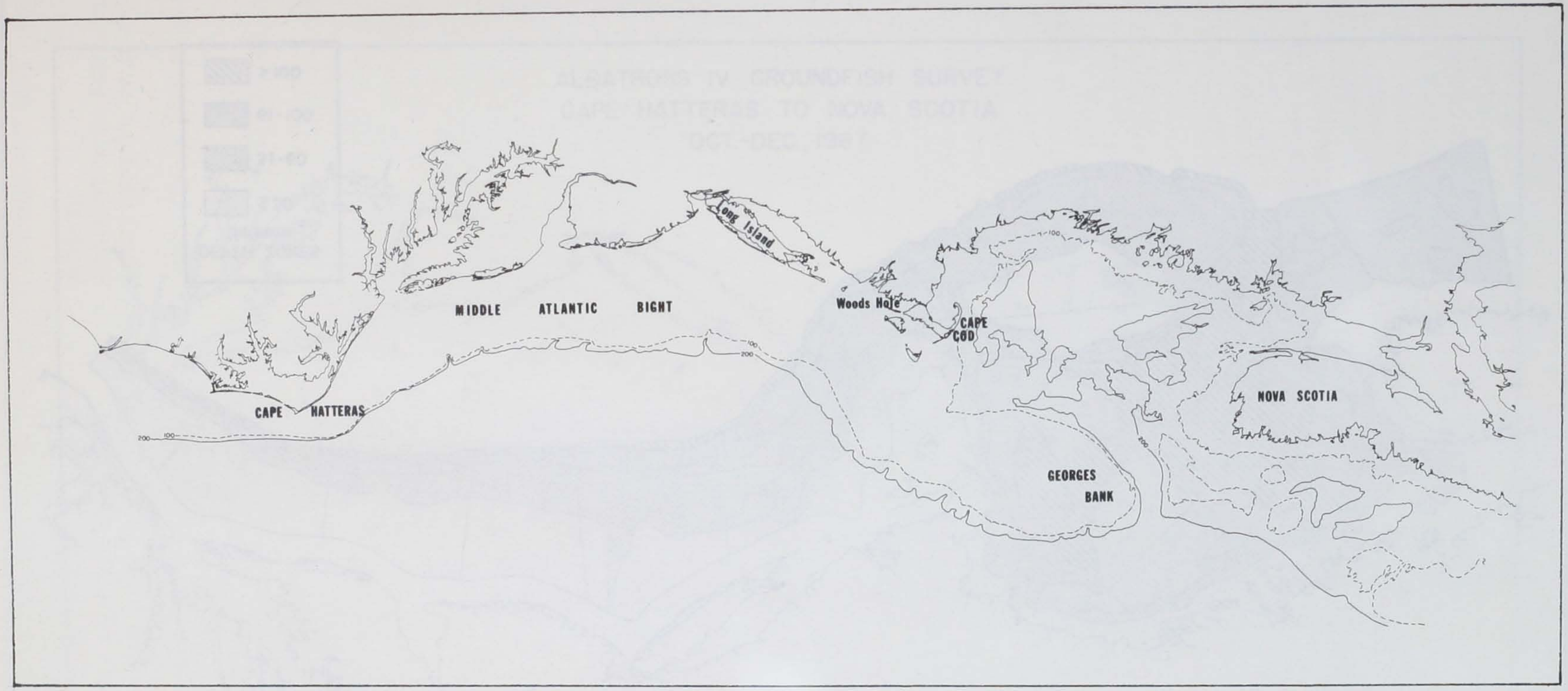


Fig. 1 - Atlantic region in which otter-trawl surveys are being made twice yearly by BCF Biological Laboratory, Woods Hole, Mass.

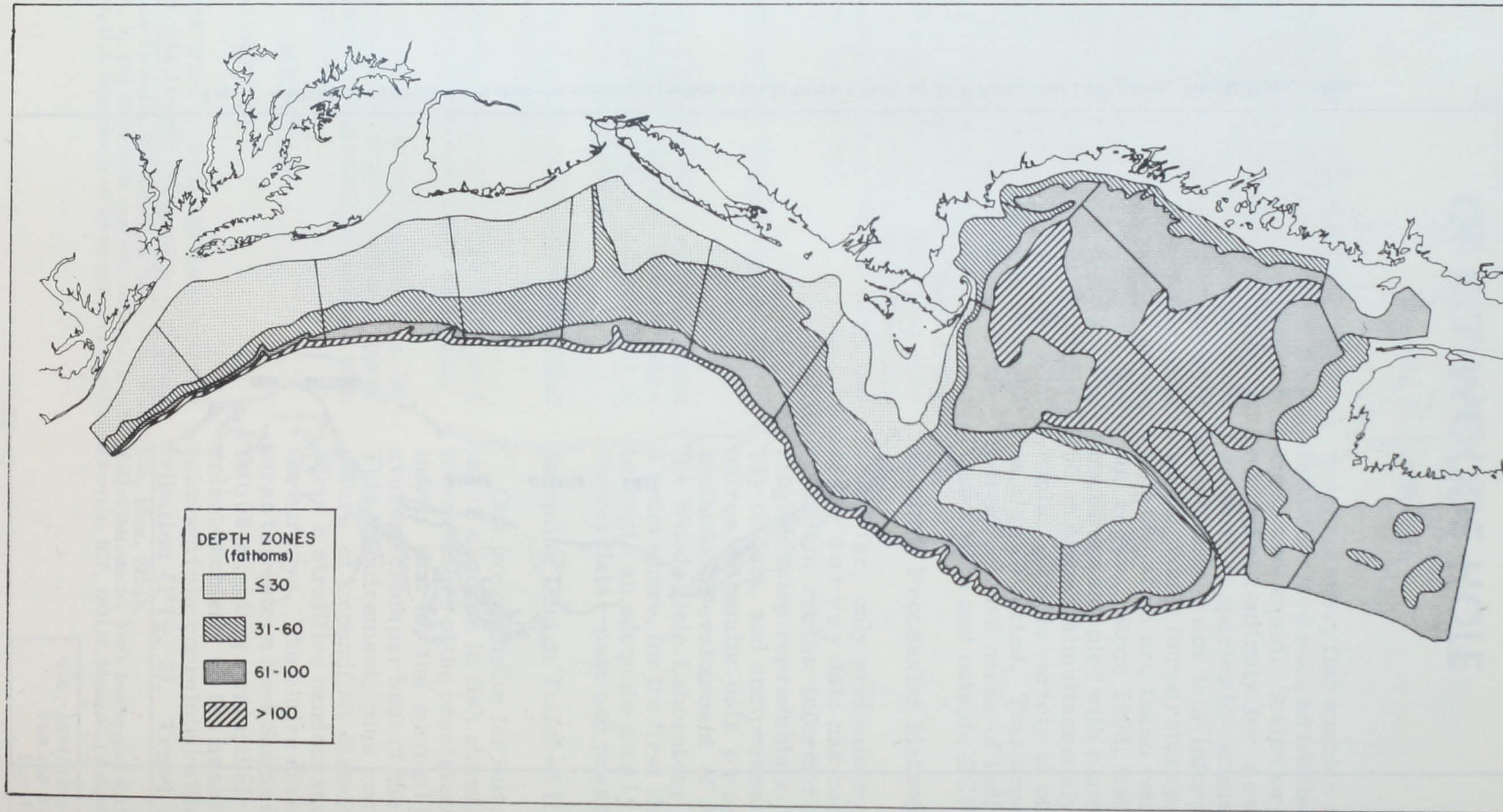


Fig. 2 - Sampling strata used on groundfish surveys with Albatross IV.

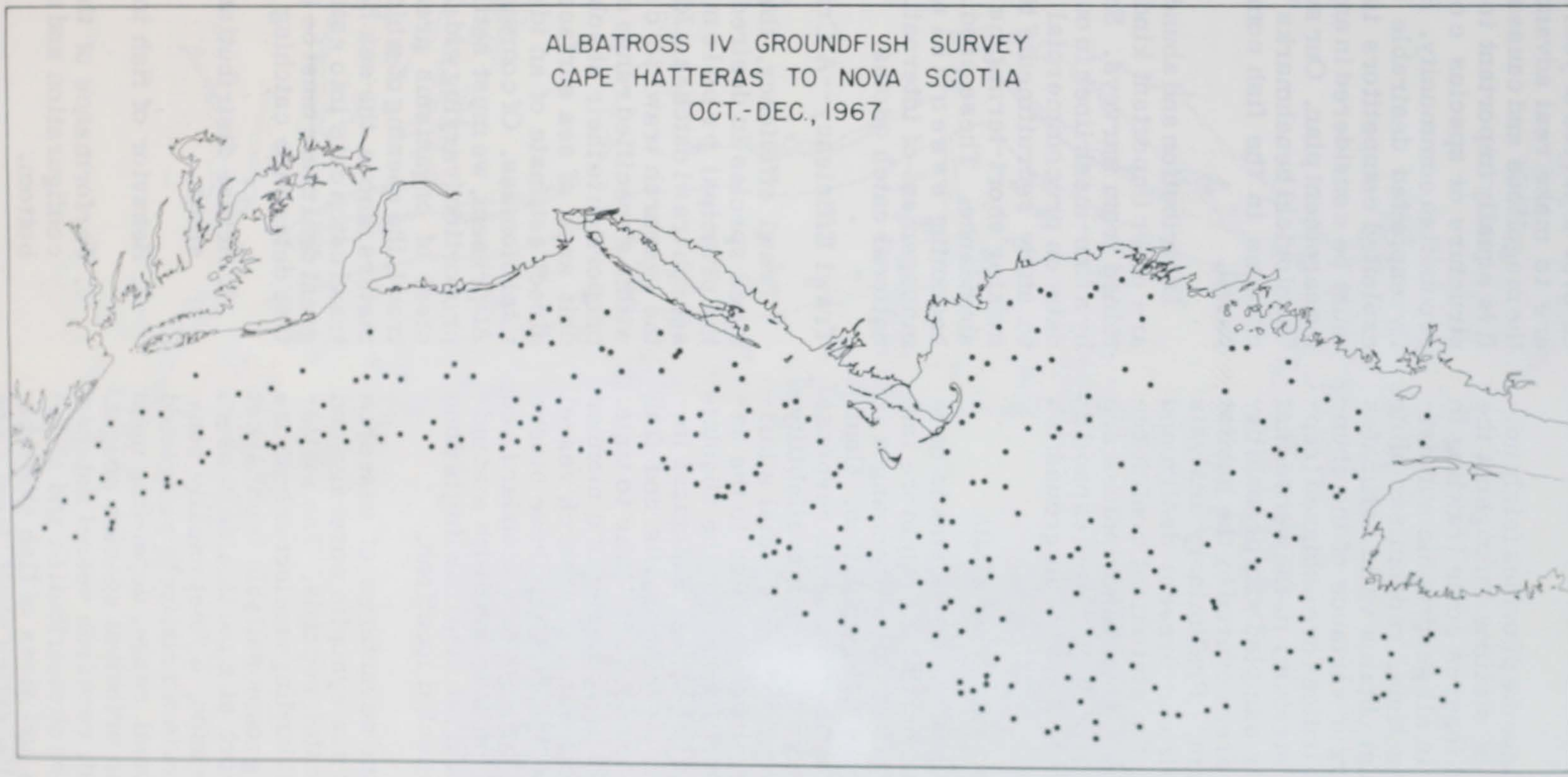


Fig. 3 - Pattern of 272 otter trawl stations occupied by Albatross IV on 1967 fall groundfish survey.

randomly located within each sampling stratum. A typical station pattern is shown in Fig. 3.

This sampling scheme provides fairly uniform distribution of stations throughout the survey region and insures some trawling in every depth zone in all geographic subdivisions. At the same time, random sampling within each stratum obtains valid estimates of the sampling error variance of the abundance indices. The indices are unbiased (representative of the stratum) in the sense that every habitat type is sampled with probability proportional to the area covered by the habitat within each stratum. Preliminary analysis indicates that, with our present design and sampling intensity, the statistical confidence intervals around our abundance indices are sufficiently small to provide a new capability in monitoring fluctuations in groundfish stocks.

Advantages of Research Vessel Data

Relative abundance indices should have small sampling error; it is even more important that they reflect faithfully changes in true abundance of the fish population. Commercial fishing practices change in response to market demand as well as fish availability. And availability from a commercial standpoint may be more closely related to the degree of aggregation of fish than to the absolute abundance. In addition, technological improvements in commercial trawls and fish detection gear occur from time to time. These increase fishing power in a manner very difficult to measure. Research vessel abundance indices are free of these biases because they are based on a standardized fishing method (30-minute haul with a standard survey trawl) and because trawling is done at randomly preselected locations.

Other important advantages of research vessel surveys are synoptic coverage and completeness of catch records. The statistics of commercial landings reflect only those species and size groups suitable for market in a particular port at a particular season. Within any one season, a fleet usually concentrates its effort in a relatively restricted portion of its annual range, depending upon aggregation of the principal species sought. On the other hand, research vessel catches provide information on distribution and abundance of all kinds and sizes of fish available to the trawl over the entire shelf, from Cape Hatteras to western Nova Scotia, within a period of 6-8 weeks.

Rapid and complete coverage of the survey area at specific seasons of the year, as well as over a period of years, is necessary if we are to make real advances in understanding the magnitude and causes of fish movements. It is equally important to monitor the general structure or species composition of the groundfish community. Replacement of heavily exploited desirable species by their unexploited competitors is a possibility that must be considered in any rational long-term management plan. Our surveys are providing "ecological benchmarks" against which future changes in the fish community can be compared.

Distribution and abundance of juvenile fish are other important kinds of information obtained from surveys. Small fish are retained by a fine-mesh liner in our survey trawl. The data on precommercial sizes are necessary to study recruitment; they are useful for making short-term predictions of future abundance. These predictions are rapidly becoming essential as we enter an era of management of international fisheries by national catch quotas.

Trawl Efficiency--A Critical Problem

Trawl efficiency, the ability to catch desired species in desired quantities, imposes the principal problem in interpreting research trawl catches. Ideally, we would like the research trawl to catch all organisms within a specified range of size, in some known proportion to their absolute numbers under a unit area of sea surface. This would give a direct estimate of an identifiable segment of total biomass. Of course, this is not possible. At present, we must settle for some unknown proportion (varying widely for different species) of organisms present in the path of a trawl, the opening of which extends only a few meters above the sea bed. To convert such trawl catch data into estimates of biomass, a great deal more must be learned about factors that determine catching power. These are:

1. Actual distribution of fish in 3 dimensions.

2. Behavior of fish in front of the trawl.

3. Performance of the trawl itself: its configuration and motion relative to the bottom.

Direct measurement of these factors will require remote sensing devices. In particular,

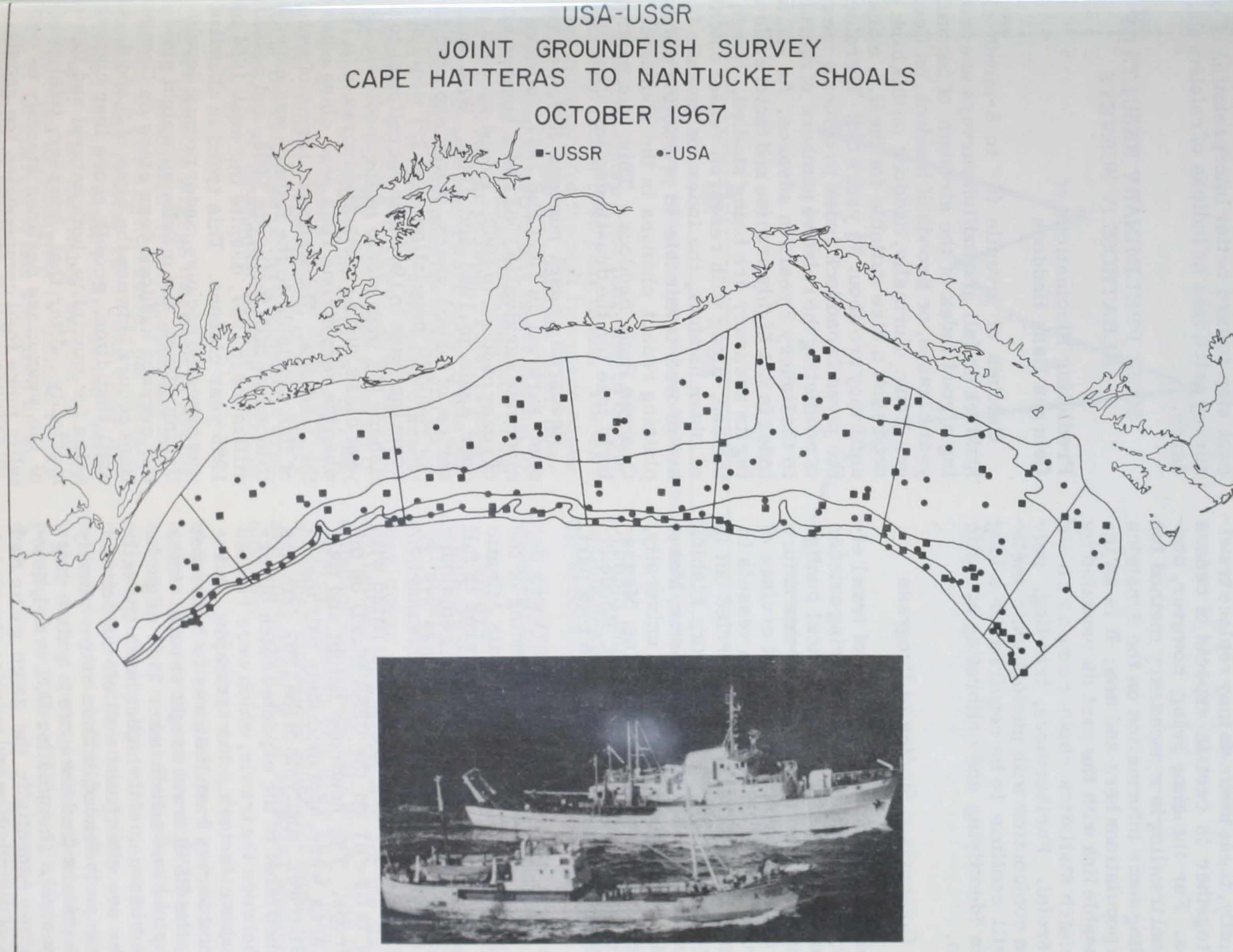


Fig. 4 - Otter trawl stations occupied by Albatross IV and a Soviet research vessel in 1967 joint groundfish survey. Albatross IV is in background (slightly ahead).

development of acoustic methods for assessing absolute abundance and distribution of fish appears to hold considerable promise. Eventually, these methods may replace trawling altogether in certain aspects of census studies. For the time being, however, conventional trawling is a necessary method for providing some information on the dynamics of fish populations here and now. It is an indispensable link with the past as revealed by trawl catch statistics--both research and commercial. Furthermore, trawling, perhaps in conjunction with photographic methods, will continue to be required for a long time in identifying and calibrating acoustic targets.

Trawl Comparison Studies in Progress

Some insight into the problem of trawl efficiency can be obtained by comparing catches of different trawls for which physical configurations are known. Studies of this nature were conducted as part of the joint cruises of Albatross IV and USSR research vessels in 1967 and 1968. These were carried out in cooperation with BCF's Exploratory Fishing and Gear Research Base at Gloucester, Mass. (Fig. 4). Biologists from state, university, and Federal laboratories in Maine, Massachusetts, New York, New Jersey, Rhode Island, Maryland, and Virginia also took part.

The first cruise (October 1967) was designed to improve our understanding of the dynamics of fish stocks in the Middle Atlantic Bight. The same area was covered in fall 1968; then it was extended to the remainder of the Albatross IV survey area (see Fig. 2).

The U.S. survey trawl was fitted with rollers (absent on the USSR trawl) on the groundrope. The headrope height and total mouth area were approximately half that of the USSR trawl. Analysis of the 1967 data has confirmed most of the expected catch differences between the trawls, which were related to the above factors. For example, on the 1967 joint survey from Hatteras to Nantucket shoals, the USSR trawl caught several times as many red and silver hake. This might be expected because of its higher headrope (silver hake are often found well off the bottom) and because it tended bottom more closely without rollers (red hake are a bottom-hugging species). The smaller U.S. trawl, however, gives essentially the same general picture of distribution and relative abundance (Fig. 5 in appendix). The final results of these joint studies, which are still being analyzed, will provide valuable data on factors affecting fishing power. The results will be a significant step toward better interpretation of our survey catch data as indices of relative abundance.

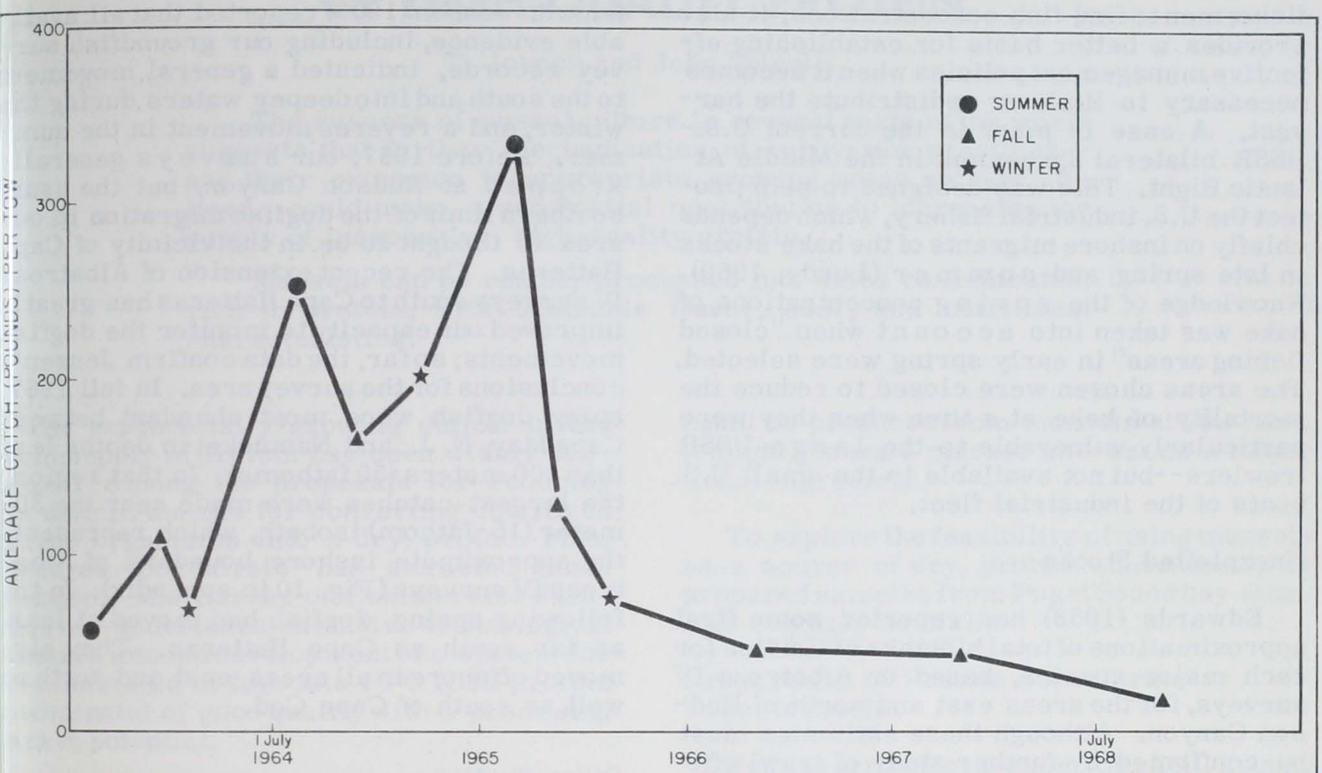
SOME PRELIMINARY RESULTS OF ALBATROSS IV SURVEYS

Predicting Fluctuations of Georges Bank Haddock

Catches of juvenile (6- to 8-month-old) haddock on fall groundfish surveys are proving a good index of the strength of incoming year classes, or broods of haddock, on Georges Bank. Normally, haddock on this bank do not reach a size suitable for the U.S. market until they are about $2\frac{1}{2}$ years old. Therefore, the juvenile haddock index provides a means of predicting the relative numbers of recruits to the fishery 2 years in advance. As yet, the index is not highly precise and factors affecting its accuracy are being studied. Nevertheless, along with research vessel catches of older haddock, the index for juvenile fish has proved invaluable in predicting and explaining recent changes in the abundance of Georges Bank haddock. This was particularly true for the drastic decline since 1965.

Research vessel surveys indicated very poor survival in 1960 and 1961, followed by moderate survival in 1962 and a bumper crop of young haddock in 1963. Brood success was poor again in 1964 and 1965. With such a series of brood years, it was expected that the fishable population (age 2+) would show some increase in 1964 with recruitment to the fishery ($4\frac{1}{2}$ inch mesh) of the moderate 1962 year class, and a substantial increase in 1965 when the very strong 1963 year class entered the landings. Abundance in terms of weight of fish available to the fishery was expected to increase still further in 1966, and possibly still more in 1967, despite the weak 1964 and 1965 year classes. This trend in abundance was expected because, under normal levels of fishing effort, the maximum weight yield of the average haddock year class on Georges Bank occurs between the ages of 3 and 4. Up until that time, growth more than compensates for mortality, both natural and fishing mortality. After that, however, total weight of the year class declines steadily as mortality more than compensates for growth.

The expected increases in total abundance for 1964 and 1965 occurred as shown in fig. 6.



ig 6 - Haddock abundance indices (average catch per 30 minute haul with standard survey trawl) for Georges Bank from Albatross IV groundfish surveys.

ge analysis showed the increase to be due rincipally to the 1963 year class. The ex-ected increases for the next two years never naterialized for the U.S. haddock fleet, how-ver, because of extremely heavy fishing by oreign fleets on Georges Bank haddock in the atter half of 1965 and in 1966. Total landings n each of those 2 years were about triple the revious long-term annual average, and large umbers of the 1962 and 1963 year classes ndoubtedly were removed. A substantial roportion of the 1963 year class apparently vas removed in 1965 and the first half of 1966 efore full recruitment of that year class to he U.S. fishery. The effects of such heavy ishing are reflected in the precipitous drop n Albatross IV abundance indices early in 1966 (Fig. 6).

In addition to a large increase in fishing nortality generated by the sudden increase in fishing by foreign vessels, the juvenile haddock index for the 1966 year class was low: the 1967 year class index was the lowest on record. The inevitable serious decline vas reflected in Albatross IV indices shown in fig. 6. Of course, it has appeared as well in the scarcity of haddock to the commercial trawlers. The 1968 juvenile haddock index also was very low. Therefore, the earliest possible improvement in haddock abundance on Georges Bank is in 1971. It will depend on the success of the 1969 spawning.

Distribution and Seasonal Movements

Surveys on the scale of the Albatross IV series are particularly valuable in determining the relation between fish distribution and environmental factors. The reason is that they cover a large area within a short time and neither the environment nor the fish distribution will change very much. With proper spacing, surveys can measure efficiently seasonal migrations which, for most species, are correlated with seasonal temperature changes.

Red and silver hake, for example, are in shoal waters during summer and autumn when bottom temperatures are high (maximum in autumn). They move off the shoals into deeper water during the winter, presumably in response to winter cooling; they are concentrated along the shelf edge in deeper, warmer water during spring, when shoal water temperatures are lowest (Figs. 7, 8, 9, in appendix).

Improved knowledge of distribution and seasonal movements makes it easier for fishermen to find fish concentrations; it also provides a better basis for establishing effective management policies when it becomes necessary to limit or redistribute the harvest. A case in point is the current U.S.-USSR bilateral agreement in the Middle Atlantic Bight. This was designed to help protect the U.S. industrial fishery, which depends chiefly on inshore migrants of the hake stocks in late spring and summer (Lundy, 1969). Knowledge of the spring concentrations of hake was taken into account when "closed fishing areas" in early spring were selected. The areas chosen were closed to reduce the mortality of hake at a time when they were particularly vulnerable to the large USSR trawlers--but not available to the small U.S. boats of the industrial fleet.

Unexploited Stocks

Edwards (1968) has reported some first approximations of total biomass estimates for each major species, based on Albatross IV surveys, for the areas east and north of Hudson Canyon. Although these estimates must be confirmed by further study of trawl efficiency, they have served to focus attention on certain abundant species that so far have not been exploited.

For example, the largest single unexploited resource is the spiny dogfish, which has long been a nuisance to most U.S. fishermen. Since the dogfish is caught and sold for food in the eastern north Atlantic, the population off our coast very likely will be harvested in the near future.

Spiny dogfish migrate seasonally, but the nature of these movements is not yet well known. Jensen (1969) reported that all available evidence, including our groundfish survey records, indicated a general movement to the south and into deeper waters during the winter, and a reverse movement in the summer. Before 1967, our surveys generally stopped at Hudson Canyon, but the usual southern limit of the dogfish migration in our area is thought to be in the vicinity of Cape Hatteras. The recent extension of Albatross IV surveys south to Cape Hatteras has greatly improved our capacity to monitor the dogfish movements; so far, the data confirm Jensen's conclusions for the survey area. In fall 1967, spiny dogfish were most abundant between Cape May, N. J., and Nantucket in depths less than 100 meters (55 fathoms). In that region, the largest catches were made near the 30-meter (15-fathom) isobath, which represents the approximate inshore boundary of Albatross IV surveys (Fig. 10 in appendix). In the following spring, dogfish had moved at least as far south as Cape Hatteras. They also moved offshore in all areas, east and north as well as south of Cape Cod.

Other Studies

Details of the studies mentioned above and many others will be forthcoming in the next few years in papers by BCF biologists. The groundfish surveys also are providing valuable data for many non-BCF scientists. In particular, there are current investigations by state biologists, graduate students, and others on various phases of the ecology of several species of hake, squid, flounders, dogfish, crabs, butterfish, skates, and sea robins.

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