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An Evaluation of the Bottom Trawl Survey Program of the Northeast Fisheries Center

Survey Working Group, Northeast Fisheries Center

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EXECUTIVE SUMMARY

In March of 1986 the Survey Working Group (SWG), consisting of personnel from the Population Dynamics and Population Biology Branches of the Conservation and Utilization Division as well as staff from the Fisheries Ecology Division, began an evaluation of the Northeast Fisheries Center (NEFC) bottom trawl survey program. Objectives were to:

1) document significant aspects of the Woods Hole bottom trawl survey program, including its history, areas covered, and vessels, gear, and procedures used;

2) document current assessment-related uses of survey data;

3) evaluate current levels of precision attained;

4) investigate methods of improving survey precision and reliability; and

5) study the implications of changes in sampling intensity including modifications in existing survey coverage.

Results are intended for use by personnel within NEFC and other organizations for scientific research purposes and by agencies responsible for design and implementation of resource surveys. The following report summarizes the results of this evaluation.

I. OVERVIEW OF THE NEFC BOTTOM TRAWL SURVEY PROGRAM

The SWG reviewed major features of the NEFC bottom trawl survey program. Significant aspects are as follows:

1) The program was initiated in Summer of 1963. To date, 62 offshore surveys at depths >27 m (15 fm) and 40 inshore surveys at depths <27 m have been completed. Offshore spring and autumn surveys (dating back to 1968 and 1963, respectively) provide the longest time series; winter and summer surveys have also been run intermittently. Inshore survey coverage was initiated in 1972.

2) Spring and autumn survey coverage has included the region from Cape Hatteras to the Scotian Shelf since 1967. Additional coverage of areas south of Cape Hatteras was provided in most spring and autumn surveys from 1978-1985 but since the latter year most of this coverage has been discontinued. Inshore coverage has been more variable and has generally been most intensive in the Middle Atlantic region.

3) Vessels and gear have been standardized insofar as possible so as to provide consistent results. Offshore surveys and most inshore surveys have been conducted aboard R/V ALBATROSS IV and R/V DELAWARE II. A standard "36 Yankee" trawl has been used in all autumn surveys and in spring surveys conducted from 1968 to 1972 and since 1982, while a modified "41 Yankee" trawl was used in spring surveys from 1973 to 1981. Both trawls are equipped with a 1.25 cm (0.5 inch) stretched mesh liner in the codend and upper belly for sampling juvenile fish and roller gear to make them suitable for use on rough bottom.

4) A stratified random sampling design has been used in these surveys, with stations allocated to strata roughly in proportion to area and assigned to specific locations within strata at random. Between 350 and 400 stations (one for every 200 square nautical miles) are routinely occupied during a given survey.

5) Data collected at sea includes both "station" data (location, depth, meteorological observations and sea state, expendable bathythermograph or XBT profiles, and similar information, and "biological" data (numbers, weight, size composition and sex and maturity information). Biological samples are also collected for ageing and other purposes. Plankton samples are collected at selected stations for use in other Center programs.

6) Following completion of the cruise, data are entered into preliminary data files for use in industry reports and for meeting immediate assessment and management needs. Data files are then audited, corrected as needed and merged into the master survey data base.

II. SURVEY DATA APPLICATIONS

The SWG documented assessment-related applications (relative abundance, growth, population size/age composition, mortality, maturation patterns, and recruitment indices) for each survey. Results were as follows:

1)Because of the availability of a longer and more consistent time series the autumn survey is used preferentially to provide indices of relative abundance. Spring survey data are important for providing corroboration of population trends, particularly for species for which alternative sources of information are not available.

2) The autumn survey is also used to a greater extent for developing recruitment indices. In this case, however, the importance of the spring survey is proportionally greater because of increased availability of juveniles of several species/stocks to the survey gear.

3) As a rule, data from both surveys are used for estimating biological parameters (growth, mortality, maturity, age/size composition) because of a need for the widest possible seasonal time span. Spring survey data provide an important source of maturity information for many species.

4) Surveys provide an exclusive source of assessment-related information for anywhere from 30-55% of the species considered, depending upon category.

III. PRECISION OF SURVEY RESULTS

The SWG evaluated the underlying statistical characteristics of NEFC survey data and determined the degree of precision and reliability that could be achieved using appropriate transformations. Results were as follows:

1) For most species, analyses indicated an aggregated form of distribution. The SWG partitioned catches into zero and non-zero values and took logarithms of the latter, which were found to be normally distributed. Estimators for the mean and variance of the mean for the partitioned data (Delta distribution) have been shown to be more efficient than the corresponding sample statistics in such cases. Accordingly, the SWG developed Delta distribution estimators which generally agreed closely with the corresponding sample statistics (linear scale). Standard errors were not necessarily less than those calculated from untransformed data.

2) As a general rule, precision of the Delta distribution estimators was found to be highest for demersal species, and higher in autumn than in spring. Precision for flounders tended to be generally poor, however.

3) Examination of confidence intervals about the mean suggested that for general management applications levels of precision achievable through use of the Delta distribution were reasonable for demersal species. This is less true for pelagics although we have reasonable information on pelagic species of major importance from other sources.

4) Lower precision achieved for flounders suggests the need for alternative procedures, e.g., specialized surveys to monitor trends in abundance.

IV. IMPROVEMENT OF SURVEY PRECISION

The SWG attempted to smooth random variability by fitting time series models to the Delta distribution estimators. Results were as follows:

1) Time series models proved to be very effective in filtering out random variability in the data sets examined. They also appear to provide considerable insight into reliability of individual data points and of the time series as a whole.

2) Correspondence between the smoothed indices and alternative population measures was generally very good. Discrepancies observed are thought to have resulted primarily from biases in reporting and/or analysis of commercial data.

3) Attempts to achieve maximum benefit from the surveys by combining spring and autumn data and fitting time series models to the combined data sets were less successful; no consistent differences in residual mean square error were detected between the single-season and combined season models. This result may relate to seasonal catchability differences.

V. EFFECTS OF CHANGES IN SAMPLING INTENSITY OR AREAS SAMPLED

Evaluations of relationships between vessel time, sampling intensity, and sampling precision provided the following:

1) The impact of reductions in vessel time on survey coverage can be quite significant, e.g., a 30% reduction in sea days would necessitate a 45% reduction in number of stations that could be occupied.

2) For modest losses in vessel time (<20% of current levels) reductions in precision would be minor, but precision drops rapidly if vessel time is further reduced. Reductions in the order of 35% increased the standard deviation over 50% for most species-stocks examined.

3) No consistent differences in precision were detectable between species-stocks or species groups with changes in sampling intensity.

The following modifications to existing survey coverage could be made with minimal losses in information:

a) Survey coverage south of Cape Hatteras could be eliminated.

b) Sampling intensity in offshore strata (>110 m) from Georges Bank to Cape Hatteras could be reduced by perhaps 50%.

c) Sampling can be reduced or eliminated in some inshore areas and in certain areas within the Canadian Economic Zone.

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INTRODUCTION

Since 1963, the Northeast Fisheries Center (NEFC) has conducted an intensive multispecies bottom-trawl survey program off the northeast coast of the USA. An autumn survey was initiated in 1963; a spring survey was initiated in 1968, and summer and winter surveys have also been conducted intermittently. These surveys are designed to monitor trends in abundance and distribution, to determine population age/size composition, and to evaluate the biology and ecology of a broad suite of finfish and invertebrate species. Over the years these surveys have become important multipurpose research tools, providing both an essential component of the assessment data base and opportunities to collect information used in many NEFC programs.

While these surveys have provided unbiased and generally comparable results over time, procedures used are not above question and in recent years increasing attention has been focused on the precision and efficiency of these surveys and potential methods for improvement. Questions relating to precision and accuracy for these surveys have been considered in papers by Grosslein (1971), Pennington and Grosslein (MS 1978), Pennington and Brown (1981), Pennington (1983), and Pennington and Berrien (1984). Papers by Collie and Sissenwine (1983) and Pennington (1985, MS 1985) examine the problem of between-survey variability. These studies have been extremely useful in developing the tools necessary for a comprehensive analysis of survey precision and efficiency.

In 1983, the Resource Assessment Division (now Conservation and Utilization Division, CUD) began a series of research projects designed to define and document procedural and gear changes and their impacts on the assessment data base, to examine sources of variability with particular reference to those that can be controlled, and to evaluate survey design and analytical methods. Subsequent efforts under this program have included documentation of survey gear, design, and procedures; evaluation of the impacts of changes in survey gear and procedures on catchability; re-assessments of sampling priorities; and development of at-sea data entry and auditing procedures. Particular interest, however, has been focused on sources of variability (i.e. spatial, temporal, and measurement error with particular reference to between-survey components), survey design, and methods of analysis (transformation, modelling using time-series approaches, etc.). The present study, initiated in March of 1986, represents an extension of this work and focuses directly on survey precision and efficiency.

Objectives of the present study were (1) to provide an overview of the NEFC survey data base and time series, documenting survey procedures and uses of survey data, and (2) to evaluate the precision and efficiency of NEFC bottom trawl surveys with particular reference to levels of precision attained, methods for improving survey precision and reliability, and implications of changes in sampling intensity. Analyses have been undertaken cooperatively by a working group consisting of staff members from the Population Dynamics Branch and the Population Biology Branch of CUD and the Fisheries Ecology Division (FED), hereafter referred to as the Survey Working Group (SWG), or "Group." This technical memorandum represents an interim report on this work.

OVERVIEW OF THE NEFC BOTTOM TRAWL SURVEY PROGRAM

Historical Aspects

In the early 1950's, staff members of the Bureau of Commercial Fisheries[1] Woods Hole Laboratory in Woods Hole, Massachusetts initiated surveys to gather information on the distribution and biology of commercially important fish species aboard the R/V ALBATROSS III. Cruises were conducted on Georges Bank and the Gulf of Maine to locate concentrations of redfish, Atlantic cod, haddock, and Atlantic herring in order to determine their abundance and spawning capacity. While these cruises provided useful data for a variety of purposes, procedures and temporal and spatial coverage were variable, detracting considerably from the value of the data base. The need was obvious for a repeatable survey employing standardized procedures and equipment which would not only provide comprehensive data on biology and distribution but would also provide a fishery-independent source of data for monitoring and predictive purposes.

Accordingly, a comprehensive bottom trawl survey program was initiated in 1963 employing standard gear and sampling procedures which has been continued to the present day. Objectives of this program were to monitor population fluctuations, to assess the fish production potential off the northeast coast, to determine environmental factors controlling the distribution and abundance of fish species, and to provide the basic ecological data required to understand interrelationships between fish and their environment (Grosslein 1969). The resulting data base has been extremely valuable for fish stock assessments and has also been widely used for other applications.

The first survey cruises covered the region from the Hudson Canyon to

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[1]Now National Marine Fisheries Service (NMFS).

western Nova Scotia (Figure 1, strata 1 to 49) in depths of 27 to 366 m (15 to 200 fm). This area was surveyed in summer, autumn, and winter from the summer of 1963 (the first survey) through the winter of 1966. Beginning in autumn 1967, survey coverage was extended south to Cape Hatteras, North Carolina (Figure 1, strata 61-76). A spring survey time series was initiated in 1968. The autumn survey has continued uninterrupted since 1963 and forms the longest time series (Table 1).

In 1972, coverage was expanded into inshore areas at depths shallower than 27 m (15 fm). Few stations have been occupied shallower than 9 m (5 fm) due to vessel safety considerations. Inshore strata from Eastport, Maine to Buzzards Bay, Massachusetts are shown in Figure 2; inshore strata from Cape Cod Bay to Cape Hatteras are shown in Figure 3. These cruises have provided at least partial coverage of inshore areas from New England to the Carolinas since 1972 (Table 1).

In autumn of 1974, the NEFC provided funds to the State of South Carolina to survey the inshore and offshore areas from Cape Fear, North Carolina to Jacksonville, Florida (Figure 4, inshore strata 66-91, offshore strata 78-93). See Azarovitz 1981. As NMFS coverage extended only as far south as Cape Hatteras, a small gap in coverage was created between Cape Hatteras and Cape Fear (Figure 4, inshore strata 51-64, offshore strata 50-77) which was surveyed beginning in autumn of 1978. Shortfalls in vessel time, and limited applicability of data collected from south of Cape Hatteras for NEFC research purposes have since resulted in more limited coverage of that region, i.e., only the region from Cape Hatteras to Cape Lookout, North Carolina (Figure 4, inshore strata 51-52, offshore strata 50-53) is now being sampled. For similar reasons South Carolina no longer conducts a broadscale ecological survey but concentrates on estuarine and hard bottom/reef areas.

A summer survey was initiated in 1963 and conducted from 1963-1965 and again in 1969 (Table 1). A more specialized summer survey time series was initiated in 1977 to provide additional data with special reference to species of recreational interest (Azarovitz 1981). Coverage of areas shallower than 110 m (60 fm) was stressed on this survey since many economically important species tend to concentrate in these areas during summer. This survey was discontinued in 1981 after further analyses showed that many important species actually tended to concentrate in estuaries and were, therefore, unavailable for capture. A winter survey time series was also conducted during 1964-1966; and a specialized winter survey time series was initiated in 1981 concentrating primarily on areas shallower than 27 m (15 fm). The primary intent of this survey was to collect biological data on Atlantic herring. This survey was discontinued in 1985.

The NEFC survey data base has also been augmented by cooperative cruises with foreign nationals. Intensive exploitation of fishery resources in USA continental shelf waters during the mid-to-late 1960's and increasingly restrictive management under the International Commission for the Northwest Atlantic Fisheries or ICNAF led to cooperative surveys with the Soviet Union, the Federal Republic of Germany, France, the German Democratic Republic, Japan, Poland, Spain, and Canada. Since passage of the Magnuson Fisheries Conservation and Management Act (MFCMA) such activity has been much reduced and in recent years only Poland has participated in cooperative surveys. Data from these surveys have been highly valuable in specific instances, e.g., initial gear trials employing the USA "36 Yankee" trawl (described below) and Soviet commercial gear were instrumental in demonstrating the utility of the NEFC survey data base for monitoring trends in abundance and species composition (Grosslein MS 1968). Joint USA - Soviet studies were also valuable in development of conversion factors for USA gear which have since been widely used (Sissenwine and Bowman 1978). As a rule, however, cooperative surveys with foreign nationals have not been as valuable as NEFC surveys because of the variety of vessels, gear and procedures involved.

Vessels and Gear

In the above time series, vessels and gear have been standardized insofar as possible to provide consistent results. Offshore and most inshore surveys have been conducted aboard the National Oceanic and Atmospheric Administration (NOAA) R/V ALBATROSS IV, a 57 meter (187 foot) stern trawler and R/V DELAWARE II, a 47 meter (155 foot) stern trawler. Specifications for both of these vessels are given in Table 2. Several inshore survey cruises during 1972-1975 were conducted aboard R/V ATLANTIC TWIN, a smaller vessel designed for inshore studies.

Three bottom trawls have been used in this program. A "36 Yankee" trawl has been used in all autumn surveys and in spring surveys conducted between 1968 and 1972 and from 1982 to the present (Table 1). From 1973 to 1981, however, a modified high opening "41 Yankee" trawl was used during spring surveys in an attempt to increase fishing power for pelagic species. Both trawls are equipped with roller gear to make them suitable for use on rough bottom and a 1.25 cm (0.5 inch) stretched mesh liner in the codend and upper belly for sampling juvenile fish. A "3/4 Yankee" trawl rigged with a chain sweep and ground cables was used aboard R/V ATLANTIC TWIN during several inshore cruises between 1972 and 1975. Again, the "3/4 Yankee" was equipped with a 1.25 cm stretched mesh liner. Specifications for the "36 Yankee" and the "41 Yankee" trawls are given in Table 3.

The "41 Yankee" trawl was fished with BMV oval doors weighing 682 kg (1,500 lb). Until 1985, the "36 Yankee" was fished with lighter BMV oval doors weighing 545 kg (1,200 lb). In the spring of that year these were replaced by Portuguese-type polyvalent doors of approximately the same weight since it was becoming increasingly difficult to obtain BMV oval doors built to standard specifications. Studies are presently underway to determine effects of this door change on fishing power.

Sampling Design

The sampling design used in this program is stratified-random, with stratification being based on depth, latitude, and historic fishing patterns. Seven primary depth zones have been recognized, as follows:

Inshore Strata		Offshore Strata	
Meters	Fathoms	Meters	Fathoms
<9	<5	27-55	15-30
9-17	5-9	56-110	31-60
18-26	10-14	111-183	61-100
		>183	>100

This system has been used for all offshore strata and all inshore strata from Cape Hatteras to eastern Long Island. Further north and east, different depth zones have been used on occasion due to irregularities in bottom topography (Table 4).

Given that the original stratification scheme is valid, this design can be expected to provide increased precision relative to simple random sampling and has other desirable features, e.g., it insures a fairly uniform distribution of stations throughout the survey area yet provides flexibility for increased sampling intensity in critical areas if needed. In the present program, sampling stations are allocated to strata roughly in proportion to area (which facilitates post-stratification if necessary). Some inshore and deeper offshore strata have been sampled more intensively, because they have been assigned a minimum of two stations to permit variance computations. Certain strata off Southern New England and on Georges Bank have also been sampled more heavily because of assessment priorities. Areas of individual strata sampled in this program, together with the average number of stations historically sampled in each, are given in Table 4. (See also Figures 1-4, depicting individual strata).

Following Cochran (1977) the stratified mean catch per tow and its variance are expressed as:

$$\bar{y}_{st} = \sum_{h=1}^{\ell} \frac{N_h \bar{y}_h}{N}$$

and

$$V(\bar{y}_{st}) = \frac{1}{N^2} \sum_{h=1}^{\ell} \frac{N_h^2 \, s_h^{\,2}}{n_h}$$

where N = total area of all strata;

N_h = area of Stratum h;

$\bar{y}_h$ = sample mean in Stratum h;

$s_h^{\,2}$ = sample variance in Stratum h;

n_h = number of sample observations in Stratum h, and

ℓ = number of strata in the strata set.

An approximate confidence interval about the stratified mean (using a large-sample approximation) may be calculated as:

$$\bar{y}_{st} \pm 1.96[V(\bar{y}_{st})]^{1/2}$$

The exact expression for the confidence interval is given by Cochran (1977: 95-96).

Station Selection

Sampling stations are selected as follows. Each stratum (Figures 1 through 4) is divided into rectangular units of 5 minutes of latitude by 10 minutes of longitude. Each rectangular unit is further subdivided into 10 sampling locations of 2 1/2 minutes of latitude and 2 minutes of longitude which are numbered consecutively. Each location is considered to be homogeneous, requiring only one station to characterize it. A random number generator is used to locate the appropriate number of stations within each stratum. If two stations are selected within a 5 x 10 minute unit, the second is eliminated and another selection is made. Stations are plotted on nautical charts before each cruise. Between 350 and 400 stations (approximately one station for every 200 square nautical miles) are routinely occupied during seasonal survey cruises.

In recent years, increased activity by fishermen employing fixed gear in both inshore and some offshore strata has made it necessary to relocate stations or to drop them altogether. In order to avoid this gear, these stations are often occupied only during daylight hours, possibly introducing bias to the data base. Known hard bottom areas may also be avoided with stations being moved by as much as several nautical miles.

Cruise tracks are designed to provide synoptic coverage of major species/ stock areas and to facilitate travel between stations in as short a time as possible. The direction of each tow is generally made toward the next station, although exceptions may be made due to strong currents, inclement weather, known hard bottom areas and attempts to follow depth contours. A survey cruise requires from 45-55 days.

Data Collection at Sea

Work is conducted on a 24-hour basis with two watches of 5-6 individuals standing a 6-hour on and 6-hour off schedule. Upon arriving at a station, the position (latitude, longitude and Loran bearings) is recorded, and a surface to bottom temperature profile may be taken. From 1963 to 1970 temperature profiles were recorded on glass slides with mechanical bathythermographs. Since 1970 an expendable bathythermograph (XBT) system has been used, which produces analog chart recordings. In 1985, the XBT system was modified to permit transmission of seawater temperature profile data to shore-based facilities on a real-time basis; XBT analog chart recorders were replaced by SEAS (Shipboard Environmental Acquistion System). This is a computer based system that records digital information and transmits it via satellite. Current procedures require collection of XBT data at 1/3 to 1/2 of the total number of stations, depending on location and biological sampling requirements (for example, XBT probes are launched at stations where plankton collections are taken). Plankton tows are made at selected stations employing a 61 cm bongo frame fitted with 0.505 mm and 0.333 mm mesh plankton nets. Observations on weather, sea state and position are also recorded.

After the above information is recorded, the trawl is set with the amount of wire out (or scope) dependent upon depth. For the "36 Yankee", a 3:1 scope is used except in depths greater than 183 meters (100 fathoms) when the scope is 2 1/2:1. The net is towed at 6.5 kilometers/hour (3.5 knots) relative to the bottom for thirty minutes from the time the brake drums are set. A fathometer trace is recorded during each tow. Acoustically linked mensuration gear is now used during many tows to measure headrope height, wing spread and bottom temperature. Periodic readings are taken and averaged for the duration of the tow. Information relative to position, depth, environmental parameters, and trawl setting and performance is collectively referred to as "station data."

After haulback, the codend contents are sorted by species (spiny dogfish, lobsters and crabs are further separated by sex) and weighed to the nearest 0.1 kg. Most fish species are measured to the nearest whole centimeter (fork length). Other measures include wing width for rays, carapace length for lobsters, carapace width for crabs, shell height for scallops, and mantle length for squids. Shrimp are weighed only. For catches that are too large to sort completely, a subsample by weight or volume is taken and later expanded to represent the entire catch. All catch and station information is recorded on a two sided waterproof log (Figure 5) which serves as an original written record of all data obtained at a station.

After initial processing, ageing samples (i.e., scales or otoliths) are collected for approximately 26 species for later processing and age determinations at the laboratory. Sex and maturity information is also recorded, as well as a variety of disease observations. Stomach contents of selected species are routinely examined for food habits studies. Whole specimens or parts thereof are also preserved and documented as needed by researchers in other agencies and academic institutions. Detailed observations on marine mammals and birds are also recorded throughout the cruise, usually by experts from other organizations, e.g., Manomet Bird Observatory. A schematic outlining the general flow and disposition of this material and resulting data is given in Figure 6.

Data Processing

Initial data processing is accomplished at sea by watch chiefs and the chief scientist, who review and code all logs prior to returning to port. Weights and total number at length by species are determined; a numerical code is assigned to each species, and entry of station data (position, depth, time, etc.) is completed.

Upon returning to port, cruise logs are subjected to a second review for omissions and miscalculations, after which a station plot is created. Data are then entered into computer format and a preliminary "Fishermen's Report" is produced providing catch data (number and weight) for 24 commercially important species and environmental information for each location sampled. Catch data are also plotted by species. Similar information, together with length frequency data, is also generated by species for priority assessment requirements. This information is produced within a week of the final cruise leg (Figure 7).

Auditing of the preliminary data files is the next step (Figure 7). In the station data audit, a total of 56 parameters are compared to a computerized master data file to check for gross errors and error diagnostics are reviewed and data corrected. Temperature data recorded from XBT traces or shipboard sensors (SEAS System) are checked, verified, and merged with the audited station data when available. (Salinity data can be handled in similar fashion). A "preaudit" then compares the cruise, station and strata-tow numbers on both the station and biological records to identify inconsistencies in these four fields. Corrections are made, and the catch data audit is then submitted (Figure 7) which checks length data by species and employs length-weight equations to check observed and calculated weights. Subsampling, coding and length recording errors are most often discovered through this audit. Once audits are complete, the data are appended to the master data files.

SURVEY DATA APPLICATIONS

Stock Assessment Data

The relative utility of the NEFC spring and autumn bottom trawl surveys as a source of data for assessment-related applications has been of primary interest due to possible redundancy in these time series and potential future losses in vessel time. Accordingly, the Group documented the uses to which these data have been put.

Both surveys are important in assessing the multispecies complex off the northeast coast of the USA. Most species in this region undergo seasonal shifts in distribution, some more pronounced than others. Thus, areas of concentration for many species differ seasonally, often with a marked influence on both amount and size/age composition of the survey catch. Maturation, spawning, and recruitment also differ seasonally. It follows that the relative utility of these surveys will vary considerably depending upon species and application.

The Group considered the following categories of assessment-related information for 28 species of major commercial or recreational significance: (a) relative abundance, (b) growth, (c) population age/size composition, (d) maturity, (e) mortality, and (f) recruitment. Figure 8 documents the relative utility of each survey by species and category as reflected by the best judgement of the assessment scientist concerned (summarized in Figure 9) and also indicates whether NEFC surveys provide the only source of such information (summarized in Figure 10). Specifics for each category are discussed below.

Spring and autumn survey data have been of primary importance in monitoring trends in relative abundance. The bottom trawl surveys provide the only source of statistically valid unbiased indices of abundance and at the same time provide the only monitoring capability we have for many species for which adequate commercial information is lacking.

The autumn survey has been relied upon most extensively for development of abundance indices (Figure 8). For 23 of the 28 species considered (82%) autumn data are used in preference to spring data or at least appear to be of comparable utility (Figures 8 and 9). To a large degree this reflects the availability of a longer autumn time series and gear changes in spring as described earlier; conversion factors are not available for many species and the task of developing them is not a trivial one. Of the five monitored by spring indices, those of major commercial or recreational significance (pollock and mackerel) can be reliably tracked by virtual population analysis (VPA) or commercial catch per unit effort (CPUE). In the absence of a spring survey, alternative monitoring tools would be lacking for dogfish, skates, and ocean pout; and while these species are of minor commercial significance at present, dogfish and skates are major ecosystem components with potential significant impacts on a number of fisheries. It is probable that alternative procedures, e.g., CPUE or autumn survey modifications could provide this capability.

Although the autumn survey time series has been clearly preferable for this purpose, it should be noted that spring data are often no less important as a "backup" tool. Short-lived species, e.g., squids, also require seasonal monitoring. The capacity for "backup" monitoring becomes particularly important in the case of intensively utilized species under strict management regimes as well as for species for which no alternative measures are available, e.g., certain flounders, white hake, and cusk, which collectively comprise an important component of the New England and Mid-Atlantic fishery resource.

NEFC survey data have been widely used for evaluating growth and maturation. For growth, there tends to be more balanced usage of the spring and autumn surveys than for developing relative abundance indices. Seasonal coverage provides considerably more information, particularly for juvenile fish, since many commercial species do not recruit fully to the survey gear for a full year (spring at age 1). Such surveys also provide representative sampling of the population in space and time and data for other species of lesser importance that are not readily available from other sources. Accordingly both spring and autumn data have generally been used for growth studies (Figures 8 and 9). The spring survey has also been of considerable importance as a source of maturity data. Spring data are collected immediately before or during the spawning season of many important species, thus providing the best opportunity for determination of sexual maturity. Consequently, there has been more of a tendency to rely on spring survey data for maturation studies. These considerations indicate the importance of adequate seasonal coverage in providing biological data required for management, e.g. for development of mesh size regulations keyed to growth and maturation.

The NEFC survey data base has been utilized less for evaluation of mortality rates (Figure 8) since greater reliance has typically been placed on analysis of commercial data for this purpose. This capability has, however, been useful for intensively utilized species for which VPA's or similar analyses are lacking and for preliminary assessments. Both surveys have been used for this purpose (Figure 9).

Perhaps the most important application of survey data in general lies in determining population size and age composition with particular reference to predicting the strength of recruiting year classes. For age/size composition, use of these time series is again relatively well balanced (Figures 8 and 9). In the case of recruitment, use of autumn data again reflects the availability of a longer standard series which facilitates development of empirical relationships. On the other hand, many important species become fully available to the survey gear in spring at age 1 thus providing the earliest reliable indicator of year-class size. In addition, reliable predictions cannot be made for certain key species, e.g. mackerel and yellowtail, based on autumn survey results. The "backup" capability is equally important for other species, e.g. for haddock, only one reliable index-autumn survey catch per tow at age 1 - would be available prior to recruitment to the commercial fishery if the spring survey were to be discontinued. With the spring survey, three index values - spring and autumn survey catch per tow at age 1 and spring survey catch per tow at age 2 - are available. Given the inherent variability in survey data it is possible that we might fail to predict a large incoming haddock year class if only autumn survey data were available.

Figure 10 summarizes the relative importance of the surveys as a sole data source by category, expressed as a percentage of the total number of species in that category for which the information indicated is available. For relative abundance, the surveys provide the only monitoring capability we have for 13 of the 28 species included (46%) as well as for others of lesser importance not included in Figure 8. For growth, survey data can be supplemented by other sources although again about half our information for the species considered is supplied by this source alone (and obviously, surveys provide the only consistent source for age groups not yet recruited to the commercial fishery). Surveys are also heavily relied on in the case of the other categories of information. In the case of recruitment, historical data are provided by VPA's but the surveys provide the only basis for prediction. They also provide the only historical data source we have for the species indicated (Figures 8 and 10).

It is extremely important to note that these evaluations were intentionally directed towards species of major commercial or recreational importance for which alternative sources of data are likely to be available. If all species in the ecosystem are considered, the surveys become overwhelmingly important as a scientific data source.

Other Data

In addition to the assessment information mentioned above, NEFC spring and autumn surveys have provided a basis for studying distribution, fecundity, and food habits; monitoring prevalence of fish disease and anthropogenic impacts, and other miscellaneous studies. Biological samples are also collected for a wide range of studies at numerous colleges, universities, state or federal research agencies and the private sector. Normally, such studies would be far too expensive because of the high cost of chartering and equipping vessels to make such collections. In addition, oceanographic and ichthyoplankton sampling is routinely conducted for other Center research programs, e.g. studies of recruitment variability. The necessary seasonal coverage for such programs can be provided in part by "piggy-backing" on spring and autumn surveys. In addition, the need to develop an adequate understanding of ecological relationships for multispecies management insures the need for continued seasonal monitoring of species assemblages. Such work can best be accomplished through intensive seasonal surveys.

PRECISION OF SURVEY RESULTS

The SWG examined relative levels of sampling precision that are currently attained with existing survey design and sampling intensity. Studies of survey precision have been previously conducted for several species but this is the first comprehensive analysis. The Group chose an assemblage of 41 species-stocks, representing 20 species, for detailed analyses (Table 5).

The Group first examined the relationship between the stratum mean and variance for each species over all strata sets used to evaluate general distribution patterns. Taylor (1961) derived the following empirical relationship between the mean and variance of a sample:

$$V = aX^b$$

where X and V are the mean and variance, respectively, and a and b are coefficients. On a logarithmic scale, the relationship is linear. The slope (b) is a measure of the amount of aggregation; for $b > 1.0$ a contagious distribution is indicated. The appropriate transformation (Taylor 1961) is

$$Y = X^{(1-b/2)}$$

Note that if $b = 2.0$, the $\log_e$ transform is indicated.

The Group tested the null hypothesis that the slope of the $\log_e$ mean - $\log_e$ variance relationship was 2.0, using data for 19 of the above species collected during the 1985 autumn bottom-trawl survey (Table 6). A functional regression (Bartlett's three group method; see Sokal and Rohlf 1981) was used, since both the mean and variance are measured with error. Slopes were significantly greater than 1.0 for 16 of the 19 species examined (Table 6), indicating aggregated distribution patterns. For three species (Atlantic herring, American lobster, and black sea bass), the confidence interval of the slope included 1.0; for herring and sea bass this result can be attributed to low sample sizes. In the majority of cases, one would fail to reject the null hypothesis that the slope is 2.0. Examples of $\log_e$ mean - $\log_e$ variance plots are provided in Figures 11 and 12.

For bottom trawl survey data it is axiomatic that for any given species a high proportion of "zero catches" will be encountered over a broad geographical area, i.e. the species in question will be present in only a fraction of the tows. This results in a highly skewed distribution of catch per tow. Development of confidence intervals about mean catch-per-tow values will be complicated by this asymmetric distribution, and at the same time the occurrence of zero catches complicates the development of an effective normalizing transformation. To illustrate this point the observed distribution of catch per tow in weight for Georges Bank cod taken during the 1985 autumn survey is provided in Figure 13. The observed distribution on a linear scale is markedly asymmetrical, with a high proportion of zero catches. If we attempt to normalize the data using the $\log_e (X+1)$ transform the data remain highly skewed; there is still a pronounced peak representing the zero catches ($\log_e (X+1) = 0$). For the original and $\log_e (X+1)$ transformed data, the null hypothesis of a normal distribution is rejected (Kolmogorov-Smirnov test; $P<0.01$).

An alternative approach involves partitioning the catches into zero and nonzero values and taking natural logarithms of the latter set of values (Pennington 1983). The transformed nonzero catches are more nearly normally distributed (Figure 13); the hypothesis of a normal distribution is not rejected (Shapiro-Wilk test; $P>0.05$). Accordingly, the Group tested the distribution of the transformed nonzero tows for 26 of the species/stocks identified earlier (Table 7). To obtain a sufficiently large sample size, the distribution of catch-per-tow indices for relatively broad geographical regions was considered, e.g. strata sets for Georges Bank, southern New

England, Mid-Atlantic, Scotian Shelf, Gulf of Maine, etc., see Table 7. It should be noted, however, that tests of this type should be conducted at the stratum level, since the operational level is the individual stratum in actual practice. Thus, results must be taken as suggestive but not definitive.

Since few observations were available for most of these tests, the Group used the Shapiro-Wilk statistic for small sample sizes (N<50). This statistic is robust and provides one of the most powerful tests available for normality in such cases (Shapiro and Wilk 1965). The hypothesis of a normal distribution for the log-transformed catch values could be rejected for few of the species/stocks tested (Table 7). These results support the general application of the Delta distribution to NEFC bottom trawl survey data.

The Delta distribution estimator (c) for stratified mean catch per tow in numbers or weight is defined as:

$$c = \sum_{i=1}^{n} W_i \left[(m_i/n_i)\exp(y_i)\ G_m\left(\frac{1}{2}s_i^2\right)\right] \qquad m>1$$

The variance of this estimator (Pennington 1983) is:

$$\mathrm{Var}\ (c) = \sum_{i=1}^{n} W_i^2 \left[\frac{m_i}{n_i}\ \exp(2\bar{y}_i)\left\{\frac{m_i}{n_i}\ G_m^2\ \left(\frac{1}{2}s_i^2\right) - \left(\frac{m-1}{n-1}\right) G_m\left(\frac{(m-2)}{(m-1)}\ s_i^2\right)\right\}\right] \quad m>1$$

where W_i = weight assigned to stratum i;

m_i = number of nonzero tows in Stratum i;

n_i = total number of tows in Stratum i:

y_i = mean of the log-transformed data in Stratum i;

s_i^2 = variance of the log-transformed data in Stratum i;

G_m = an infinite series (used to correct for bias during retransformation).

Comparisons of the Delta distribution estimators with corresponding stratified mean catch-per-tow values (linear scale) for Atlantic cod, haddock, yellowtail flounder, and silver hake are provided in Tables 8-11 and Figures 14 and 15. The Delta distribution estimators of the mean are generally in close agreement with the linear values; more pronounced differences are evident for the standard errors although no consistent trends are evident. The Delta distribution estimator for the standard error is not necessarily less than the traditional estimator (S); this result is due to the inefficiency of S which may result in artificially low estimates of sample variability. Pennington (1983) has shown that Delta distribution estimators for large sample sizes are more efficient than the corresponding traditional estimators, if the nonzero observations are log-normally distributed.

The Group examined precision of the Delta distribution estimators for the 1984 and 1985 spring and autumn surveys. These two years were chosen because they are representative of current conditions with respect to both sampling intensity and resource status. Relative precision for the species/stocks listed in Table 5 was examined by computing and plotting distributions of the coefficient of variation of the mean (standard error/mean * 100) for each survey. Frequency distributions were constructed using 1984 and 1985 estimates for each species/stock as an individual observation (no differential weighting was applied).

The modal values for the coefficient of variation (CV) for both spring and autumn surveys for all species ranged from 30-40% (Figure 16). Autumn survey precision tended to be higher, i.e. the observed proportion of coefficients of variation exceeding 50% was higher in spring. The group also computed CV's for demersal species only, pelagic species only, and flounder species only (Figures 17, 18, and 19). The list of species included in each group is provided in Table 12. Precision was highest (lowest CV's) for the demersal complex (Figure 17). This result is not unexpected since a bottom-tending gear is used. Precision was higher in autumn than in spring for this group. Pelagic species were characterized by some very high CV's although again, the CV's were somewhat lower in autumn (Figure 18). Interestingly, the flounders also had generally high CV's although in this case, the autumn surveys were characterized by higher CV's than the spring surveys (Figure 19).

The Group evaluated the relative importance of these results in terms of confidence intervals about the mean. When calculated and summarized for these species stocks as frequency distributions, the modal 80% confidence interval for demersal species was 40% of the mean. For pelagic species and flounders, however, the modal value was considerably higher. Modal values for higher confidence intervals, e.g. 95% would, of course, be shifted to the right as well. While the levels of precision necessary for management applications must, of course, be subject to final determination by the managers, it is suggested that 80% confidence limits - that is, accepting a probability level of 80% that the interval includes the true population mean - is probably adequate for assessment and management.

The Group concluded that levels of precision achievable through use of the Delta distribution estimators were reasonable. Estimates for pelagic species and flounders were less precise; this result was not unexpected for pelagic species as they tend to be distributed in schools rendering survey catch per tow extremely variable. Fortunately, we have reasonable information on pelagic species of primary importance from the commercial fishery and are not dependent on the survey alone.

The lower precision for flounders deserves further attention. It is believed that this problem relates primarily to gear performance, i.e. use of roller gear, which causes the net to pass over individuals lying on or burrowed into the substrata. For the same reason, availability may vary to a greater extent for this group due to diel activity changes. Efficiency could be increased by use of a chain sweep but this would restrict surveys to smooth bottom area (thus in effect requiring development of a special survey for this group).

IMPROVEMENT OF SURVEY PRECISION

The SWG next considered ways of improving the precision of the estimators. The first analysis attempted was to smooth random variability in the estimates by fitting time series models to the survey data (Pennington 1985). This approach is based on the concept that full advantage should be taken of the survey time series; the rationale being that biomass of multi-age class stocks would not be expected to change radically from year to year unless a causative agent could can be identified. (In other words, there is "memory" in the system). This is less true for short-lived species with high mortality rates. The time series models considered in these analyses were built on the supposition that much of the interannual variability in catch per tow is due to random variation in catchability. The objective was, therefore, to filter out this random variation to provide better estimates of population trends.

Results of applying this technique to four species/stocks are given in Figures 20 and 21. It is evident that the technique is very effective as a smoothing function and provides insight into reliability of the time series as a whole, e.g., for Georges Bank haddock the autumn survey index was obviously inflated upward in 1976 by some anomalously high catch per tow values (Figure 20) as was the index for southern New England yellowtail in autumn of 1972 (Figure 21). Similarly, the population increase observed in the early 1980's for yellowtail, while real, was apparently not of the magnitude evidenced by untransformed data (Figure 21). The utility of the procedure in filtering out random "noise" in the system is also evident.

Comparisons for species/stocks for which alternative measures of abundance exist appear in Figures 22-25. Correspondence between the smoothed or adjusted survey index and the alternative measure was very good for Georges

Bank cod, Georges Bank haddock, and redfish (see Figures 22 and 23). The relationship between the smoothed survey index and yellowtail flounder CPUE was generally good although a notable discrepancy occurred in the latter part of the series in both cases (Figure 24). This appears to be due to an upward bias in CPUE estimates for more recent years when stock size was declining rapidly on Georges Bank and off southern New England. CPUE was computed for only those trips in which yellowtail comprised 50% or more of the catch; this would result in a positive bias when stocks were declining since lower CPUE levels would not be represented. Recent CPUE data for the southern Georges Bank - Middle Atlantic silver hake stock may be similarly biased (Figure 25).

The conclusion of the Group was that time series modelling approaches are very promising. There is also a marked improvement in precision of the estimators when using the smoothing technique, as a result of more information being used in computing the smoothed index (Pennington 1985). We rely not only on the point estimate for a given year but the estimates from adjacent years (full benefits therefore do not apply to the ends of the series where there is less information).

The Group next attempted to achieve maximum benefit from the surveys by combining spring and autumn data and fitting time series models to the combined data sets (1968-present; two points per year). Combining information in this way increases the number of data points available for analysis and provides a basis for consistent interpretation of trends in abundance (it is not uncommon for the two seasonal series to exhibit differences in short-term trends due to differences in sampling variability).

Examples of time series models fitted for spring and autumn surveys (two observations per year) are provided in Figures 26 through 28. Comparisons in residual mean square error for the seasonal models to that for the corresponding single season model revealed no consistent differences. For southern New England yellowtail flounder, the seasonal model was characterized by a 23% reduction in mean square error relative to the single season model; for Georges Bank yellowtail, residual error for the seasonal model was nearly identical to that of the model based on the above autumn series, and for Georges Bank haddock, an increase of 13% residual error was observed for the combined model relative to the single season model. This result was not unexpected given the potential for seasonal differences in catchability. An alternative approach such as averaging spring and autumn survey data and modeling the averaged series may be more effective in such cases.

EFFECTS OF CHANGES IN SAMPLING INTENSITY OR AREAS SAMPLED

Sampling Intensity

The effects of reductions (or increases) in sampling intensity were of primary interest in this analysis, given the need for vessel time and the potential for future losses associated with funding constraints or mechanical breakdowns. Since it is more convenient to deal with "sea days" rather than stations from an administrative standpoint, the Group worked directly with sea days whenever possible, assuming an average requirement of 50 days for covering the region from Cape Hatteras to the Scotian Shelf. (Note that coverage of the region south of Cape Hatteras would require an additional 5-6 days, discussed below).

The Group first examined the relationship between sea days and sampling intensity expressed as number of stations that could be occupied per survey cruise (percentage increase or decrease as compared to current levels). Potential changes in sampling intensity of up to ±50% were considered, since it was deemed unlikely that sampling intensity could be increased by as much as 50% given current vessel and funding constraints or conversely that the survey could remain viable with a reduction exceeding this amount. Several hypothetical scenarios were examined within this range based on vessel speed, average time on station, and time requirements for port calls; results are given in Figure 29. It can be seen that within this range the impact of reductions in vessel time on survey coverage can be quite significant, e.g., loss of 15 sea days (30% of our current 50-day requirement to survey from the Scotian Shelf to Cape Hatteras) would result in a 45% reduction in the number of stations that could be sampled. The disparity reflects the relative increase in steaming time (relative to time on station) needed to maintain the basic integrity of the survey region. The disparity becomes proportionally lower with further reductions in vessel time, e.g., loss of 40 sea days or 80% of the current total would necessitate a 90% reduction in station coverage. Obviously such a scenario would have no practical significance from a statistical standpoint; indeed, losses in the order of 20 days would probably necessitate significant reductions in areal coverage to maintain acceptable levels of sampling precision for at least part of the data base.

Since the relationship between vessel time (sea days) and number of stations that can be covered is reasonably well defined over a practical range (Figure 29) and since changes in precision can be related to changes in sampling intensity (stations) it follows that a direct relation can be developed between number of sea days and sampling precision. Such a relationship has been developed between number of sea days and percentage change in standard deviation for 35 species/stocks. Increase or decrease in standard deviation in relation to sample size was calculated for the 1985 autumn bottom trawl survey in terms of conventional sampling theory (Cochran 1977). Calculations were based on the above relationship between vessel time and station coverage applied proportionately to each stock. Results are given in Table 13.

The most striking result in Table 13 is the relative uniformity over all species/stocks; no consistent differences in precision can be detected as sea days are decreased or increased (see Figure 30 for combined plots of percentage change in standard deviation in relation to reductions or increases in sea days for demersals, pelagics and flounders). Reductions in precision associated with modest losses in vessel time (6-9 sea days or 12-18% of the present total) are generally minor; no case was observed in which the standard deviation was increased by more than 16%. With greater reductions in sea days, however, precision drops off rapidly (Table 13); a reduction of 18 sea days (36% of the current total) increased the standard deviation in most cases by over 50%. On the other hand, the addition of 18 days to the current schedule would only reduce the standard deviation by 20% or so (Table 13). An evaluation of the acceptability of such reductions (or the need for increased sampling levels) from an assessments standpoint is beyond the scope of the present report.

Areas Sampled

The Group considered alternative methods of reducing sea time and possible implications including (1) eliminating all sampling south of Cape Hatteras, (2) reducing or eliminating sampling in deep water strata (>110 m from Georges Bank south), and (3) eliminating sampling in other areas of lower priority or for which alternative coverage exists, e.g., inshore strata surveyed by the State of Massachusetts.

The Group examined data collected south of Cape Hatteras and found that although many species have been taken, species of commercial or recreational significance have generally been poorly represented. In addition, there has been little use of these data for stock assessments and related work. These data will doubtless be useful for other applications, e.g., biological or distribution studies at some future date but for such uses the existing data base is probably sufficient. The Group accordingly concluded that survey work from Cape Hatteras to Cape Fear should be discontinued. This would provide a savings of 5-6 days of vessel time as indicated above.

Deep water strata (>110 m) from Georges Bank south have been difficult to sample due to the large amounts of fixed gear that must be avoided, difficulty in following depth contours (resulting in numerous water hauls when the net fails to touch bottom) and encounters with "ghost" gear which may affect trawl performance. Accordingly, the effort which must be expended in such areas is usually considerably out of proportion to the value of such tows from an assessment standpoint, particularly when these strata are being oversampled in proportion to their area.

To evaluate the implications of eliminating these strata altogether, the Group computed survey indices with and without these strata for species of known importance in these areas. Little or no impact was observed in autumn (Figures 31-33); a more pronounced effect was evident in spring although for the species in question autumn survey data have been used preferentially (or are at least adequate) for assessment purposes. The Group concluded that sampling in these strata should be reduced, either by (1) reducing the number of samples in these strata to one per stratum and assigning variances based on historical relationships between the variance and the mean, or (2) by combining adjacent deepwater strata and sampling each enlarged stratum in proportion to total area. The latter would appear preferable given the fact that relationships between the variance and mean would be subject to change over time.

Inshore stations are typically close together and tows in such areas are often characterized by high catches of juvenile fish. This often necessitates "laying to" while the catch is processed. The Group considered possible alternatives for reducing sample coverage in these areas including (1) combining inshore strata with each other (or possibly with adjacent offshore strata) to permit reductions in sample intensity as suggested for offshore strata above, or (2) eliminating coverage in areas now surveyed by other agencies, e.g., Massachusetts Division of Marine Fisheries survey. The latter course of action would require analyses to verify the comparability of the two data sets as a source of assessment-related information.

There is also an obvious potential for improving NEFC survey efficiency by eliminating coverage of some areas in the Canadian Economic Zone, e.g., Browns Bank, Bay of Fundy stations. The Bay of Fundy (Stratum 35) has been sampled infrequently and the Group recommended discontinuing coverage in this area. For Browns Bank, the Group concluded that a final decision should be deferred subject to further negotiations with Canada (note, however, that biological sampling in this area is being discontinued wherever possible). Elimination of the area from Browns Bank - Bay of Fundy would save 3-4 days of vessel time, not to mention trawl gear.

CONCLUSIONS

Results of this project have been useful in documenting assessment-related uses of survey data, for evaluating precision including techniques for increasing it, and for evaluating gains or losses in precision associated with changes in sampling intensity. With respect to assessment-related applications, the autumn survey is clearly the primary data source, although the spring survey is important for corroborating autumn survey trends (including recruitment estimates) and for development of biological parameter estimates including maturity information. Discontinuation of the spring survey would result in significant reductions in our monitoring and predictive capabilities and in our ability to evaluate biological parameters. Other programs would also be affected.

Precision of the Delta distribution estimators was found to be highest for demersal species and was generally higher in autumn. Precision for flounders was generally poor. Comparable levels of precision were achieved for test cases in which direct comparisons were made between Delta distribution estimators and indices calculated from untransformed data. It was determined that, for general management applications, levels of precision achievable through use of the Delta distribution estimators were reasonable.

The SWG smoothed the Delta distribution estimators for selected species/stocks using time series (single-season) models. Trends for the resulting indices agreed well with those evidenced by fishery-dependent estimates. Attempts to maximize benefits from the surveys by combining spring and autumn data and fitting time series models to the combined data sets did not result in consistent improvements, probably due to seasonal differences in catchability.

Analyses to evaluate relationships between sampling intensity (in terms of vessel time) and sampling precision revealed that for modest losses in sea time (<20% of current levels) losses in precision would be relatively minor; precision drops off rapidly, however, with further losses in sea time. The Group determined that significant savings could be achieved with minimal loss in information by 1) eliminating survey coverage from Cape Hatteras to Cape Fear, 2) reducing sample coverage in offshore deepwater strata (>110 m) from Georges Bank south, and 3) modifying coverage in the Canadian Economic Zone. Coverage for inshore strata probably can also be reduced, especially in coastal waters now being surveyed by the states, with minimal effects.

Plans for future work include the following:

1) Further evaluation of existing survey coverage, particularly for inshore strata and strata in the Canadian Economic Zone, to permit reductions wherever possible;

2) Studies to improve precision and accuracy by time series modeling and by modifications to sampling design and intensity (for example, survey precision may be increased by sampling more intensively in key strata, using combinations of inshore and deepwater strata, and the addition of fixed stations);

3) Further evaluations of relationships between sampling intensity and sampling precision by species and species groups; and

4) Examination of the nature of catchability in the survey data base, with specific reference to interannual variation. Stock size estimates derived from VPAs and/or spawning biomass estimates as derived from egg surveys could provide a basis for such evaluations.

REFERENCES

Azarovitz, T. R. 1981. A brief historical review of the Woods Hole Laboratory trawl survey time series, p. 62-67. In: Doubleday, W. G. and D. Rivard, eds. Bottom trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58, 273 p.

Cochran, W. G. 1977. Sampling techniques. John Wiley and Sons, Inc., New York, 422 p.

Collie, J. S., and M. P. Sissenwine. 1983. Estimating population size from relative abundance data measured with error. Can. J. Fish. Aquat. Sci. 40:1871-1879.

Grosslein, M.D. MS 1968. Results of the joint USA-USSR groundfish studies. Part II. Groundfish survey from Cape Hatteras to Cape Cod. Int. Comm. Northw. Atlant. Fish., Res. Doc. 68/87, 28 p.

___________. 1969. Groundfish survey program of BCF Woods Hole. Comm. Fish. Rev. 31 (8-9): 22-30.

___________. 1971. Some observations on accuracy of abundance indices derived from research vessel surveys. Int. Comm. Northw. Atlant. Fish., Redbook 1971 (III):249-266.

Pennington, M. 1983. Efficient estimators of abundance for fish and plankton surveys. Biometrics 39:281-286.

___________. 1985. Estimating the relative abundance of fish from a series of trawl surveys. Biometrics 41:197-202.

___________. MS 1985. Some statistical techniques for estimating abundance indices from trawl surveys. Northw. Atl. Fish. Org., SCR Doc. 85/81, 12 p.

___________, and P. Berrien. 1984. Measuring the precision of estimates of total egg production based on plankton surveys. J. Plank. Res. 6: 869-879.

___________, and B. E. Brown. 1981. Abundance estimators based on stratified random trawl surveys, p. 149-153. In: Doubleday, W. G. and D. Rivard, eds. Bottom-trawl surveys. Can. Spec. Publ. Fish. Aquat. Sci. 58, 273 p.

___________, and M. D. Grosslein. MS 1978. Accuracy of abundance indices based on stratified random trawl surveys. ICES C.M. 1978 D:13, 33 p.

Shapiro, S. S., and M. B. Wilk. 1965. An analysis of variance test for normality (complete samples). Biometrika 52:591-611.

Sissenwine, M. P., and E. W. Bowman. 1978. An analysis of some factors affecting the catchability of fish by bottom trawls. Int. Comm. Northw. Atl. Fish., Res. Bull. 13:81-87.

Sokal, R. R., and F. J. Rohlf. 1981. Biometry. W. H. Freeman and Co., New York, 859 p.

Taylor, L. R. 1961. Aggregation, variance, and the mean. Nature, 189: 732-735.

Table 1. Bottom trawl surveys conducted by the Northeast Fisheries Center, 1963-1987.

	Dates	Vessel	Yankee Trawl No.	Area[1] Offshore	Inshore
		SPRING			
1968	6 Mar-22 Apr	ALBATROSS IV	36	NS-CH	
1969	5 Mar-10 Apr	ALBATROSS IV	36	NS-CH	
1970	12 Mar-29 Apr	ALBATROSS IV	36	NS-CH	
1971	9 Mar- 1 May	ALBATROSS IV	36	NS-CH	
1972	8 Mar-24 Apr	ALBATROSS IV	36	NS-CH	
1973	16 Mar-15 May	ALBATROSS IV & DELAWARE II	41	NS-CH	
1973	8 May- 4 Jun	ATLANTIC TWIN	3/4		BI-CH
1974	12 Mar- 4 May	ALBATROSS IV	41	NS-CH	
1974	1 Apr- 2 May	ATLANTIC TWIN	3/4		NT-JF
1975	4 Mar-12 May	ALBATROSS IV	41	NS-CH	
1975	18 Mar-24 Mar	ATLANTIC TWIN	3/4		BI-DB
1976	3 Mar- 8 May	ALBATROSS IV & DELAWARE II	41	NS-CH	BI-CH
1977	19 Mar-20 May	ALBATROSS IV & DELAWARE II	41	NS-CH	BI-CH
1978	20 Mar-23 May	ALBATROSS IV	41	NS-CH	BI-CH
1979	21 Mar-12 May	ALBATROSS IV & DELAWARE II	41	NS-CF	GM-CF
1980	16 Mar- 8 May	ALBATROSS IV & DELAWARE II	41	NS-CF	GM-CF
1981	19 Mar-24 May	DELAWARE II	41	NS-CF	GM-CF
1982	9 Mar- 8 May	DELAWARE II	36	NS-CF	GM-CF
1983	7 Mar- 6 May	ALBATROSS IV	36	NS-CF	GM-CF
1984	24 Feb-25 Apr	ALBATROSS IV	36	NS-CF	GM-CF
1985	25 Feb-13 Apr	ALBATROSS IV	36	NS-CF	GM-CF
1986	3 Mar-27 Apr	ALBATROSS IV	36	NS-CL	GM-CL
1987	23 Mar-29 Apr	ALBATROSS IV & DELAWARE II	36	NS-CL	GM-CL

Table 1. (contd)

	Dates	Vessel	Yankee Trawl No.	Area[1] Offshore	Area[1] Inshore
		SUMMER			
1963	18 Jul-19 Aug	ALBATROSS IV	36	NS-HC	
1964	27 Jul-22 Aug	ALBATROSS IV	36	NS-HC	
1965	7 Jul-10 Aug	ALBATROSS IV	36	NS-HC	
1969	14 Jul-28 Aug	ALBATROSS IV	36	NS-CH	
1977	27 Jul-31 Aug	ALBATROSS IV & DELAWARE II	36	GM-CH	GM-CH
1978	25 Jul-20 Aug	ALBATROSS IV & DELAWARE II	36	GM-CF	GM-CF
1979	25 Jul- 1 Sep	ALBATROSS IV & DELAWARE II	36	GM-CF	GM-CF
1980	11 Jul-22 Aug	ALBATROSS IV & DELAWARE II	36	GM-CF	GM-CF
1981	23 Jun-24 Jul	DELAWARE II	36	GM-CB	GM-CB
		AUTUMN			
1963	13 Nov-16 Dec	ALBATROSS IV	36	NS-HC	
1964	22 Oct-25 Nov	ALBATROSS IV	36	NS-HC	
1965	6 Oct- 9 Nov	ALBATROSS IV	36	NS-HC	
1966	12 Oct-13 Nov	ALBATROSS IV	36	NS-HC	
1967	17 Oct- 9 Dec	ALBATROSS IV	36	NS-CH	
1968	10 Oct-26 Nov	ALBATROSS IV	36	NS-CH	
1969	8 Oct-23 Nov	ALBATROSS IV	36	NS-CH	
1970	3 Sep-20 Nov	ALBATROSS IV & DELAWARE II	36	NS-CH	
1971	30 Sep-19 Nov	ALBATROSS IV	36	NS-CH	
1972	27 Sep-20 Nov	ALBATROSS IV & DELAWARE II	36	NS-CH	CH-CA
1972	31 Oct- 5 Dec	ATLANTIC TWIN	3/4		BI-CN
1973	26 Sep-20 Nov	ALBATROSS IV	36	NS-CH	
1973	1 Oct- 7 Nov	ATLANTIC TWIN	3/4		BI-CF
1974	20 Sep-14 Nov	ALBATROSS IV	36	NS-CH	BI-DB
1975	15 Oct-18 Nov	ALBATROSS IV	36	NS-CH	CC-CH
1976	28 Sep-23 Nov	ALBATROSS IV	36	NS-CH	BI-CH
1977	26 Sep-15 Dec	DELAWARE II	36	NS-CH	BI-CH
1978	5 Sep-22 Nov	DELAWARE II	36	NS-CH	GM-CF
1979	12 Sep-19 Nov	ALBATROSS IV & DELAWARE II	36	NS-CF	CC-CF
1980	17 Sep-15 Nov	DELAWARE II	36	NS-CF	GM-CF
1981	16 Sep- 7 Nov	ALBATROSS IV	36	NS-CF	GM-CF
1982	13 Sep-12 Nov	ALBATROSS IV	36	NS-CF	GM-CF
1983	12 Sep-10 Nov	ALBATROSS IV	36	NS-CF	GM-CF
1984	10 Sep- 9 Nov	ALBATROSS IV	36	NS-CH	GM-CH
1985	9 Sep-16 Nov	ALBATROSS IV & DELAWARE II	36	NS-CH	GM-CH
1986	13 Sep- 6 Nov	ALBATROSS IV	36	NS-CL	GM-CL
1987	10 Sep- 6 Nov	ALBATROSS IV	36	GM-CL	GM-CL

Table 1. (contd)

	Dates	Vessel	Yankee Trawl No.	Area[1] Offshore	Area[1] Inshore
		WINTER			
1964	16 Jan-15 Feb	ALBATROSS IV	36	NS-HC	
1965	1 Feb- 8 Apr	ALBATROSS IV	36	NS-HC	
1966	18 Jan-23 Feb	ALBATROSS IV	36	NS-HC	
1981	6 Jan-28 Jan	DELAWARE II	36	CC-CH	
1982	18 Jan-12 Feb	DELAWARE II	36	GM-DB	GM-DB
1983	14 Feb- 9 Mar	DELAWARE II	36	GM-HC	GM-DB
1984	13 Feb-24 Feb	ALBATROSS IV & DELAWARE II	36	GM-HC	GM-DB
1985	13 Feb-22 Feb	ALBATROSS IV	36	BI-NT	

1 = Geographic features referred to abbreviated as follows:

BI = Block Island
CA = Cape Canaveral
CB = Chesapeake Bay
CC = Cape Cod
CF = Cape Fear
CH = Cape Hatteras
CL = Cape Lookout
CN = Charleston, SC
DB = Delaware Bay
GM = Gulf of Maine
HC = Hudson Canyon
JF = Jacksonville, FL
NS = Nova Scotia
NT = Nantucket Shoals

Table 2. Specifications for the NOAA research vessels ALBATROSS IV and DELAWARE II.

	ALBATROSS IV	DELAWARE II
Length	57.0 m	47.2 m
Displacement	987.9 m tons	687.6 m tons
Shaft Horsepower	1,130	1,230
Number of Main Engines	2	1
Propeller	Variable pitch	Fixed Pitch
Rudder	Kort Nozzle	Standard
Main Winch, Line Pull	7,257 kg	9,072 kg
Main Winch, Line Rate	65.5 m/min	36.3 m/min
Trawl Warp Diameter	22.2 mm	25.4 mm
Towing Gear	Hydraulic Gantry	Fixed Gallows

Table 3. Specifications for the "36 Yankee" and "41 Yankee" trawls.

	#36 Yankee Trawl	#41 Yankee Trawl
Opening Height of Trawl	3.2 m	4.6 m
Opening Width of Trawl	10.4 m	11.8 m
Overall Length of Trawl	28.4 m	28.6 m
Codend Length	5.7 m	5.7 m
Foot Rope Length	24.4 m	30.5 m
Head Rope Length	18.3 m	24.4 m
Opening Mesh[1]	12.7 cm	12.7 cm
Average Body Mesh	12.7 cm	12.7 cm
Codend Mesh	11.4 cm	11.4 cm
Codend Liner	1.3 cm	1.3 cm
Number of Floats	36	53
Float Diameter	20 cm	20 cm
Roller Gear	Yes	Yes
Length of Bridles	9.1 m	18.3 m
Length of Doors[2]	2.4 m	2.5 m
Width of Doors[2]	1.4 m	1.4 m
Weight of Doors[2]	545 kg	682 kg
Type of Doors[2]	BMV Oval	BMV Oval

[1]All mesh measurements given as "stretched" values.

[2]Beginning in 1985, 450 kg polyvalent doors have been used (length, 2.5m; width, 1.4m).

Table 4. Strata used during NEFC bottom trawl surveys from western Nova Scotia to Cape Hatteras, North Carolina including area, depth zone and average number of stations fished.

Stratum	Area[1]	Depth Zone (m)	No. of Stations	Stratum	Area[1]	Depth Zone (m)	No. of Stations
			Inshore Strata				
1	44	<18	1	46	273	18-26	2
2	62	18-26	2	47	45	<18	1
3	13	<9	1	48	113	<9	0
4	26	9-17	2				
5	62	18-26	2	50	15	<9	0
6	26	<9	1	51	117	9-17	0
7	35	9-17	2	52	521	9-17	4
8	150	18-26	2	53	142	<9	0
9	40	<9	1	54	277	9-17	0
10	48	9-17	2	55	495	18-26	4
11	242	18-26	2	56	57	9-26	1
12	44	<9	1	57	34	<9	0
13	88	9-17	2	58	88	9-17	1
14	110	18-26	2	59	93	18-26	1
15	22	<9	1	60	126	27-41	2
16	62	9-17	2	61	133	42-55	2
17	238	18-26	2	62	62	<9	2
18	97	<9	1	63	78	9-17	1
19	216	9-17	2	64	90	18-26	1
20	356	18-26	2	65	75	27-41	1
21	22	<9	1	66	151	42-55	2
22	154	9-17	2	67	5	<9	0
23	167	18-26	2	68	40	9-26	1
24	53	<9	1	69	57	27-55	1
25	172	9-17	2	70	10	<9	0
26	154	18-26	2	71	72	9-26	1
27	35	<9	1	72	129	27-55	2
28	220	9-17	2	73	31	<9	0
29	185	18-26	2	74	68	9-26	1
30	75	<9	1	75	76	27-55	1
31	299	9-17	2	76	20	<18	0
32	106	18-26	2	77	34	18-55	1
33	92	<9	1	78	44	18-55	1
34	167	9-17	2	79	34	<18	0
35	88	18-26	2	80	58	18-55	1
36	119	<9	1	81	38	18-55	1
37	312	9-17	2	82	209	<18	0
38	224	18-26	2	83	80	18-55	1
39	35	<9	1	84	137	<18	0
40	176	9-17	2	85	106	18-55	1
41	383	18-26	2	86	60	<18	0
42	40	<9	1	87	153	18-55	2
43	172	9-17	2	88	34	<18	0
44	304	18-26	2	89	59	18-55	1
45	170	18-26	2	90	125	56-110	2

Table 4. (Contd)

Stratum	Area[1]	Depth Zone (m)	No. of Stations	Stratum	Area[1]	Depth Zone (m)	No. of Stations
			Offshore Strata				
1	2516	27-55	7	34	1766	111-183	6
2	2078	56-110	7	35	1097	111-183	4
3	566	111-183	3	36	4069	>183	8
4	188	>183	3	37	2108	111-183	5
5	1475	27-55	5	38	2560	111-183	5
6	2554	56-110	8	39	730	56-110	5
7	514	111-183	3	40	578	56-110	3
8	230	>183	3	41	1570	111-183	6
9	1522	27-55	5	42	156	56-110	2
10	2722	56-110	8	43	860	111-183	4
11	622	111-183	3	44	934	56-110	5
12	176	>183	3	45	150	56-110	2
13	2374	56-110	9	46	247	56-110	2
14	656	111-183	4	47	1159	111-183	4
15	230	>183	3	48	1184	111-183	4
16	2980	56-110	10	49	198	>183	3
17	360	111-183	4	61	1318	27-55	3
18	172	>183	3	62	243	56-110	2
19	2454	27-55	9	63	86	111-183	2
20	1221	27-55	6	64	60	>183	2
21	424	56-110	4	65	2832	27-55	7
22	454	111-183	4	66	555	56-110	3
23	1016	56-110	5	67	86	111-183	2
24	2569	111-183	6	68	52	>183	2
25	390	27-55	4	69	2433	27-55	6
26	1014	56-110	5	70	1024	56-110	4
27	720	111-183	4	71	281	111-183	2
28	2249	>183	7	72	105	>183	2
29	3245	>183	8	73	2145	27-55	5
30	619	>183	3	74	1273	56-110	4
31	2185	111-183	7	75	139	111-183	2
32	655	56-110	5	76	60	>183	2
33	861	56-110	4				

[1]Square nautical miles

Table 5. Species/stocks and strata set definitions for finfish and invertebrate species used to evaluate precision and efficiency of survey design.

Species/Stock	Strata Set Definition
Atlantic Cod	
Southern New England - Middle Atlantic	Spring 1, 5-6, 9-10 Autumn 1-2, 5-6, 9-10, 65, 69-70, 73-74
Georges Bank	13-25
Gulf of Maine	26-30, 36-40
Haddock	
Georges Bank	13-25, 29-30
Gulf of Maine	26-28, 36-40
Pollock	
Georges Bank - Gulf of Maine - Scotian Shelf	13-40
Redfish	
Georges Bank - Gulf of Maine	24, 26-30, 36-40
Silver Hake	
Southern Georges Bank - Middle Atlantic	1-19, 61-76
Gulf of Maine - Northern Georges Bank	20-30, 36-40
Red Hake	
Southern Georges Bank - Middle Atlantic	1-19, 61-76
Gulf of Maine - Northern Georges Bank	20-30, 36-40
White Hake	
Georges Bank - Gulf of Maine	21-30, 33-40
Yellowtail Flounder	
Middle Atlantic	1-2, 69-70, 73-74
Southern New England	5-6, 9-10
Georges Bank	13-21
Cape Cod	24-26
Gulf of Maine	27-28, 37-40
Summer Flounder	
Middle Atlantic	61-76
Southern New England	1-12
Georges Bank	13-25
Winter Flounder	
Middle Atlantic	61-76
Southern New England	1-12, 25
Georges Bank	13-22
Great South Channel	23
Gulf of Maine	24, 26-30, 36-40

Table 5. (contd)

Stock	Strata Set Definition
Atlantic Herring	
Southern New England	1-12, 61-76
Georges Bank	13-23, 25
Gulf of Maine - Scotian Shelf	24, 26-30, 36-49
Atlantic Mackerel	
Middle Atlantic - Scotian Shelf	Spring 1-25, 61-76 Autumn 1-42, 49
Butterfish	
Middle Atlantic - Georges Bank	Spring 1-12, 61-76 Autumn 1-14, 16, 19-20, 25, 61-76
Scup	
Southern New England - Middle Atlantic	Spring 2-3, 61-63, 65-67, 70-71, 74-75 Autumn 1-2, 5-6, 9, 61, 65, 69, 73-74
Bluefish	
Cape Hatteras - Cape Cod	1-25, 61-76
Black Sea Bass	
Southern New England - Middle Atlantic	Spring 61-76 Autumn 1-2, 5-6, 9-10, 61-76
American Lobster	
Middle Atlantic	61-76
Southern New England	1-12
Georges Bank	13-23, 25
Gulf of Maine	24, 26-30, 36-40
Scotian Shelf	31-35, 41-49
Northern Shrimp	
Gulf of Maine	24, 26-28, 37-40
Shortfin squid	
Middle Atlantic - Georges Bank	1-25, 61-76
Longfin squid	
Middle Atlantic - Georges Bank	1-25, 61-76
All Species	
Total Survey Area	1-40, 61-76

Table 6. Results of tests to evaluate the mean-variance relationships for 1985 autumn bottom trawl survey catches using Bartlett's three group method for Model II regression.

Species	Slope	95% Confidence Interval Upper	95% Confidence Interval Lower	Sample Distribution[1]
Atlantic Cod	1.933	2.215	1.649	22
Haddock	1.844	2.030	1.647	19
Pollock	1.716	2.034	1.375	13
Redfish	1.898	2.207	1.583	12
Silver Hake	1.797	2.032	1.567	49
Red Hake	1.741	1.919	1.546	39
White Hake	1.462	1.743	1.114	23
Yellowtail Fldr	1.739	1.966	1.540	18
Summer Flounder	1.712	2.881	1.233	8
Winter Flounder	1.521	1.782	1.203	18
Atlantic Herring	1.773	2.037	0.005	9
Atlantic Mackerel	2.000	2.003	1.998	6
Butterfish	1.842	1.997	1.696	41
Scup	1.763	1.921	1.568	15
Bluefish	1.800	2.205	1.258	13
Black Sea Bass	1.737	2.356	-0.121	7
American Lobster	1.633	2.599	0.654	34
Shortfin Squid	1.620	1.837	1.411	39
Longfin Squid	1.831	2.038	1.626	42

1 Number of strata containing the species indicated.

Table 7. Results of tests for normality for 26 species/stocks (log-transformed non-zero tows only) sampled during the NEFC 1985 bottom trawl survey.

Species	Stock[1]	Sample size (N)	Shapiro-Wilk Test Statistic[2]
Atlantic Cod	GB	24	0.9690
	GM	30	0.9602
Haddock	GB	41	0.9280*
	GM	15	0.9089
Pollock	GB-GM-SS	30	0.8484**
Redfish	GB-GM	38	0.9482
Yellowtail Flounder	MA	8	0.9061
	SNE	9	0.9483
	GB	15	0.9174
	CC	7	0.7321*
Summer Flounder	MA	11	0.9337
	SNE	9	0.8461
Winter Flounder	MA	6	0.9157
	SNE	18	0.9330
	GB	11	0.8622
	GM	8	0.9190
Atlantic Herring	GB	5	0.9555
	GM-SS	12	0.8549*
Atlantic Mackerel	MA-SS	6	0.9042
Scup	SNE-MA	38	0.9646
Bluefish	CH-CC	23	0.9432
Black Sea Bass	SNE-MA	14	0.8411
American Lobster	MA	15	0.7985
	SNE	49	0.9113*
	GB	28	0.9264
	GM	22	0.9696

1 CH=Cape Hatteras; MA=Middle Atlantic; SNE=Southern New England; GB=Georges Bank; SGB=Southern Georges Bank; NGB=Northern Georges Bank; CC=Cape Cod; GM=Gulf of Maine; SS=Scotian Shelf.

2 Shapiro-Wilk W for N<51.

* Hypothesis of normal distribution rejected at 0.05 level.
**Hypothesis of normal distribution rejected at 0.01 level.

Table 8. Stratified mean weight per tow for Atlantic cod taken in NEFC spring and autumn bottom trawl surveys from the Gulf of Maine compared to corresponding Delta distribution estimators.

Year	Linear Scale Mean	Linear Scale Std. Error	Delta Distribution Mean	Delta Distribution Std. Error
		Spring		
68	11.051	1.886	11.049	1.894
69	8.145	2.956	7.782	2.517
70	6.838	1.944	6.735	1.758
71	4.319	1.040	4.486	1.144
72	4.956	1.255	5.341	1.544
73	11.609	5.234	10.322	3.512
74	4.579	0.993	5.247	1.560
75	3.728	1.063	3.709	1.033
76	4.664	0.830	4.868	0.972
77	5.272	1.207	5.393	1.491
78	4.751	1.092	4.712	1.059
79	5.860	1.166	5.933	1.129
80	5.702	1.159	5.678	1.163
81	9.927	2.252	10.533	2.693
82	7.938	1.964	7.574	1.720
83	6.766	1.665	6.806	1.632
84	3.792	1.423	3.360	0.995
85	7.645	1.799	8.354	2.460
		Autumn		
63	11.080	4.562	10.536	3.871
64	14.073	7.541	14.178	7.579
65	7.411	2.281	7.385	2.225
66	7.973	2.052	10.290	4.889
67	5.695	1.397	5.866	1.559
68	11.998	2.603	12.312	3.039
69	9.486	2.332	9.280	2.175
70	10.149	2.690	10.226	2.729
71	10.202	3.408	11.485	4.471
72	8.017	1.841	8.654	2.561
73	5.406	1.629	5.417	1.629
74	5.530	1.221	5.515	1.183
75	5.320	0.858	5.463	1.015
76	4.161	1.015	4.114	0.987
77	9.397	1.238	10.313	1.781
78	11.884	1.929	13.080	2.544
79	10.819	1.509	11.582	1.987
80	13.085	2.187	13.595	2.746
81	4.961	1.222	5.551	1.936
82	9.827	7.313	7.051	4.065
83	5.195	1.103	5.186	1.102
84	5.392	1.906	5.445	1.935
85	8.264	3.332	7.638	2.517

Table 9. Stratified mean weight per tow for haddock taken in NEFC spring and autumn bottom trawl surveys from Georges Bank compared to corresponding Delta distribution estimators.

Year	Linear Scale Mean	Linear Scale Std. Error	Delta Distribution Mean	Delta Distribution Std. Error
		Spring		
68	13.611	3.047	13.483	3.046
69	11.212	3.289	11.534	3.807
70	11.343	7.77	8.967	5.61
71	3.308	0.782	3.290	0.772
72	4.887	0.954	5.234	1.265
73	10.182	3.471	9.472	2.656
74	11.727	4.033	12.450	4.43
75	5.438	2.334	6.047	3.198
76	10.408	3.388	15.483	8.814
77	17.599	6.313	18.538	9.725
78	20.710	5.855	21.316	6.317
79	13.088	2.495	16.458	5.157
80	35.712	12.337	35.442	15.631
81	31.945	7.224	33.423	8.865
82	11.015	2.236	11.706	2.682
83	8.750	2.274	10.437	3.657
84	4.931	1.27	6.290	2.437
85	11.143	3.569	12.902	5.35
		Autumn		
63	52.840	9.024	60.680	13.72
64	64.069	11.689	66.805	13.611
65	48.197	7.41	53.768	10.621
66	19.777	3.773	20.415	4.165
67	16.873	3.701	17.759	4.283
68	10.203	2.987	10.137	2.876
69	5.589	1.523	5.555	1.333
70	8.946	3.337	8.961	3.342
71	3.706	1.095	3.755	1.131
72	5.614	1.108	5.583	1.154
73	6.481	1.767	7.099	2.489
74	2.647	0.711	2.842	0.939
75	10.004	5.21	9.243	4.268
76	23.683	10.218	37.841	25.771
77	23.135	7.782	22.937	7.713
78	15.181	2.891	19.269	6.744
79	26.873	12.177	23.076	8.622
80	18.474	3.984	20.729	4.497
81	11.772	2.535	11.899	2.788
82	4.838	1.063	4.865	1.345
83	3.808	0.858	4.034	1.108
84	2.965	0.879	2.914	0.874
85	3.684	0.656	3.862	0.799

Table 10. Stratified mean weight per tow for yellowtail flounder taken in NEFC spring and autumn bottom trawl surveys from the Southern New England area compared to corresponding Delta distribution estimators.

	Linear Scale		Delta Distribution	
Year	Mean	Std. Error	Mean	Std. Error
		Spring		
68	18.624	4.654	21.015	6.866
69	13.340	2.836	13.998	3.795
70	11.721	2.204	11.762	2.485
71	10.693	1.948	11.068	2.247
72	10.728	2.977	10.735	3.078
73	14.678	2.497	18.401	5.124
74	5.040	1.105	5.058	1.161
75	1.984	0.423	1.973	0.414
76	2.452	0.559	3.231	1.275
77	1.993	0.613	1.965	0.575
78	5.146	0.833	5.570	1.305
79	2.147	0.495	2.349	0.662
80	5.949	0.683	6.566	1.018
81	6.846	1.680	6.974	1.756
82	6.001	1.940	6.569	2.392
83	4.641	0.851	4.868	1.109
84	1.625	0.392	1.637	0.414
85	0.666	0.130	0.675	0.138
		Autumn		
63	16.842	4.057	18.638	6.106
64	19.030	3.981	22.786	7.966
65	12.675	2.831	13.061	3.622
66	9.431	1.884	10.663	3.186
67	14.057	2.570	14.899	3.193
68	10.062	2.598	10.804	3.091
69	14.401	5.272	13.520	4.093
70	10.965	3.499	11.524	4.424
71	9.186	3.655	9.594	3.663
72	20.114	8.504	21.569	10.977
73	2.264	0.973	2.415	1.193
74	2.141	0.979	2.087	0.902
75	0.715	0.437	0.715	0.437
76	2.962	1.063	3.047	1.228
77	1.501	0.604	1.422	0.519
78	3.057	0.794	3.491	1.189
79	2.565	0.547	2.614	0.618
80	1.957	0.778	1.789	0.643
81	3.789	1.088	3.763	1.060
82	8.126	3.483	9.469	4.953
83	6.515	2.151	6.869	2.630
84	1.365	0.447	1.300	0.420
85	0.438	0.167	0.439	0.167

Table 11. Stratified mean weight per tow for silver hake taken in NEFC spring and autumn bottom trawl surveys from the Southern Georges Bank - Middle Atlantic area compared to corresponding Delta distribution estimators.

Year	Linear Scale Mean	Linear Scale Std. Error	Delta Distribution Mean	Delta Distribution Std. Error
		Spring		
68	3.627	1.501	3.756	1.616
69	2.131	0.378	2.202	0.430
70	1.223	0.161	1.233	0.176
71	2.200	0.322	2.192	0.302
72	1.372	0.182	1.399	0.210
73	7.420	0.928	7.999	1.142
74	5.728	0.930	5.594	0.889
75	9.278	1.550	9.882	1.956
76	7.202	1.723	6.618	1.167
77	6.825	1.013	7.237	1.130
78	8.675	1.593	8.547	1.501
79	3.469	0.688	3.771	0.904
80	4.432	0.785	4.475	0.763
81	5.585	0.635	6.055	0.897
82	1.982	0.392	2.018	0.459
83	1.291	0.187	1.376	0.241
84	2.282	0.636	2.209	0.550
85	2.657	0.521	2.642	0.464
		Autumn		
63	4.627	1.027	4.660	1.148
64	3.965	0.543	4.267	0.771
65	5.254	0.682	5.567	0.956
66	2.571	0.401	2.557	0.399
67	2.368	0.509	2.186	0.303
68	2.711	0.338	2.693	0.341
69	1.252	0.161	1.256	0.170
70	1.315	0.148	1.332	0.173
71	2.199	0.356	2.210	0.363
72	2.112	0.565	2.000	0.437
73	1.685	0.286	1.699	0.297
74	0.814	0.126	0.862	0.176
75	1.766	0.219	1.838	0.300
76	1.993	0.239	2.062	0.279
77	1.674	0.302	1.773	0.431
78	2.503	0.385	2.946	0.699
79	1.683	0.164	1.746	0.205
80	1.629	0.332	2.122	0.733
81	1.123	0.126	1.166	0.167
82	1.563	0.230	1.651	0.329
83	2.569	0.477	3.200	1.124
84	1.392	0.322	1.558	0.470
85	3.551	1.363	3.907	1.926

Table 12. Species/group designations used in analyses of survey precision.

Species included in the DEMERSAL category:

Atlantic Cod
Haddock
Redfish
Silver Hake
Red Hake
White Hake
Scup
Black Sea Bass
American Lobster
Northern Shrimp
Shortfin Squid
Longfin Squid

Species included in the PELAGICS category:

Pollock
Atlantic Herring
Atlantic Mackerel
Bluefish
Butterfish

Species included in the FLOUNDERS category:

Yellowtail Flounder
Winter Flounder
Summer Flounder

Table 13. Changes in sampling precision (expressed as percentage change in standard deviation) resulting from adjustments to number of sea days. Calculations based on data collected during the NEFC 1985 autumn bottom trawl survey.

SPECIES	STOCK	CHANGE (+/-) IN NUMBER OF SEA DAYS -18	-15	-12	-9	-6	+6	+9	+12	+15	+18
HADDOCK	GB	52.3	35.3	20.2	14.0	4.3	-3.4	-9.9	-12.5	-17.2	-20.3
HADDOCK	GM	58.5	30.0	29.2	11.8	11.9	-8.8	-8.8	-15.6	-15.8	-21.2
COD	GB	58.5	34.5	21.3	13.3	5.4	-4.5	-9.5	-13.0	-16.9	-21.2
COD	GM	58.2	30.3	28.3	11.6	11.5	-8.5	-8.6	-15.3	-15.9	-21.2
YELLOWTAIL	GB	56.6	30.3	19.8	12.2	5.3	-4.6	-9.0	-12.5	-15.9	-20.9
YELLOWTAIL	SNE	47.3	41.8	18.4	15.6	1.7	-1.3	-10.7	-11.7	-18.6	-19.3
YELLOWTAIL	CC	52.6	36.1	23.5	13.7	6.7	-4.8	-9.8	-13.5	-17.4	-20.4
YELLOWTAIL	MA	43.1	41.9	15.9	15.4	0.4	-0.3	-10.6	-10.8	-18.6	-18.8
WINTER FLN	GB	61.4	40.0	25.4	15.1	6.6	-5.5	-10.4	-14.4	-18.2	-21.5
WINTER FLN	SNE	43.3	41.9	16.2	15.7	0.4	-0.3	-10.8	-11.0	-18.8	-19.0
WINTER FLN	GM	58.7	29.6	29.6	11.9	12.1	-8.9	-8.8	-15.8	-15.8	-21.3
WINTER FLN	MA	52.1	28.6	25.2	10.7	10.2	-7.6	-8.1	-14.1	-15.3	-20.0
SUMMER FLN	GB	57.6	38.8	24.8	14.8	6.4	-5.4	-10.3	-14.3	-17.9	-21.0
SUMMER FLN	SNE	41.9	41.2	15.6	15.4	0.2	-0.1	-10.6	-10.7	-18.4	-18.6
SUMMER FLN	MA	51.4	28.6	22.4	9.2	9.6	-7.4	-7.1	-13.1	-15.3	-19.9
SILVER HAKE	SGB-MA	62.0	40.9	26.2	15.4	6.8	-5.7	-10.5	-14.7	-18.3	-21.5
SILVER HAKE	GM-NGB	63.9	37.7	23.3	10.8	9.0	-6.9	-8.1	-13.6	-17.6	-21.6
RED HAKE	SGB-MA	64.7	38.2	24.8	15.5	6.1	-5.0	-10.5	-14.2	-17.6	-21.8
RED HAKE	GM-NGB	55.1	35.3	24.0	13.1	7.6	-5.5	-9.4	-13.7	-17.0	-20.5
WHITE HAKE	GB-GM	64.3	37.3	26.2	12.5	9.4	-7.3	-9.0	-14.6	-17.4	-21.7
POLLOCK	GB-GM-SS	58.9	32.6	27.3	12.5	10.1	-7.6	-9.1	-14.9	-16.4	-21.2
BUTTERFISH	GB-MA	55.4	38.5	22.8	14.4	5.3	-4.3	-9.8	-13.0	-17.1	-19.5
REDFISH	GB-GM	57.8	30.0	28.1	11.5	11.4	-8.5	-8.5	-15.2	-15.8	-21.0
ATL MACKEREL	MA-SS	58.6	29.5	29.4	12.0	11.9	-8.8	-8.9	-15.8	-15.8	-21.3
BLUEFISH	CC-CH	51.9	36.6	19.4	11.7	5.7	-4.5	-8.5	-12.1	-17.4	-20.1
BLK SEA BASS	SNE-MA	39.6	26.9	13.8	7.4	5.0	-3.9	-5.6	-8.8	-12.8	-15.1
SCUP	SNE-MA	52.1	35.4	18.0	11.4	5.3	-4.2	-8.2	-11.7	-17.1	-20.1
ATL HERRING	GB	52.3	34.8	24.3	13.6	7.4	-5.3	-9.7	-13.8	-17.0	-20.4
ATL HERRING	GM-SS	58.7	29.7	29.5	11.9	12.0	-8.9	-8.8	-15.8	-15.8	-21.3
AM LOBSTER	SNE	37.4	30.8	14.2	11.4	1.7	-1.3	-7.5	-8.4	-12.8	-13.6
AM LOBSTER	SS	31.5	18.4	11.1	5.4	3.8	-2.7	-3.8	-5.8	-7.4	-8.9
AM LOBSTER	MA	38.4	26.1	13.4	7.0	5.0	-4.0	-5.4	-8.7	-12.6	-14.9
AM LOBSTER	GM	58.6	30.0	28.9	12.0	11.6	-8.6	-8.8	-15.5	-15.9	-21.2
AM LOBSTER	GB	56.3	35.0	21.9	13.6	5.6	-4.7	-9.7	-13.2	-17.0	-20.9
SFIN SQUID	MA-GB	49.0	25.2	15.5	9.1	4.6	-3.4	-6.1	-8.8	-11.1	-14.2

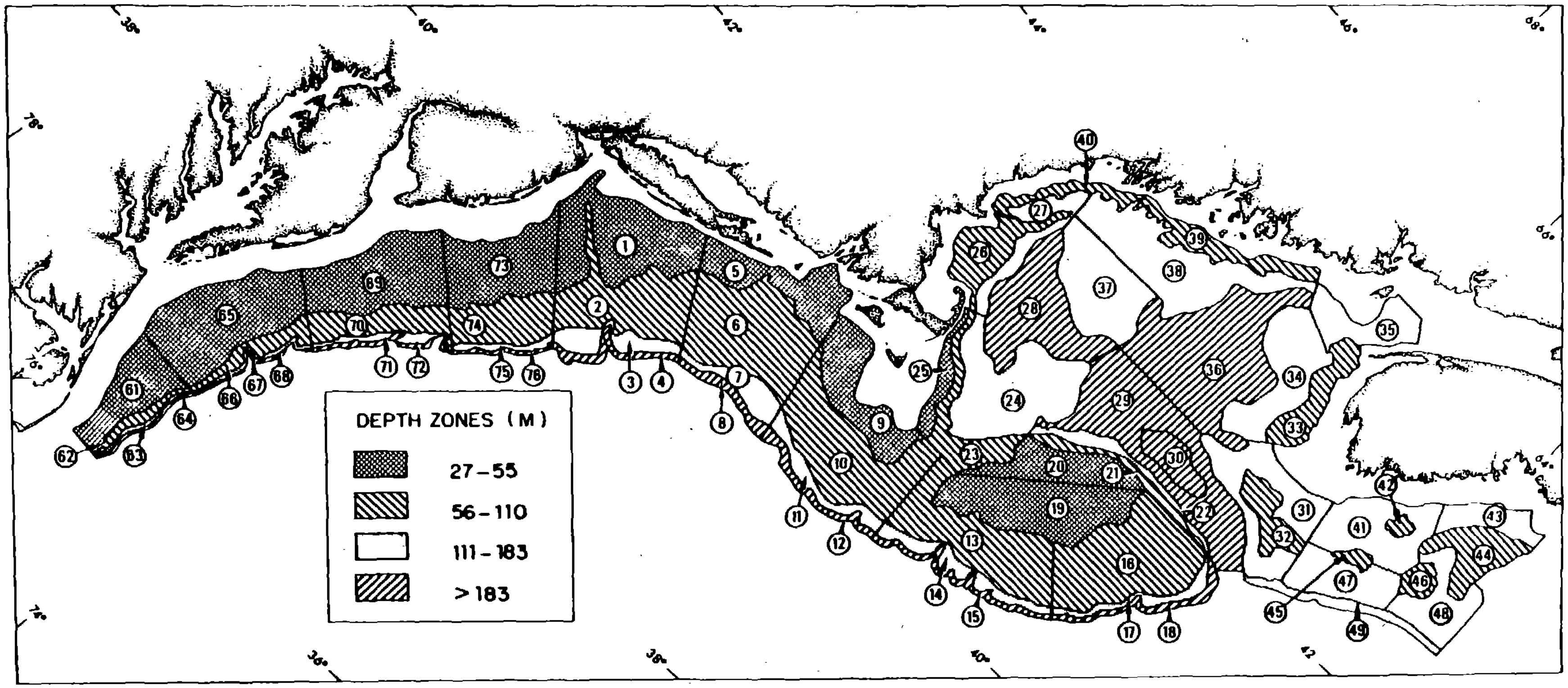


Figure 1. Strata sampled on NEFC offshore bottom trawl surveys.

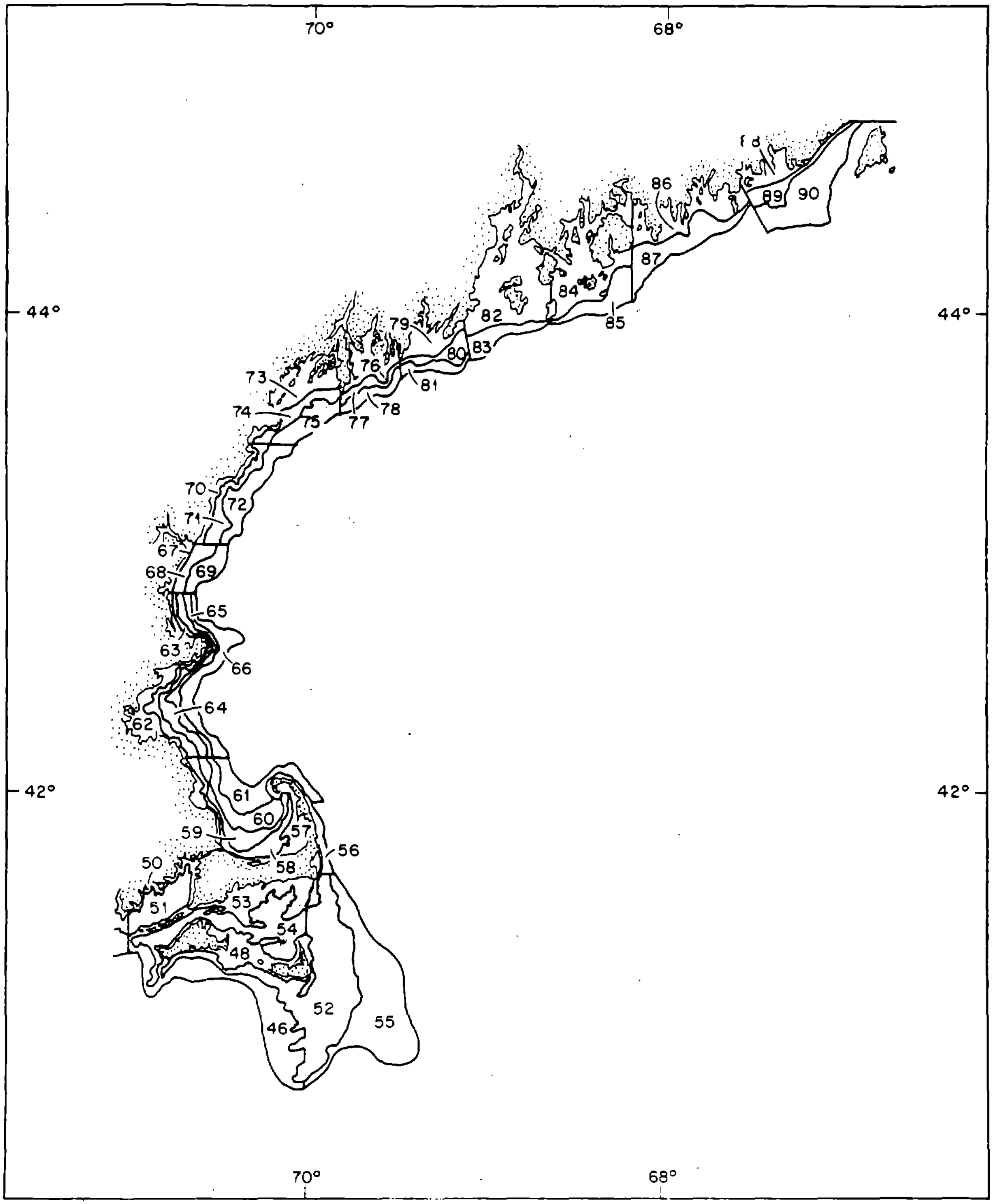


Figure 2. Strata sampled on NEFC inshore bottom trawl surveys from Eastport, Maine to Buzzards Bay, Massachusetts.

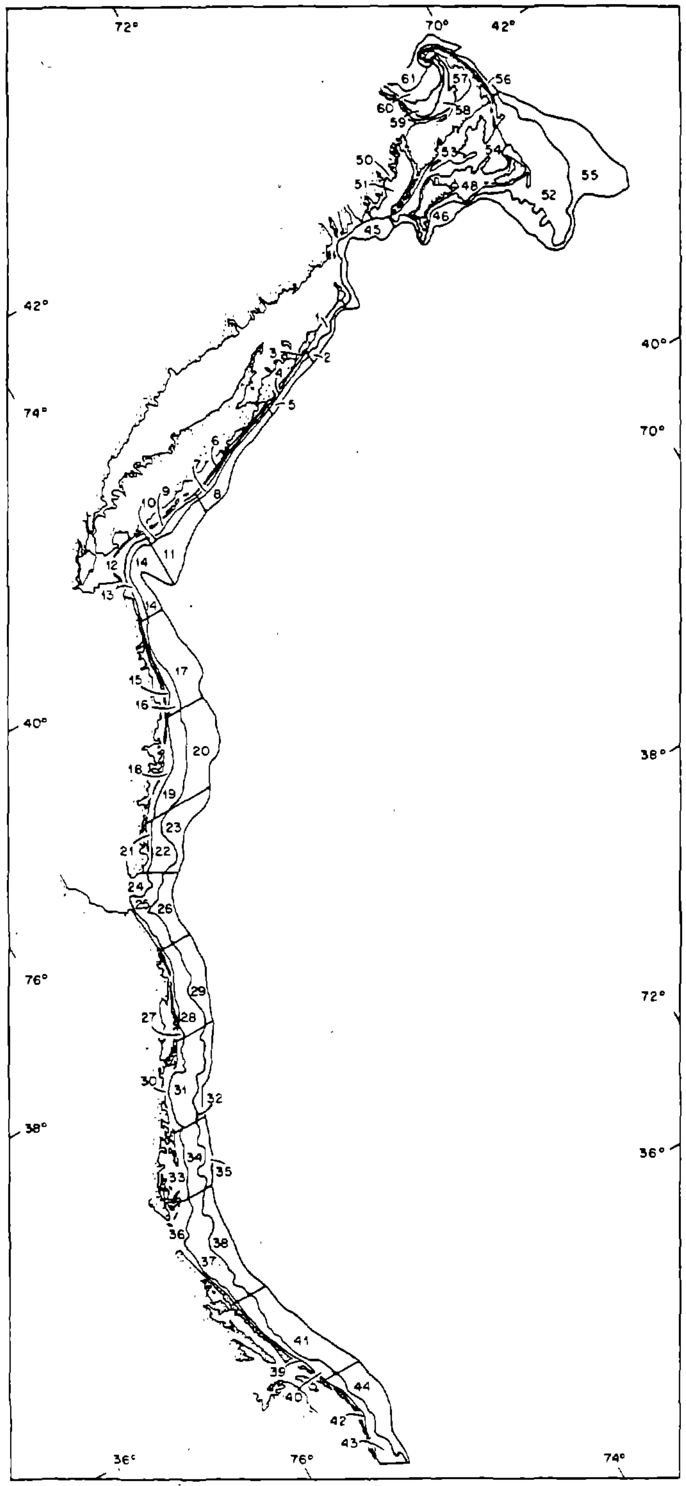


Figure 3. Strata sampled on NEFC inshore bottom trawl surveys from Cape Cod Bay, Massachusetts to Cape Hatteras, North Carolina.

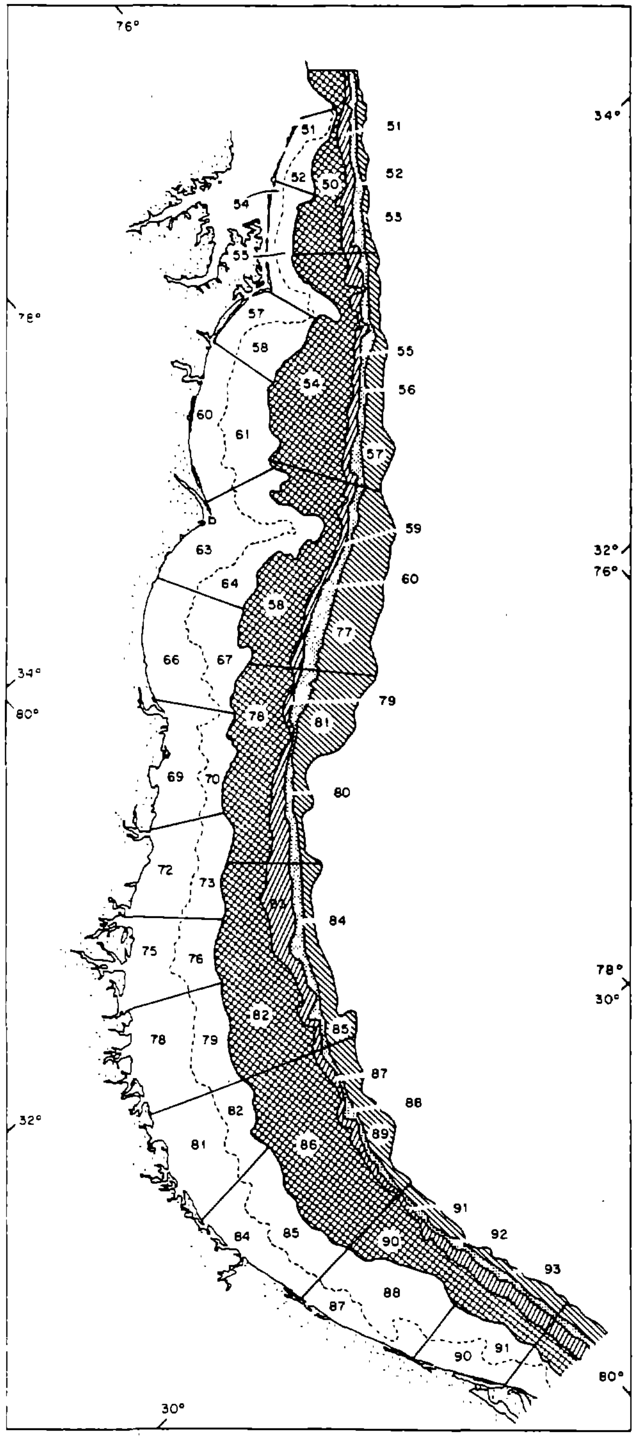
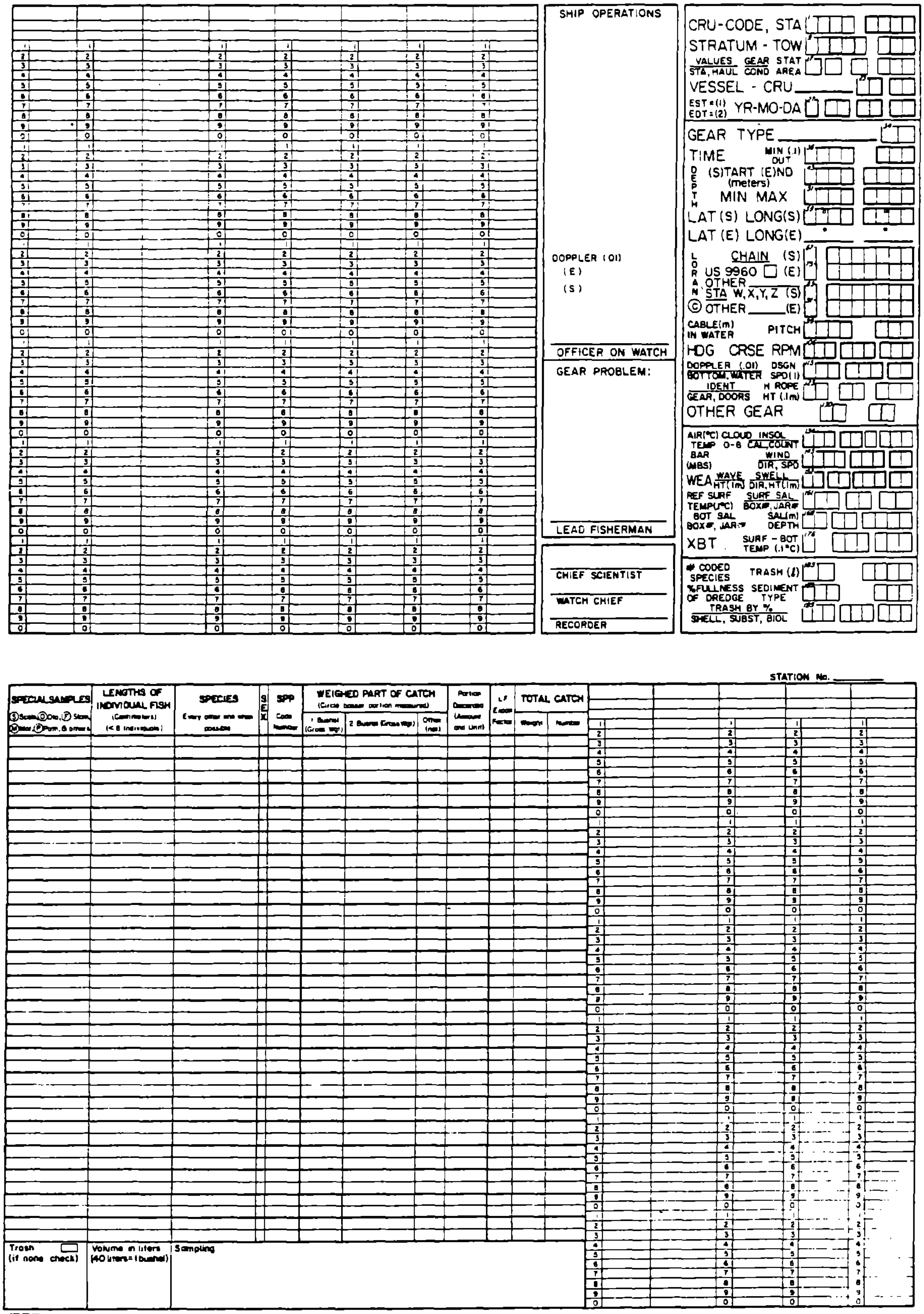


Figure 4. Strata sampled on NEFC inshore and offshore bottom trawl surveys between Cape Hatteras, North Carolina and Cape Canaveral, Florida.


SHIP OPERATIONS

DOPPLER (.01)
(E)
(S)

OFFICER ON WATCH

GEAR PROBLEM:

LEAD FISHERMAN

CHIEF SCIENTIST

WATCH CHIEF

RECORDER

CRU-CODE, STA
STRATUM - TOW
VALUES GEAR STAT
STA, HAUL COND AREA
VESSEL - CRU
EST=(1) EDT=(2) YR-MO-DA
GEAR TYPE
TIME MIN (.1) OUT
DEPTH (S)TART (E)ND (meters)
MIN MAX
LAT(S) LONG(S)
LAT(E) LONG(E)
LORAN CHAIN (S)
US 9960 (E)
OTHER
STA W,X,Y,Z (S)
© OTHER (E)
CABLE(m) IN WATER PITCH
HDG CRSE RPM
DOPPLER (.01) BOTTOM, WATER DSGN SPD(.1)
IDENT GEAR, DOORS H ROPE HT (.1m)
OTHER GEAR
AIR(°C) TEMP CLOUD 0-8 INSOL CAL COUNT
BAR (MBS) WIND DIR, SPD
WEA WAVE HT(m) SWELL DIR, HT(m)
REF SURF TEMP(°C) SURF SAL BOX#, JAR#
BOT SAL BOX#, JAR# SAL(m) DEPTH
XBT SURF - BOT TEMP (.1°C)
CODED SPECIES TRASH (ℓ)
% FULLNESS OF DREDGE SEDIMENT TYPE
TRASH BY % SHELL, SUBST, BIOL

STATION No.

SPECIAL SAMPLES (S)Scale, (O)Oto, (F) Stom, (W)Wor, (P)Path, & others	LENGTHS OF INDIVIDUAL FISH (Centimeters) (< 8 individuals)	SPECIES Every effort into when possible	SEX	SPP Code Number	WEIGHED PART OF CATCH (Circle bigger portion measured): 1 Bushel (Gross Wgt)	2 Bushel (Gross Wgt)	Other (net)	Portion Discarded (Amount and Unit)	L.F. Expan. Factor	TOTAL CATCH Weight	Number

Trash (if none check) | Volume in liters (40 liters = 1 bushel) | Sampling

Figure 5. Cruise log form used for recording data during NEFC bottom trawl surveys.

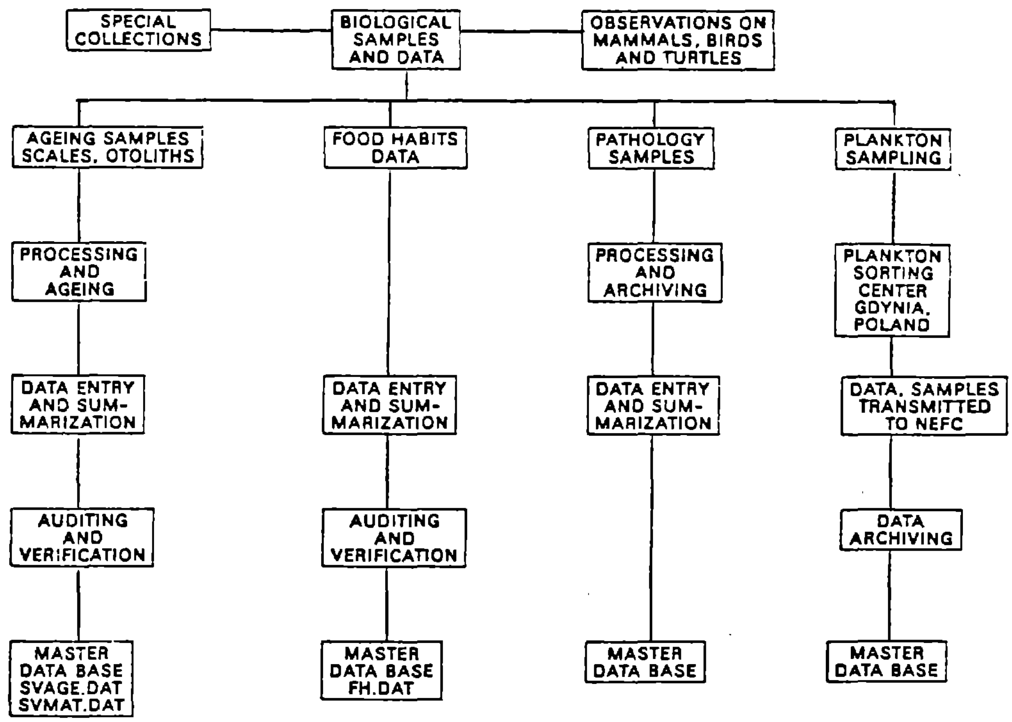


Figure 6. Flow diagram indicating disposition of biological samples and observations collected or recorded during NEFC bottom trawl surveys.

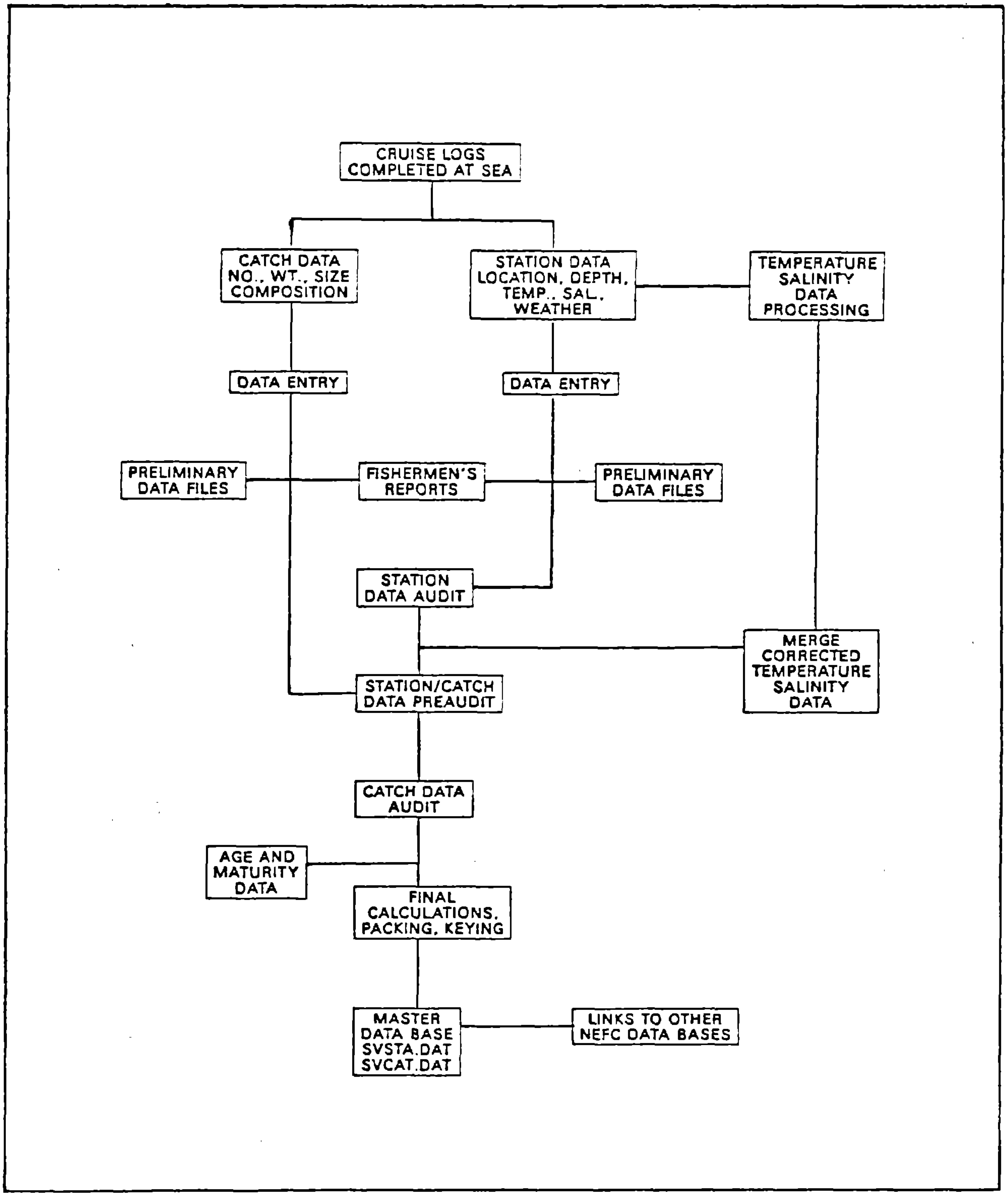


Figure 7. Flow diagram indicating NEFC survey data entry procedures and outputs.

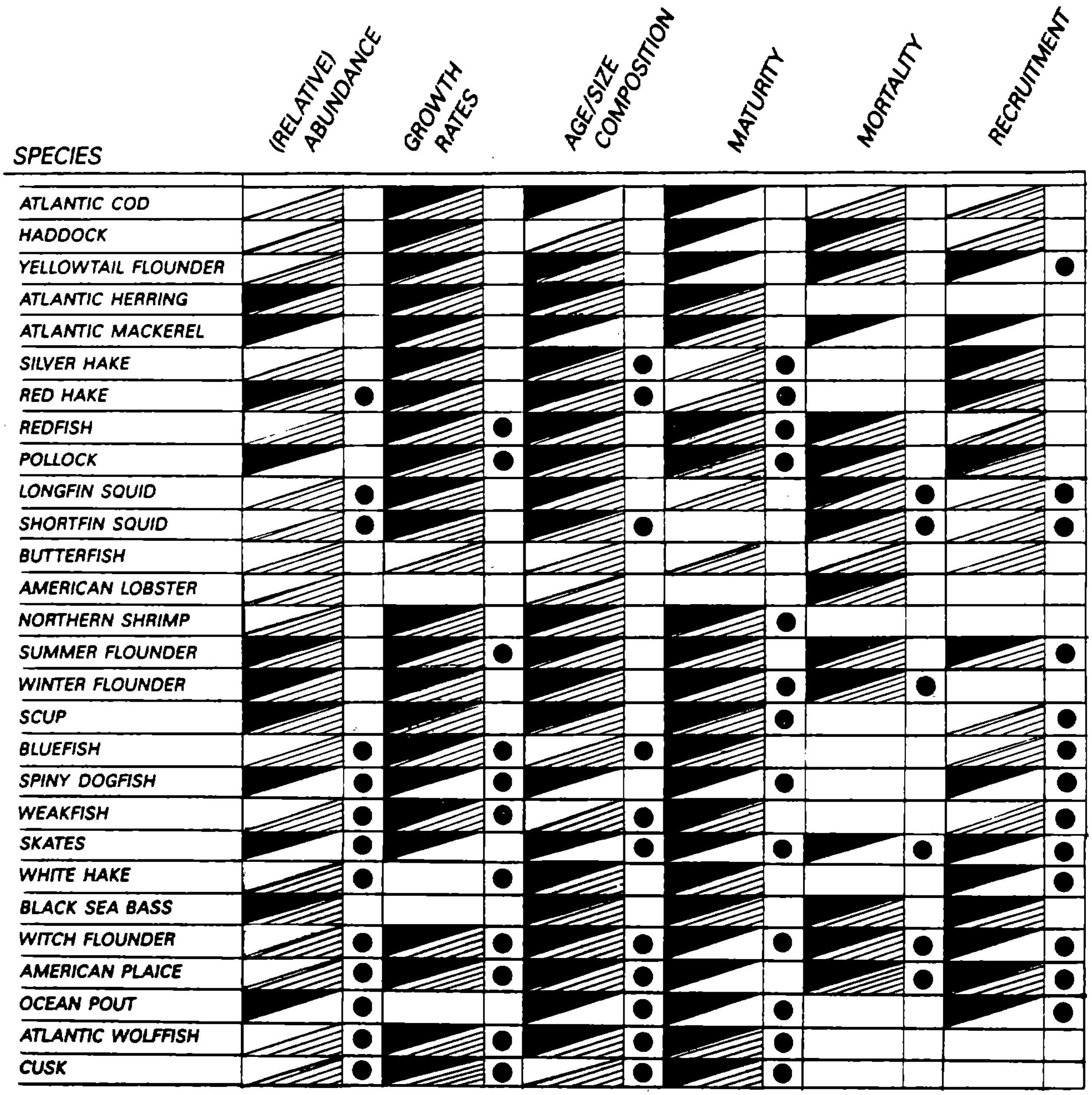


Figure 8. Relative utility of NEFC spring and autumn survey data by category (type of assessment-related information) for 28 finfish and invertebrate species. Spring = black; autumn = cross-hatched; solid circles indicate whether the surveys provide the sole source of information.

SURVEY ASSESSMENT INFORMATION SOURCE

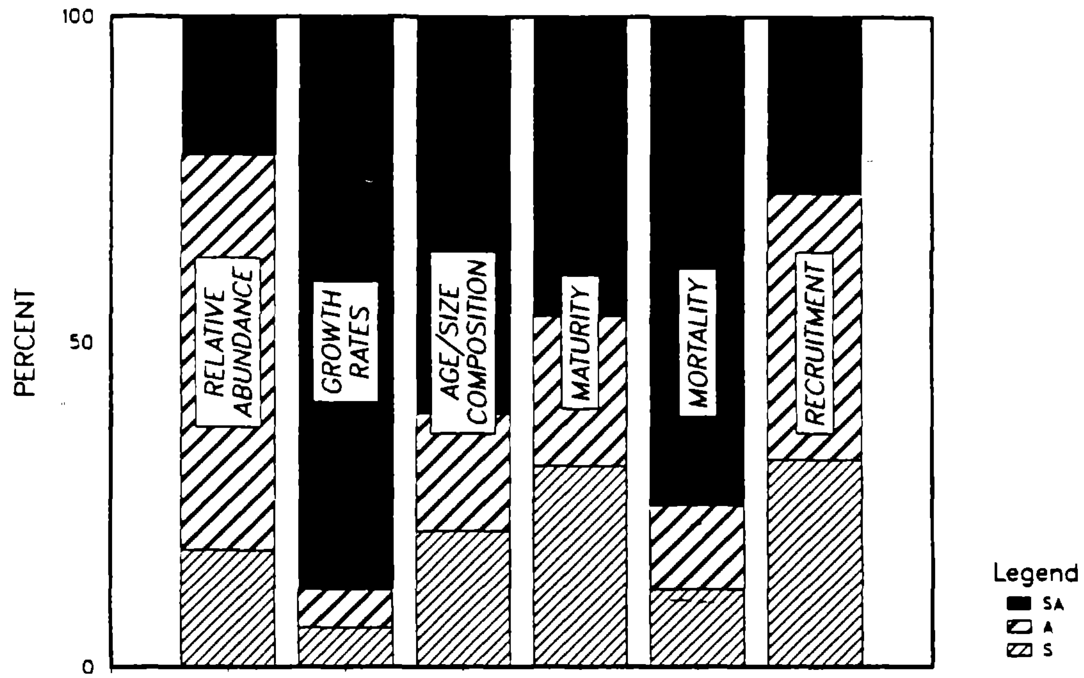


Figure 9. Relative utility of NEFC spring and autumn survey data by category (type of assessment-related information) summarized over 28 finfish and invertebrate species (see Figure 8 for species involved). Percentages for each category were based on number of species for which surveys provide information.

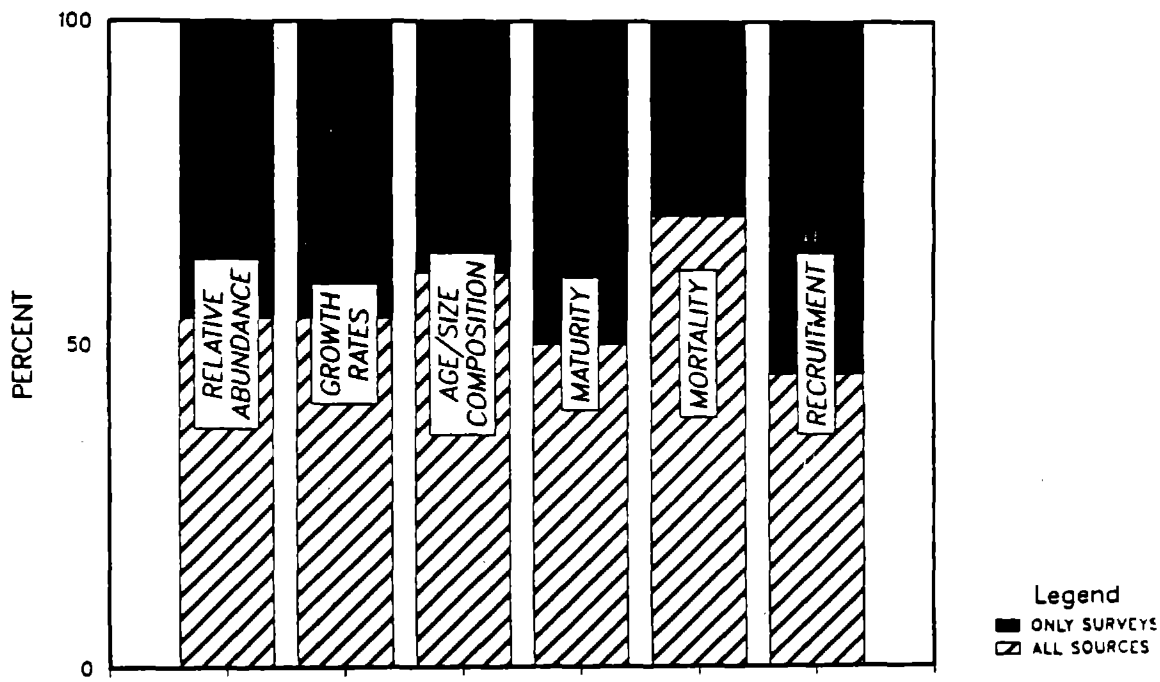
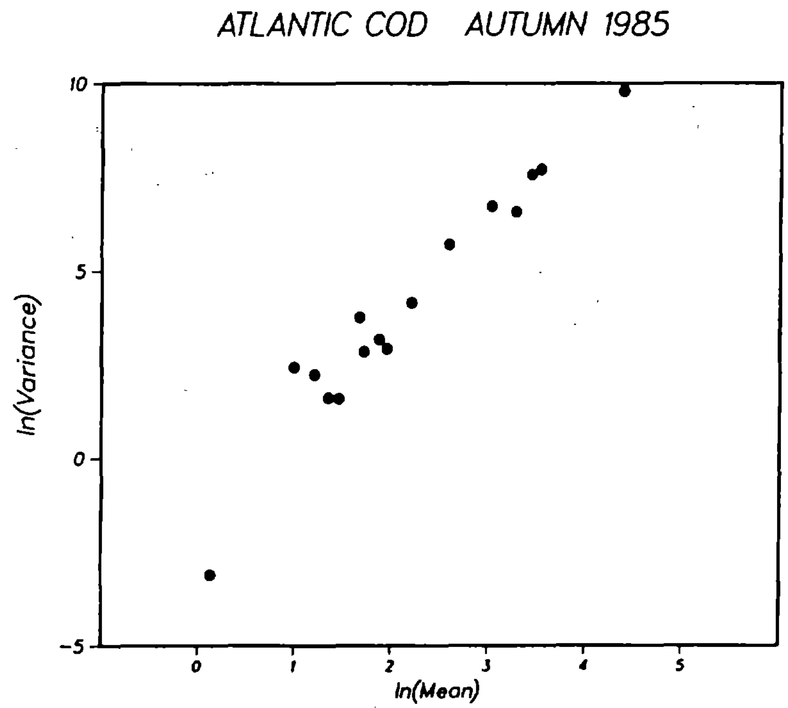


Figure 10. Importance of NEFC spring and autumn surveys as a source of assessment information for 28 finfish and invertebrate species. Percentages for each category based on number of species for which information specified is available.



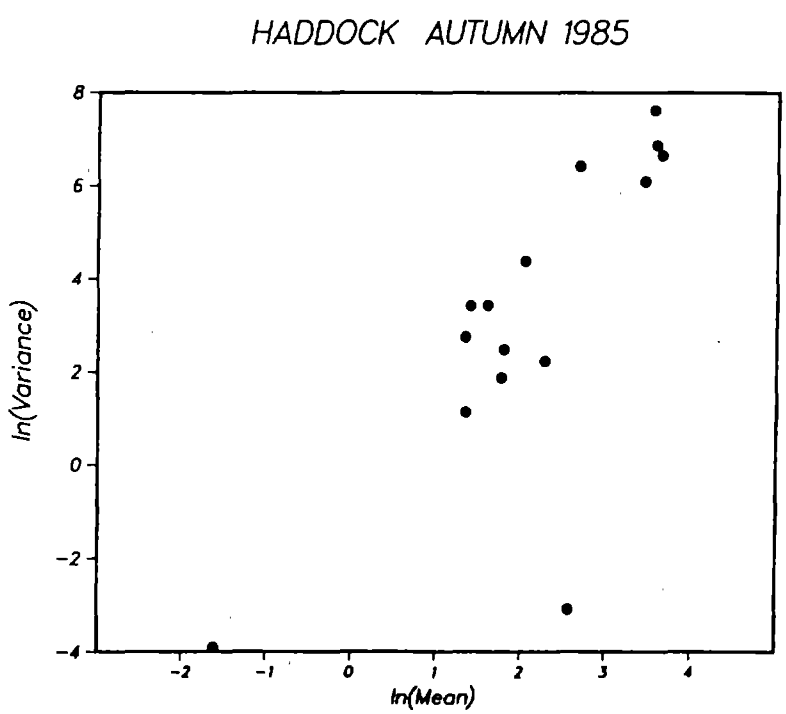
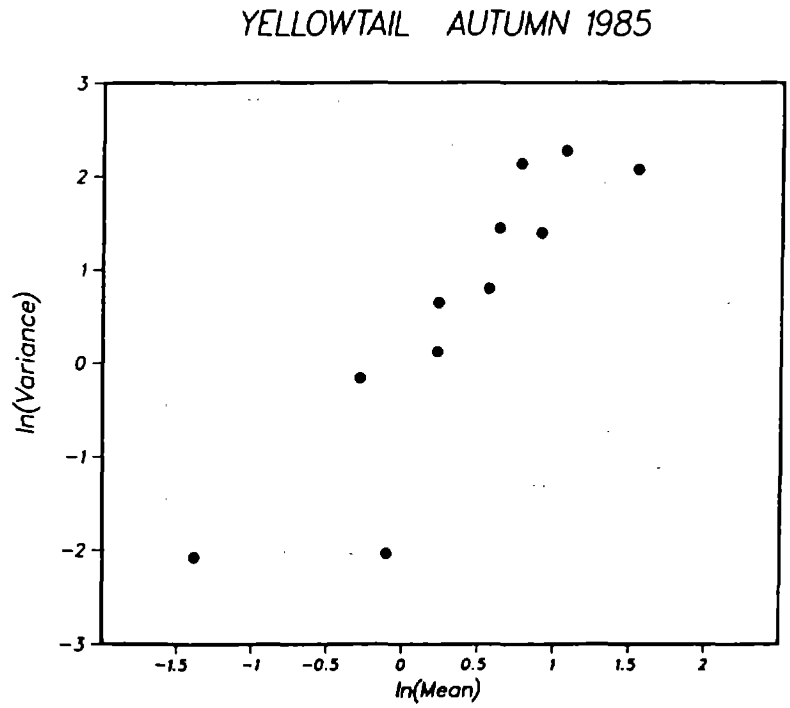


Figure 11. Relationships between variance and mean survey catch per tow for Atlantic cod and haddock taken during the NEFC 1985 autumn bottom-trawl survey (date transformed to natural logarithms).



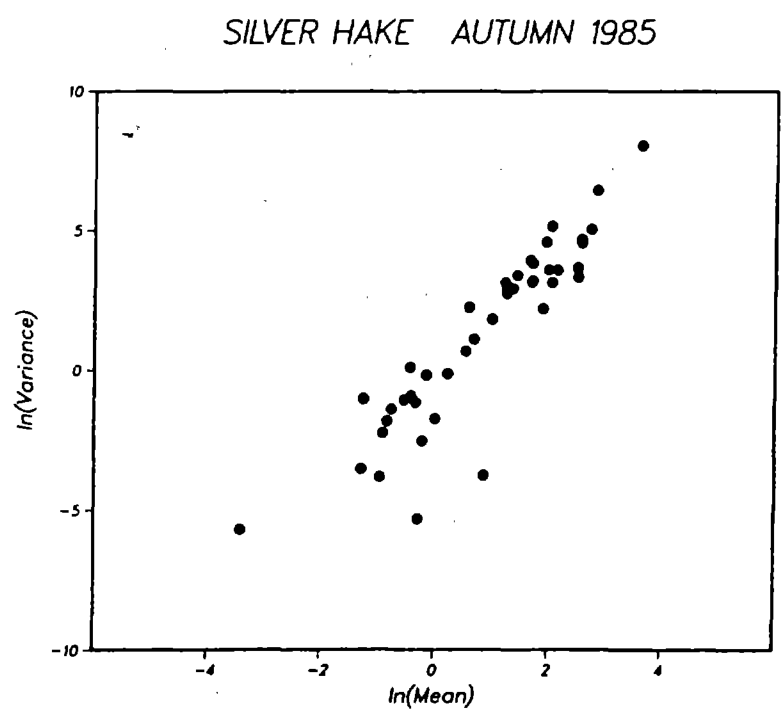


Figure 12. Relationship between variance and mean survey catch per tow for yellowtail flounder and silver hake taken during the NEFC 1985 autumn bottom-trawl survey (data transformed to natural logarithms).

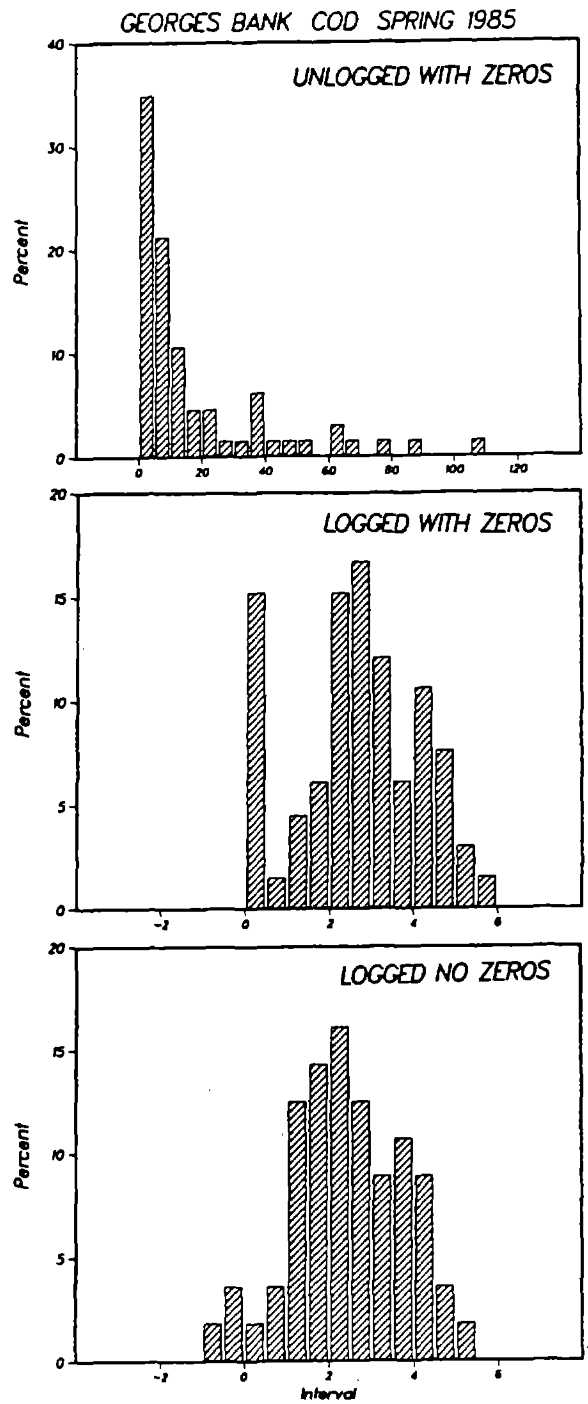
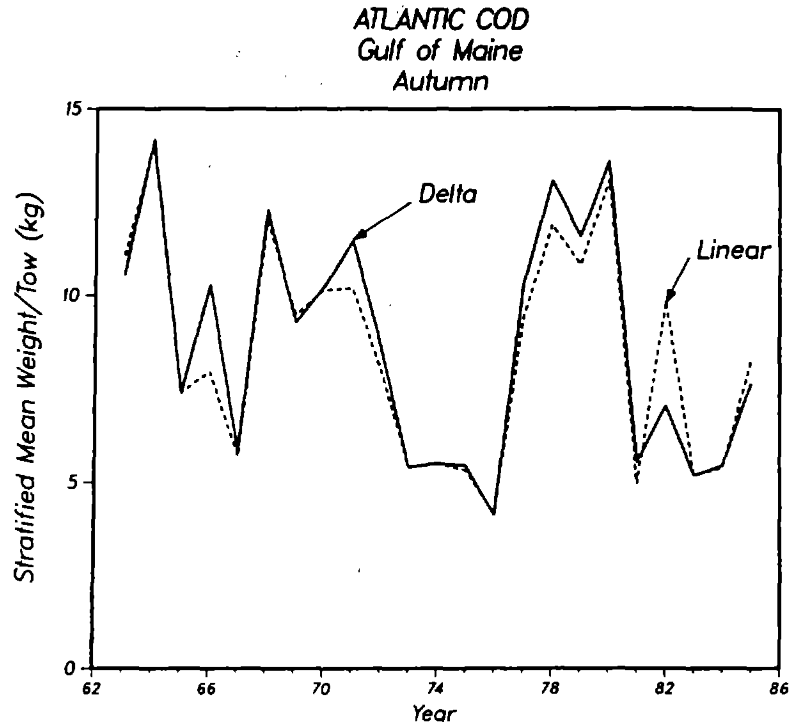


Figure 13. Observed distribution of Atlantic cod (catch per tow in weight) during the NEFC 1985 autumn survey.



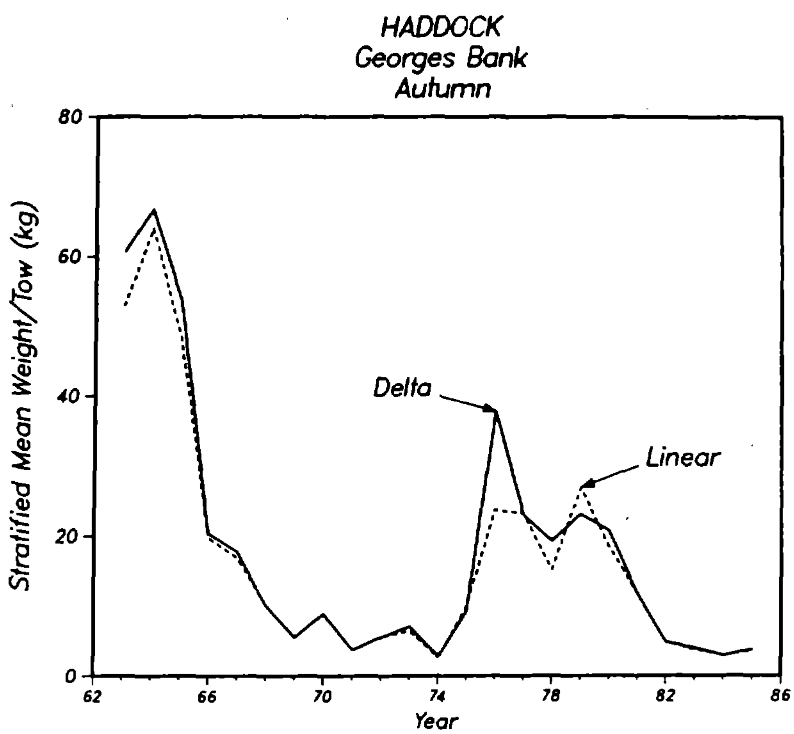
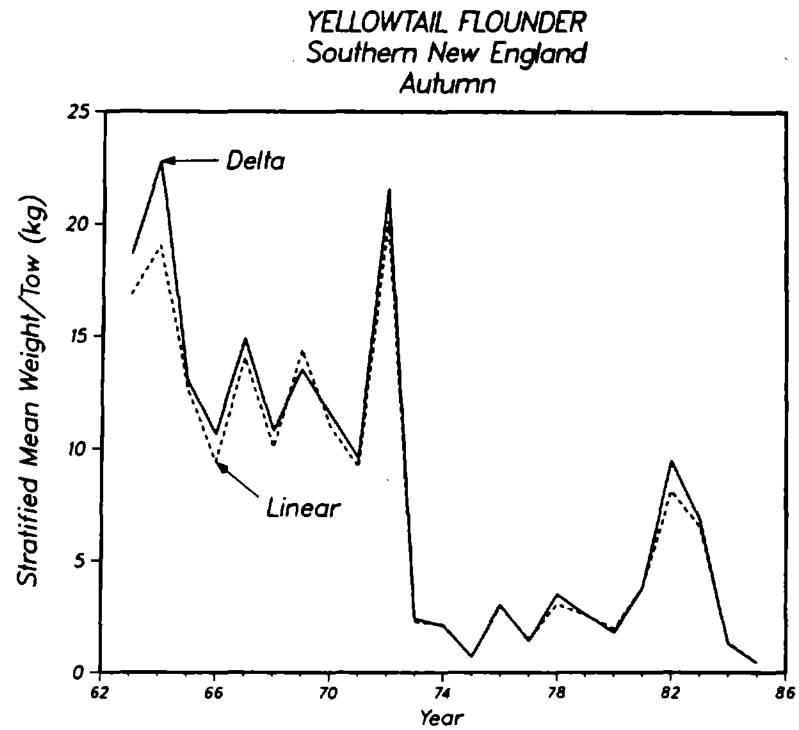


Figure 14. Stratified mean catch per tow in weight for Atlantic cod and haddock taken in NEFC autumn bottom trawl surveys plotted against the corresponding Delta distribution estimators.



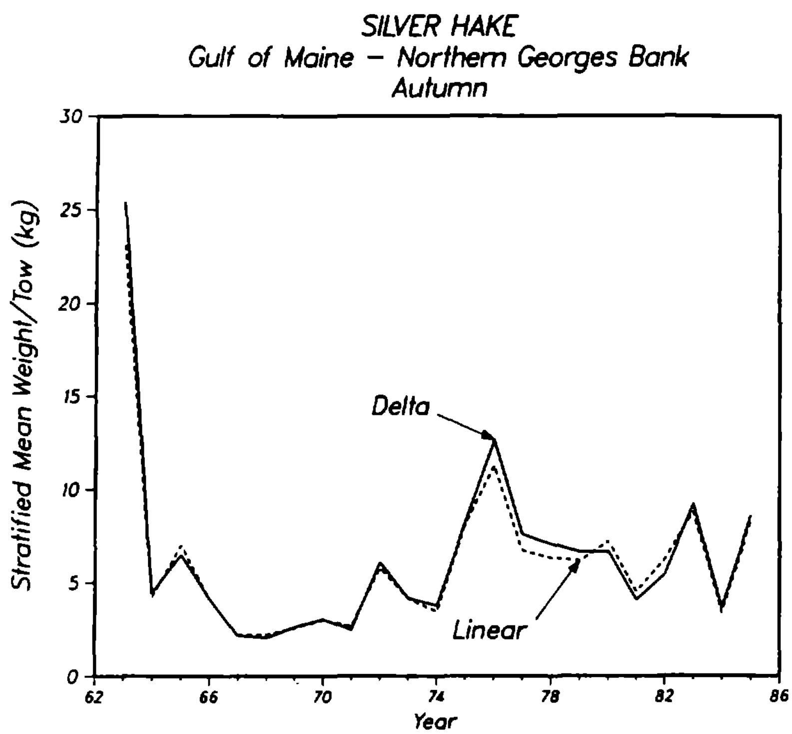


Figure 15. Stratified mean catch per tow in weight for yellowtail flounder and silver hake taken in NEFC autumn bottom trawl surveys plotted against the corresponding Delta distribution estimators, 1963-1985.

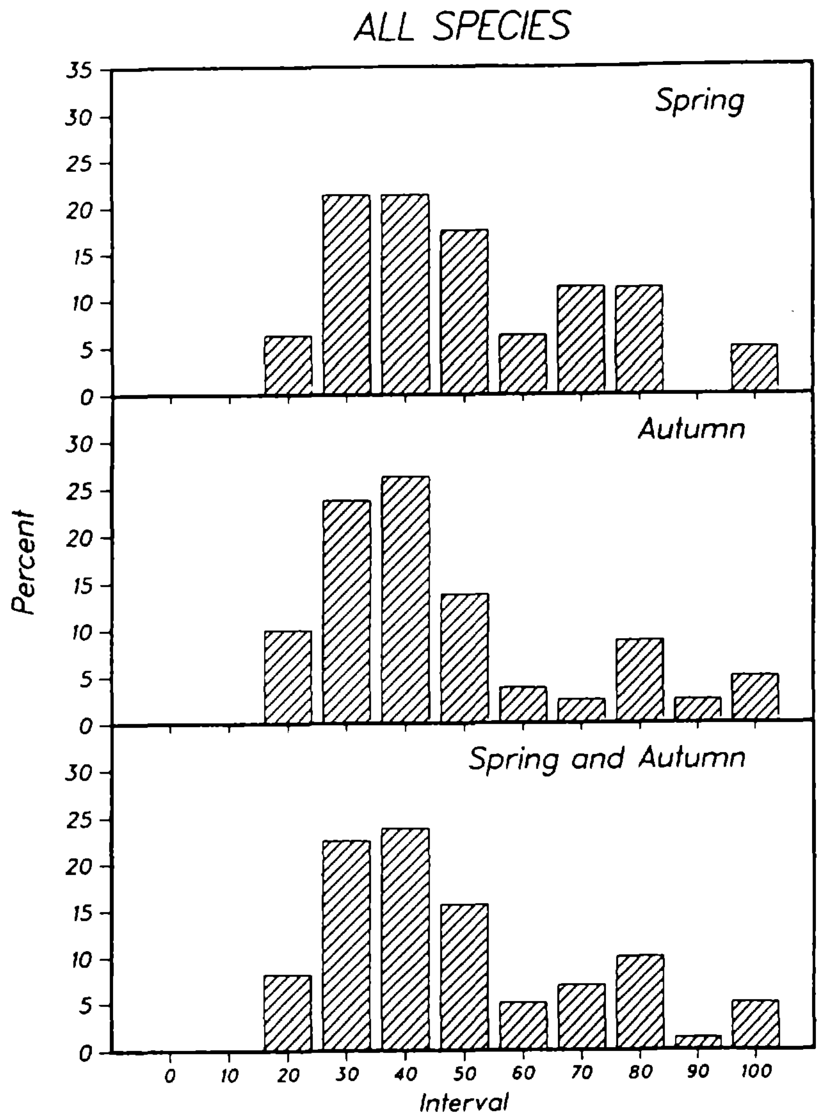


Figure 16. Frequency distribution of coefficients of variation by season for all species combined.

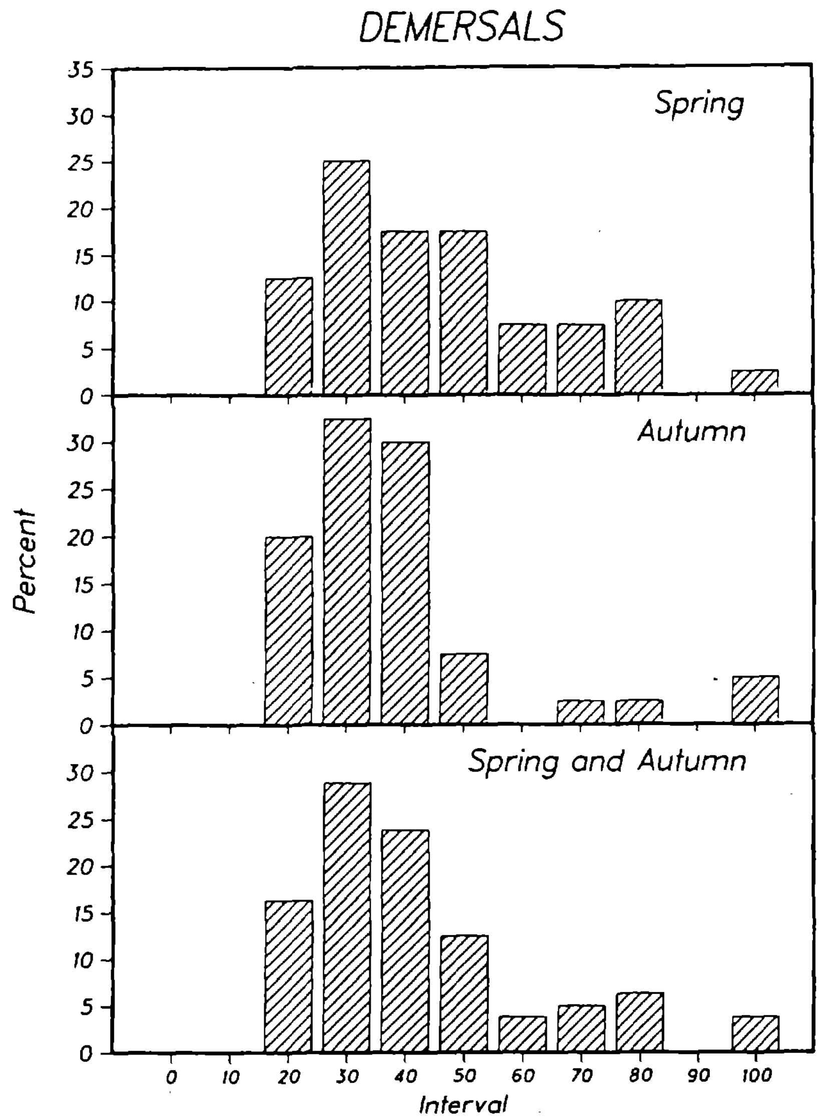


Figure 17. Frequency distribution of coefficients of variation by season for demersal species.

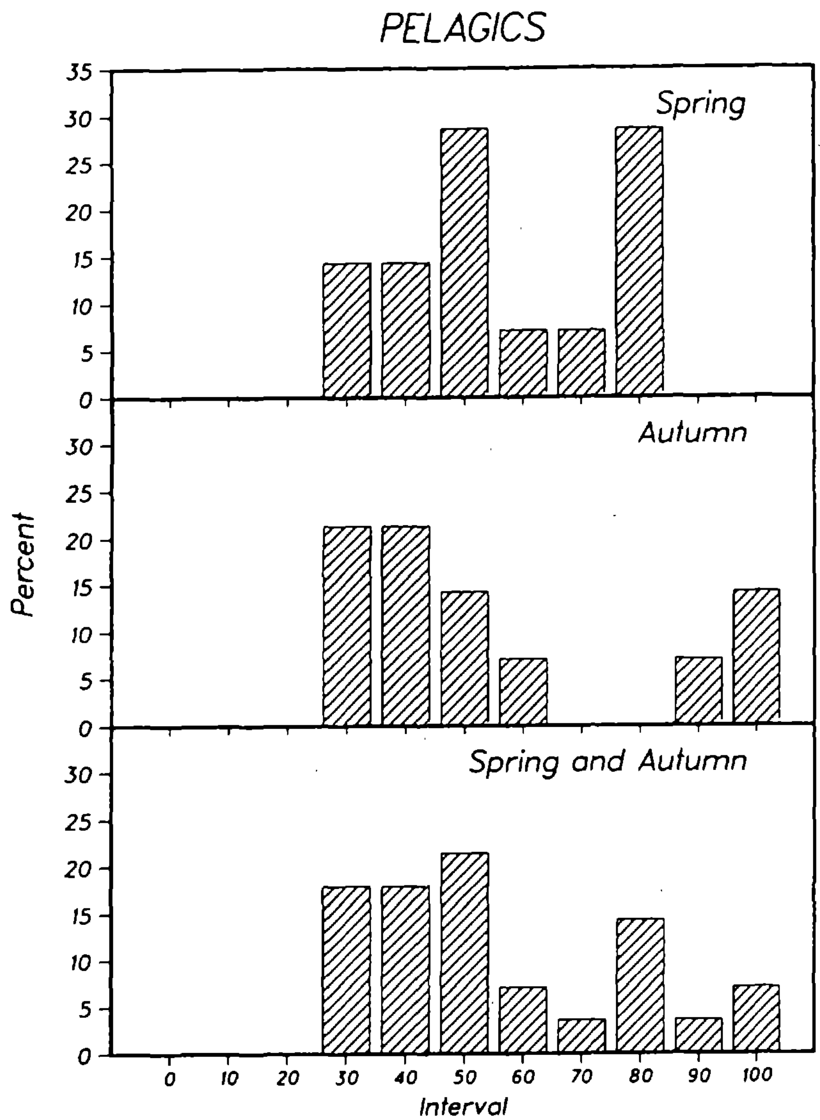


Figure 18. Frequency distribution of coefficients of variation by season for pelagic species.

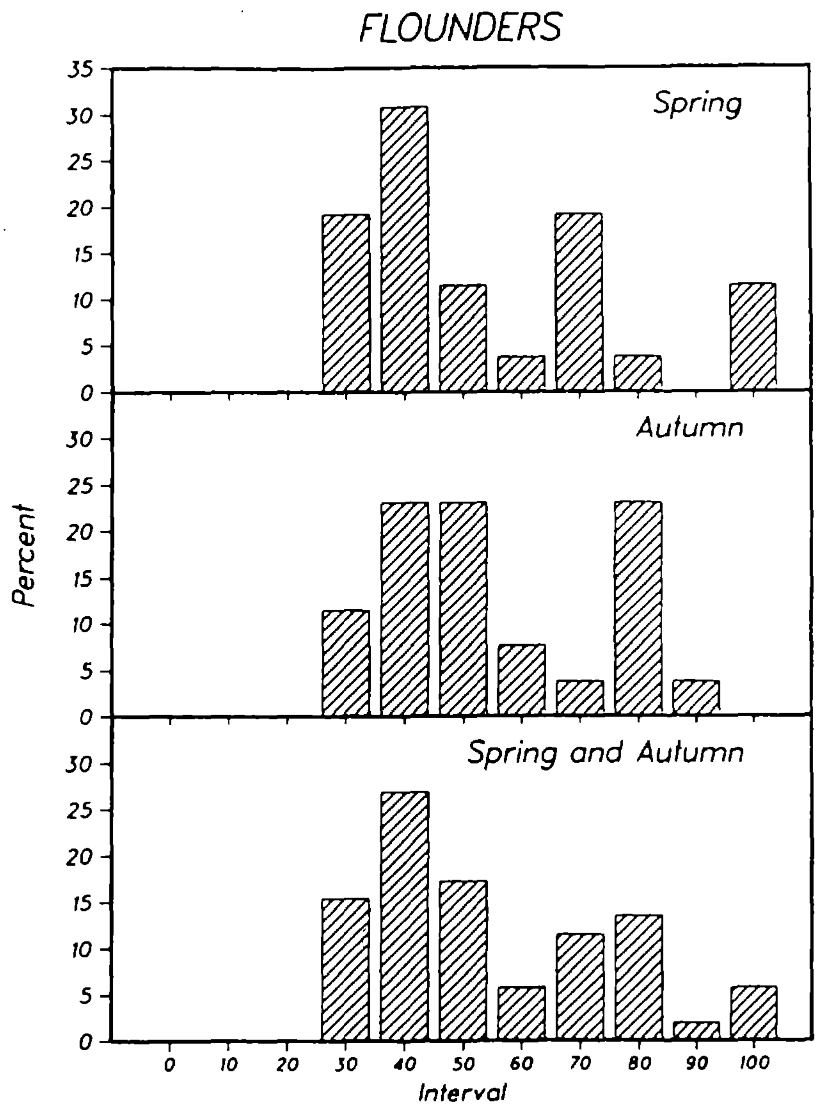
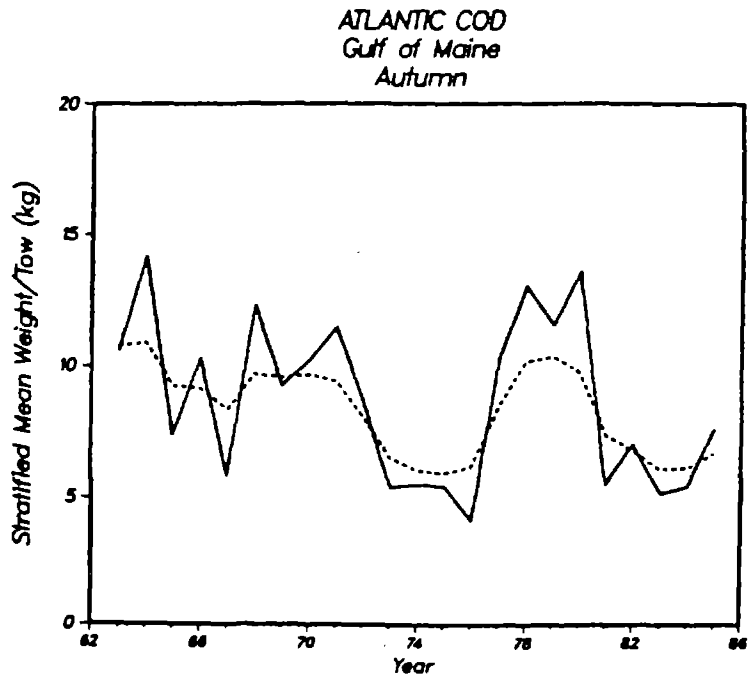


Figure 19. Frequency distribution of coefficients variation by season for flounders.



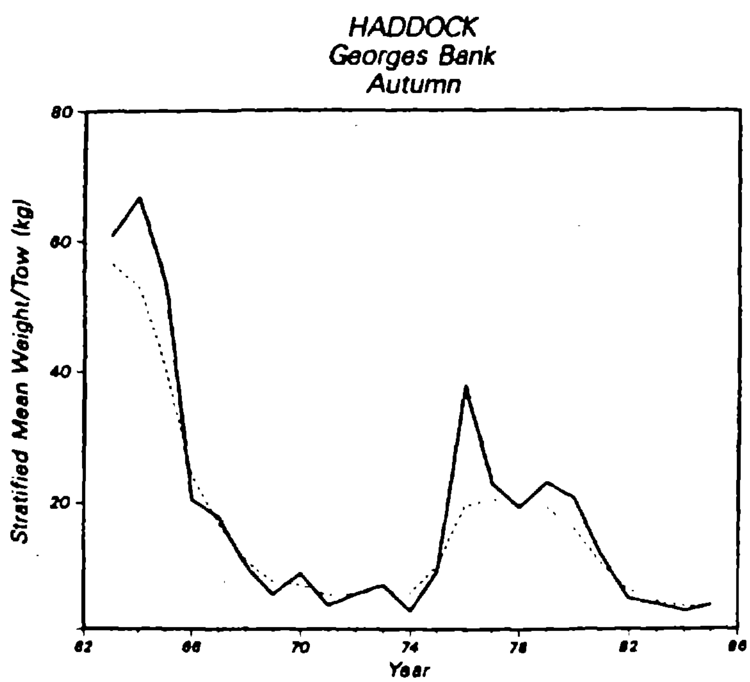


Figure 20. Effect of applying time series models to stratified mean catch per tow values (Delta distribution estimators, solid lines) for Atlantic cod and haddock.

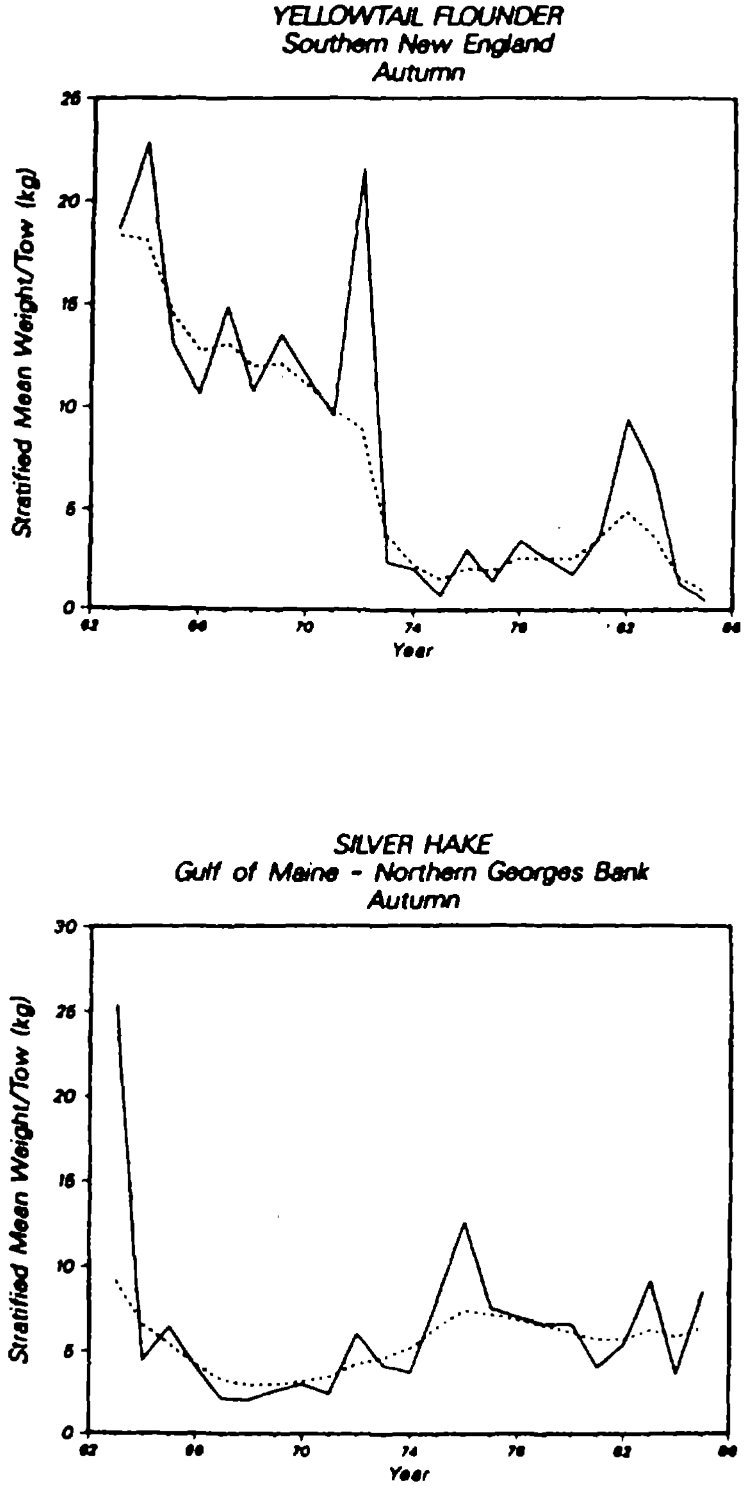
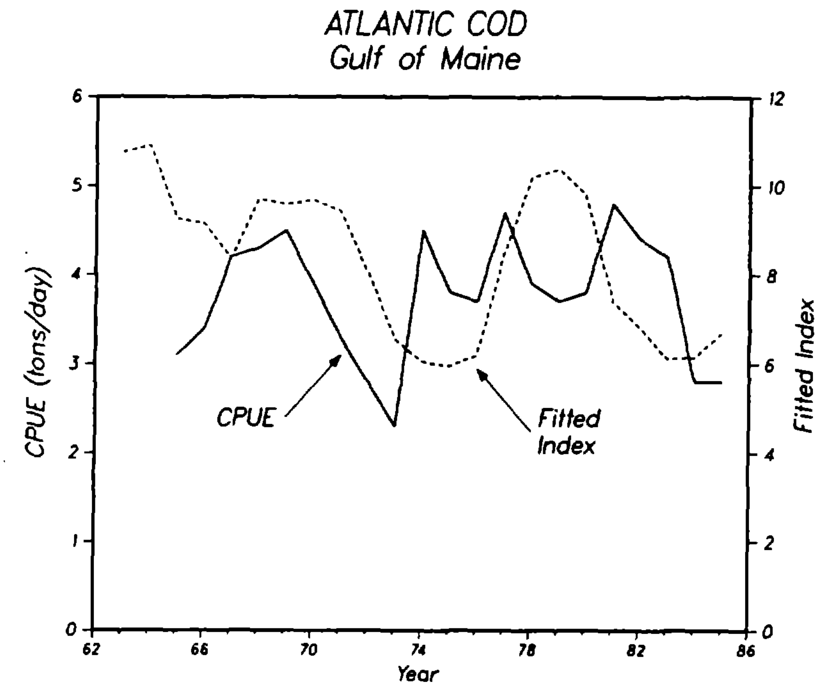


Figure 21. Effect of applying time series models to stratified mean catch per tow values (Delta distribution estimators, solid lines) for yellowtail flounder and silver hake.



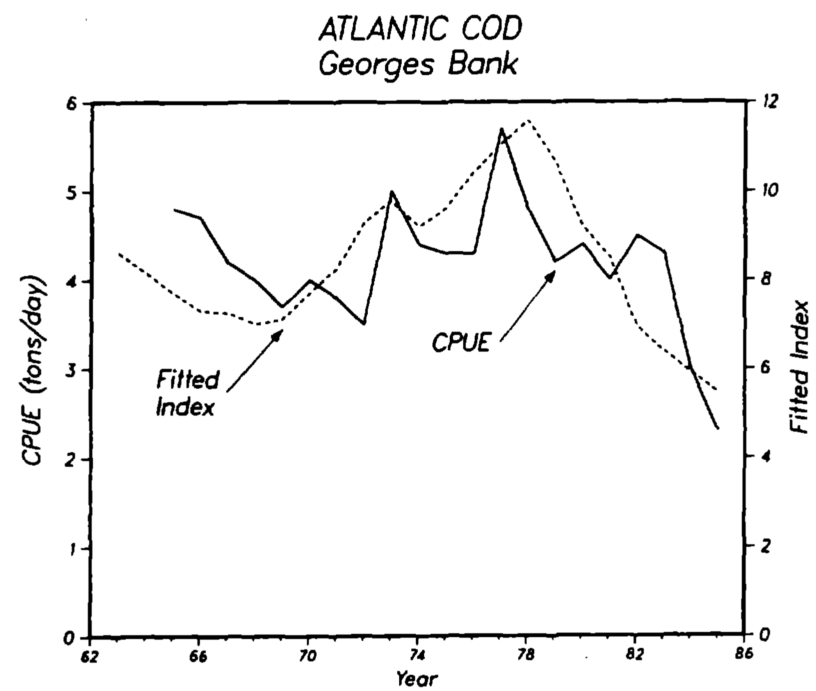


Figure 22. Comparisons between fitted (smoothed) survey indices and fishery dependent population estimates for cod.

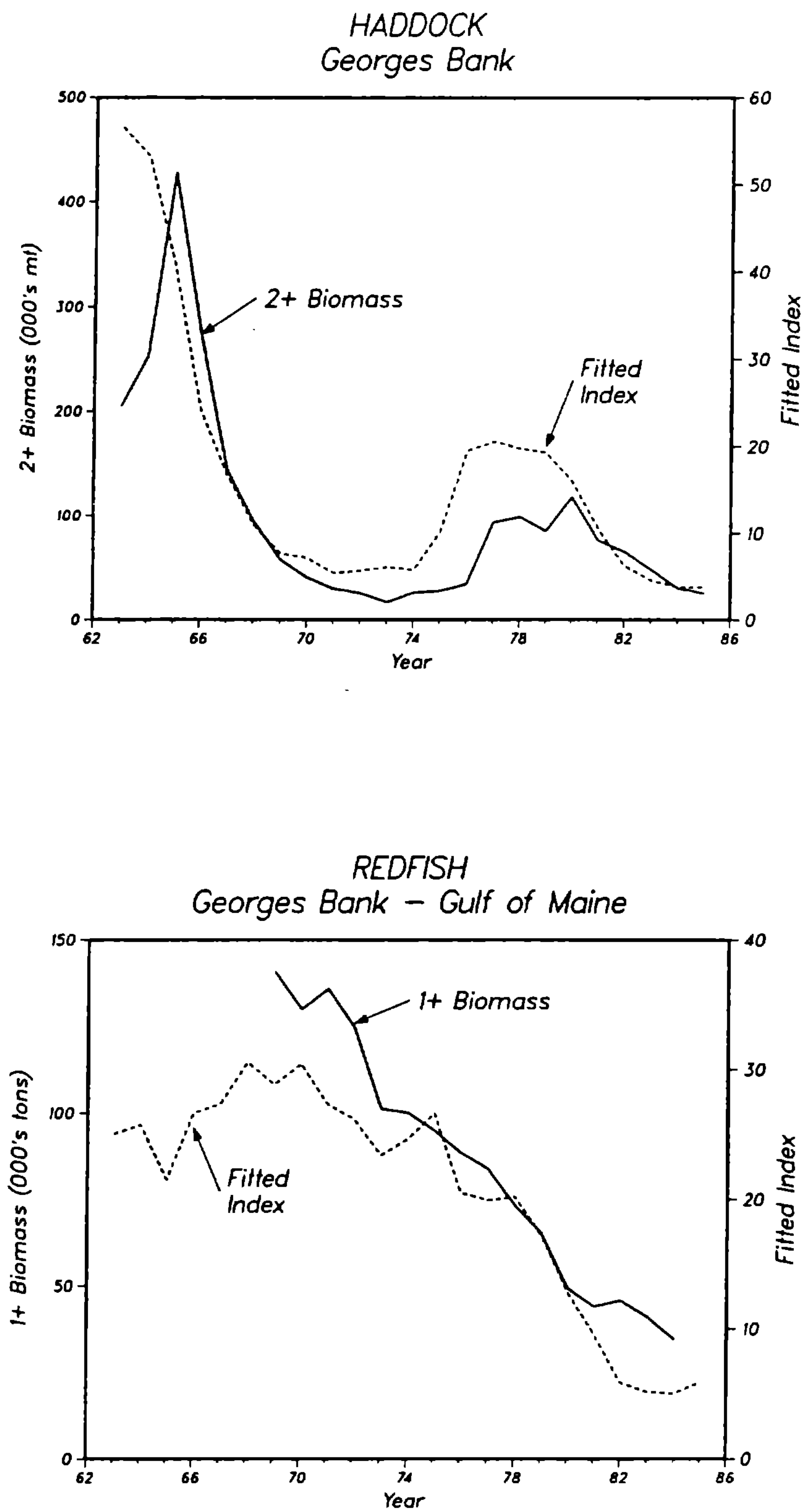


Figure 23. Comparisons between fitted (smoothed) survey indices and fishery dependent population estimates for haddock and redfish.

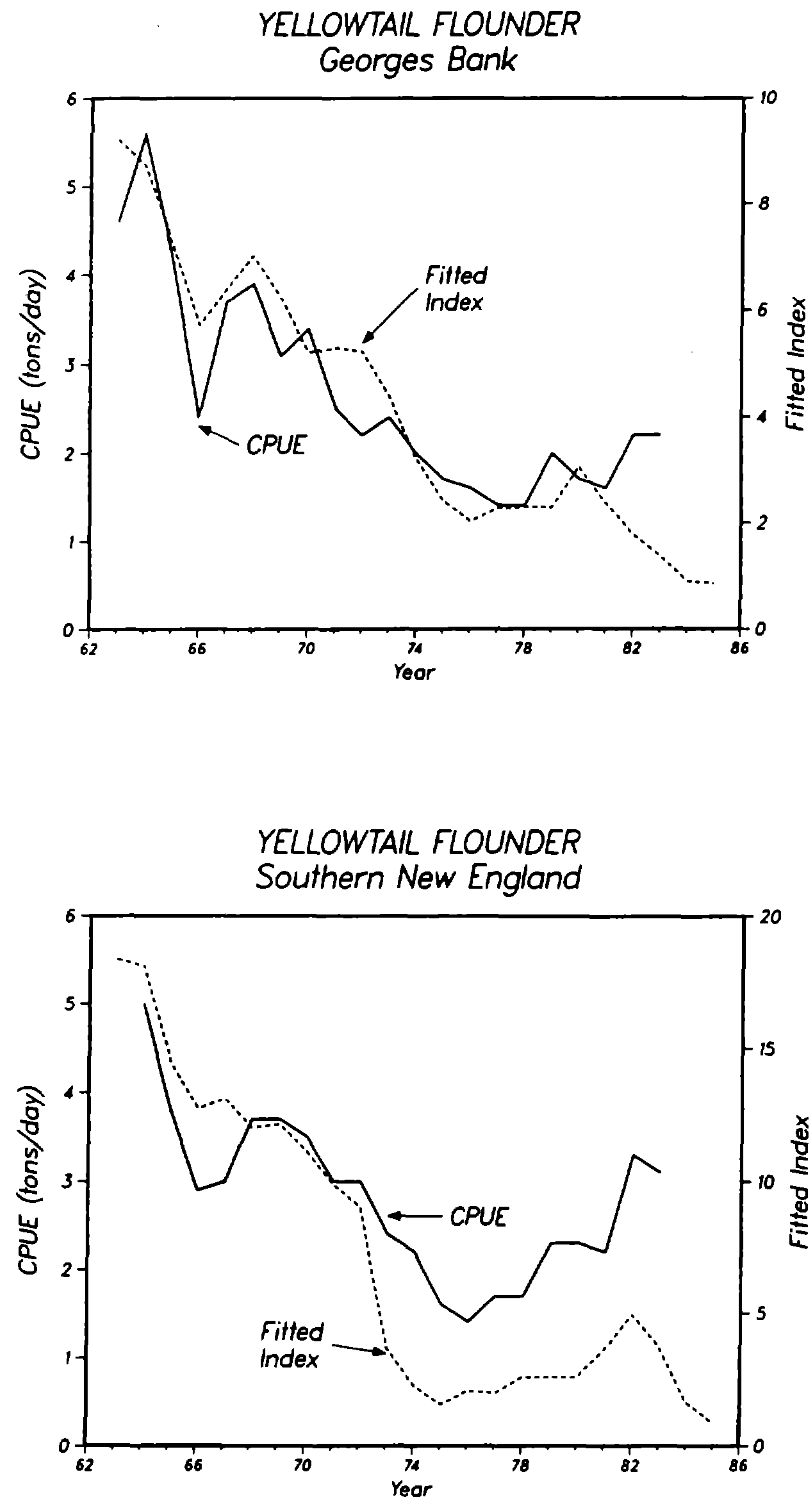


Figure 24. Comparisons between fitted (smoothed) survey indices and fishery dependent population estimates for yellowtail flounder.

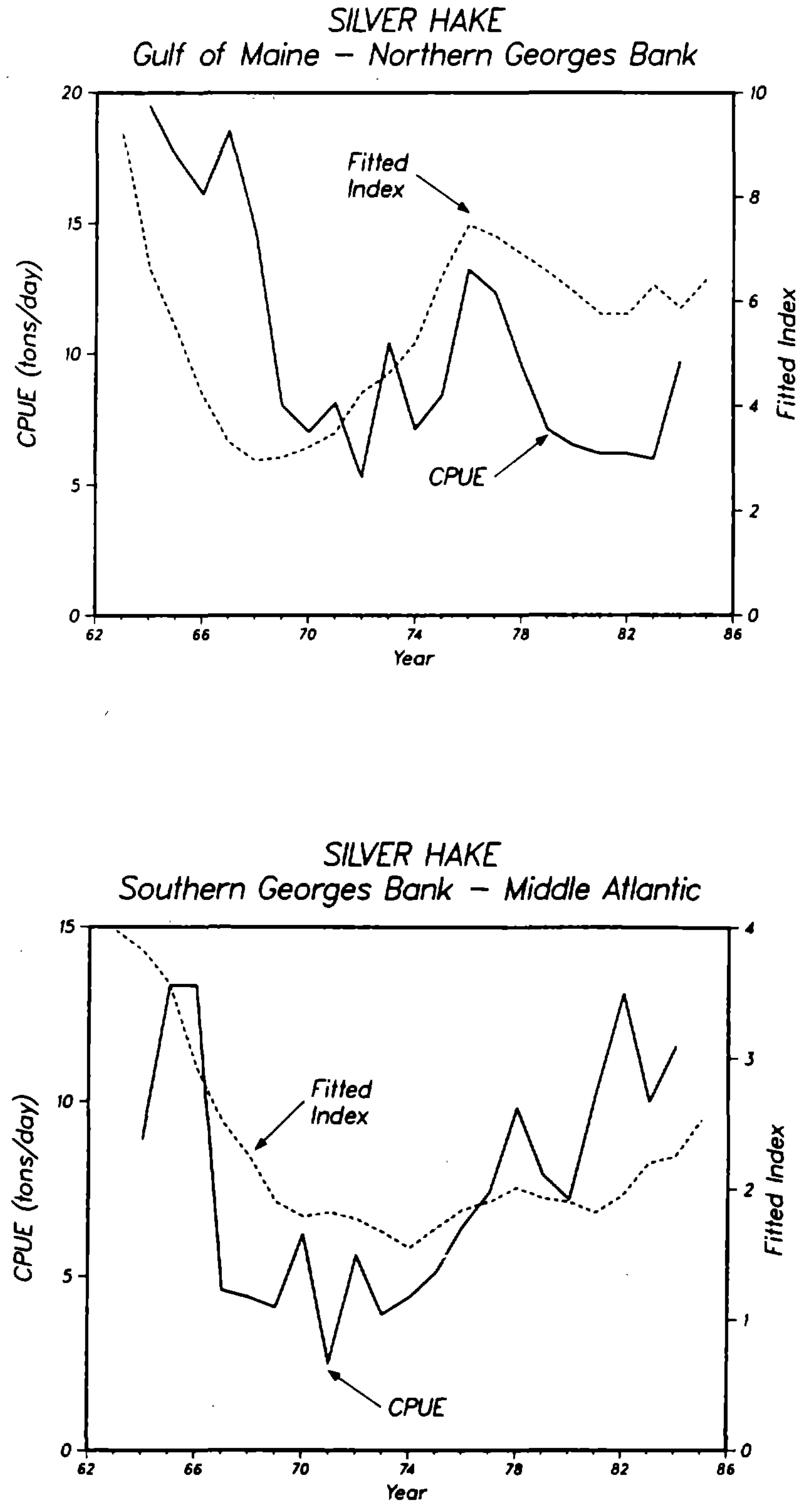


Figure 25. Comparisons between fitted (smoothed) indices and fishery dependent population estimates for silver hake.

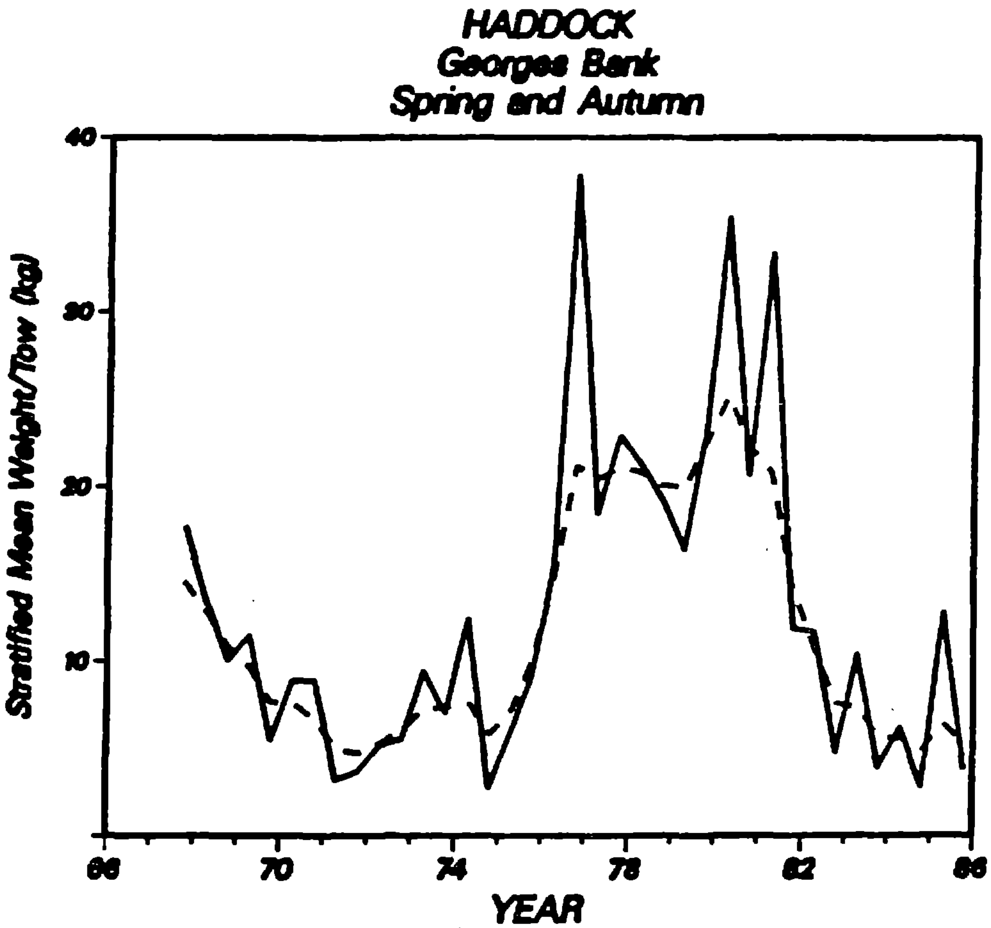


Figure 26. Stratified mean catch per tow (Delta distribution estimators. solid lines) for Georges Bank haddock taken in NEFC spring and autumn surveys, 1968-1986, smoothed by time-series modeling.

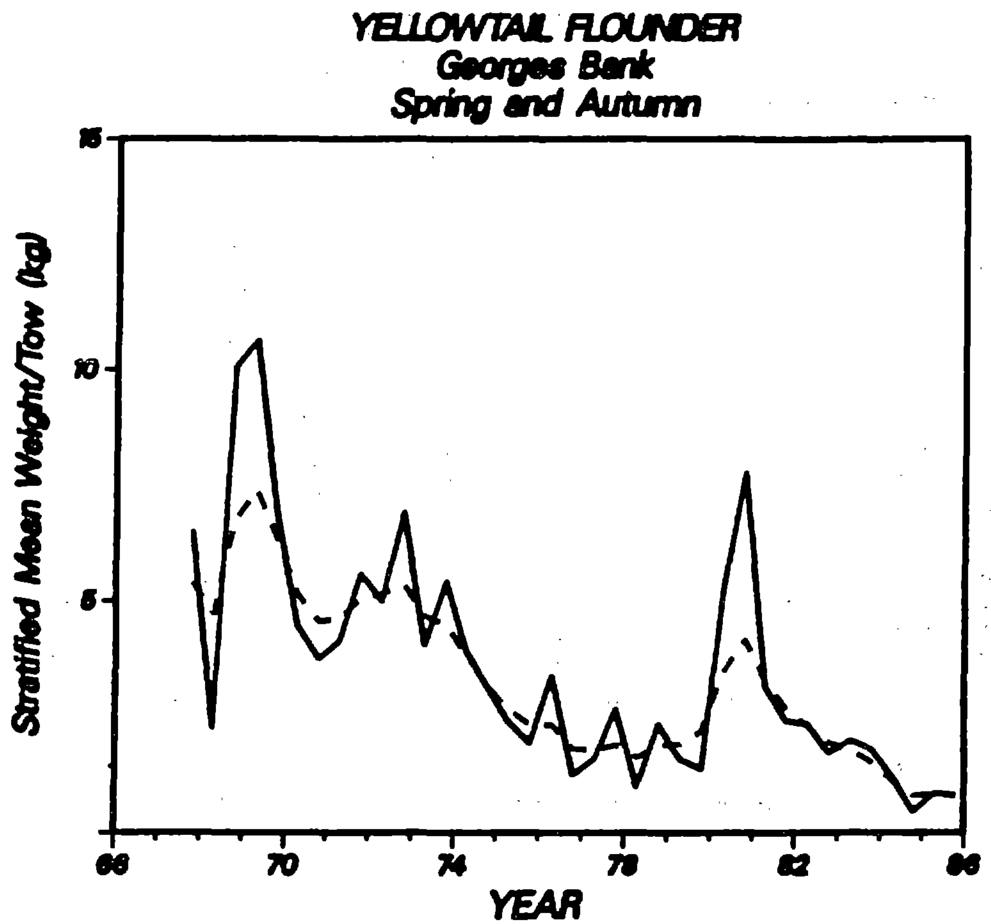


Figure 27. Stratified mean catch per tow (Delta distribution estimators, solid lines) for Georges Bank yellowtail taken in NEFC spring and autumn surveys, 1968-1986, smoothed by time-series modeling.

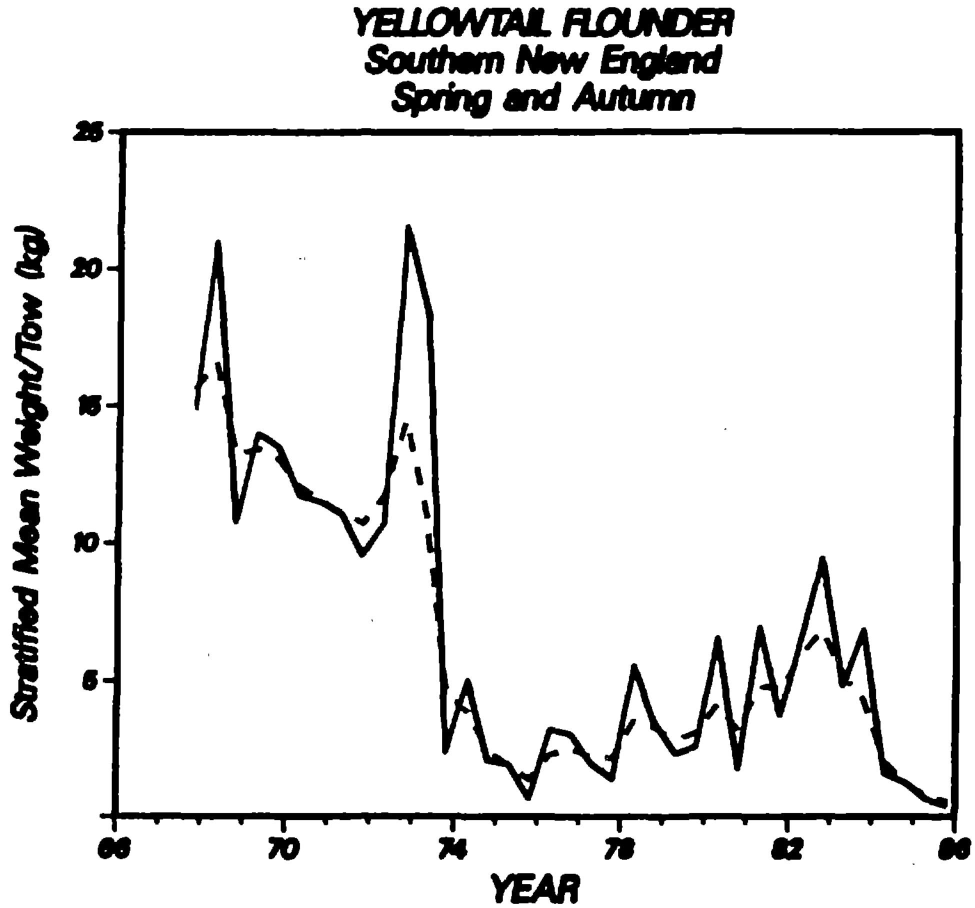


Figure 28. Stratified mean catch per tow (Delta-distribution estimators, solid lines) for Southern New England yellowtail taken in NEFC spring and autumn surveys 1968-1986, smoothed by time-series modeling.

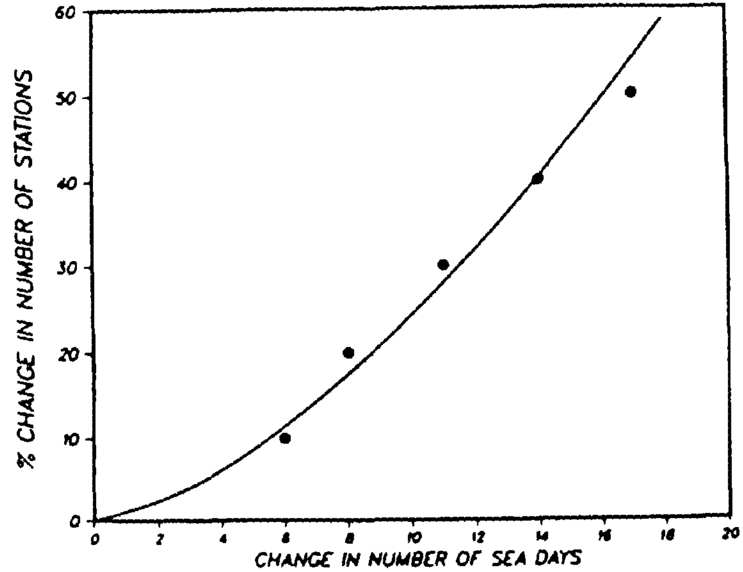


Figure 29. Relationship between change in number of sea days and percentage change in number of stations that can be occupied during NEFC spring and autumn bottom trawl survey.

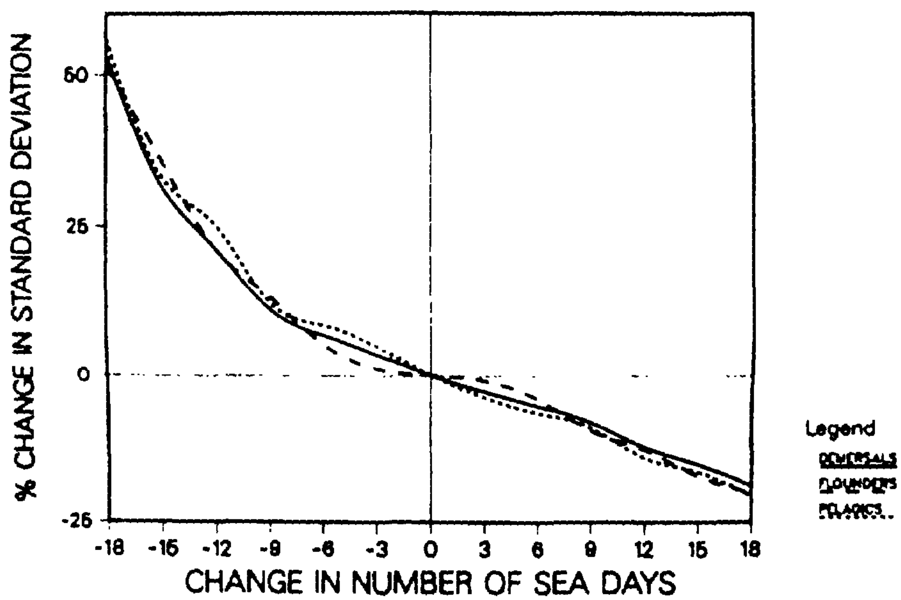
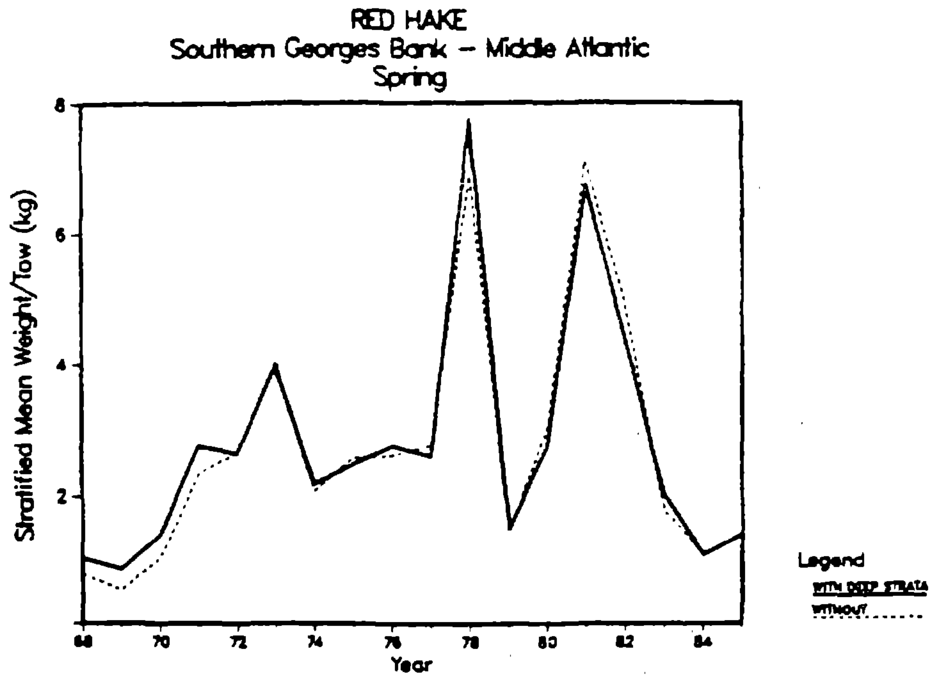


Figure 30. Relationship between changes in number of sea days and percentage change in standard deviation for demersal, pelagic and flounder species taken during the NEFC 1985 autumn bottom trawl survey.



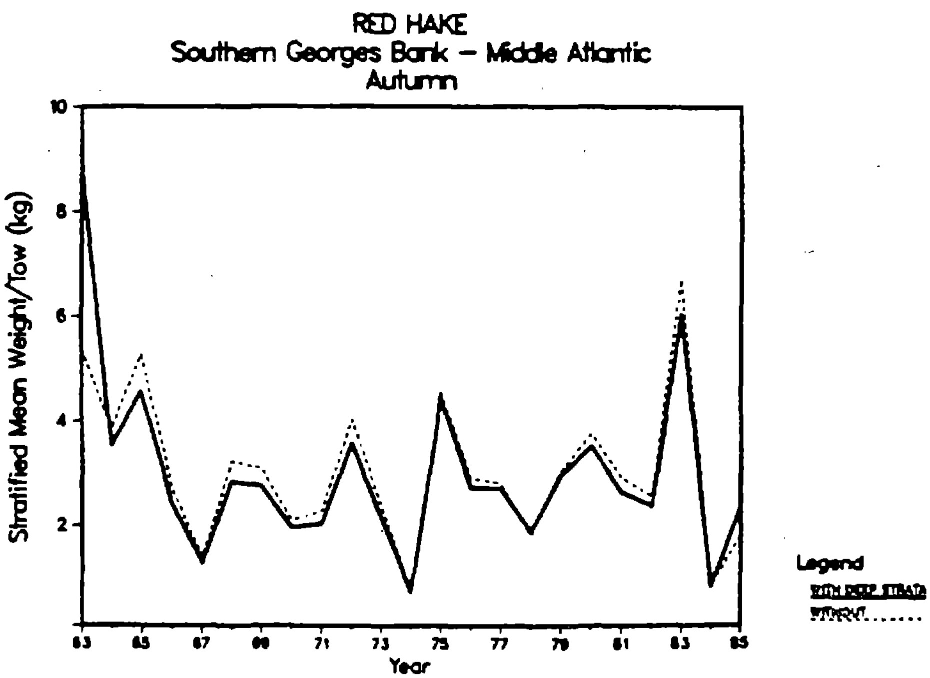
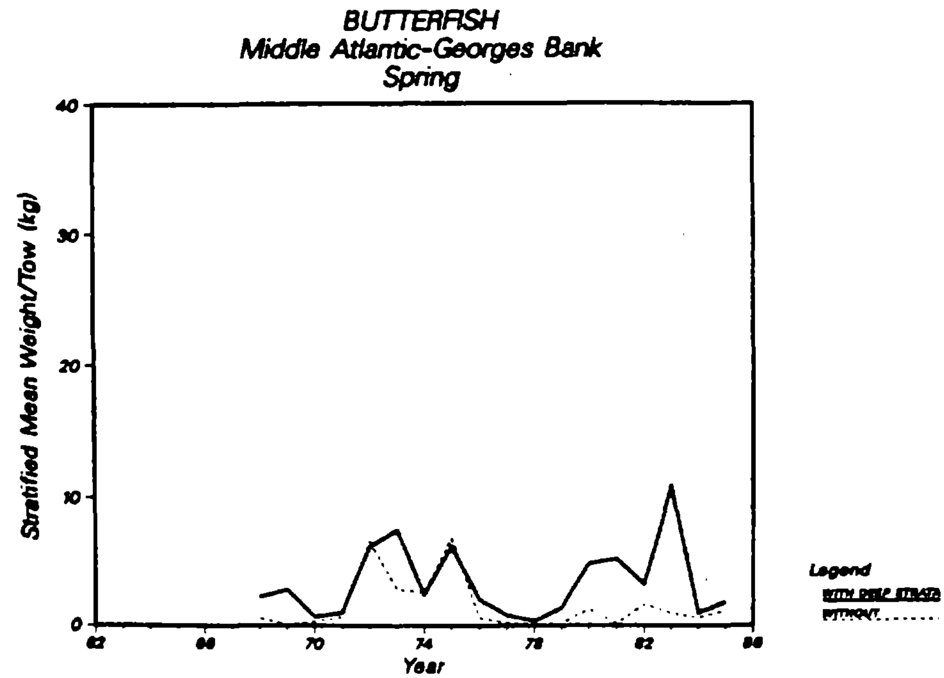


Figure 31. Comparison of stratified mean weight per tow (Delta distribution) with and without strata of depths greater than 110 m for red hake.



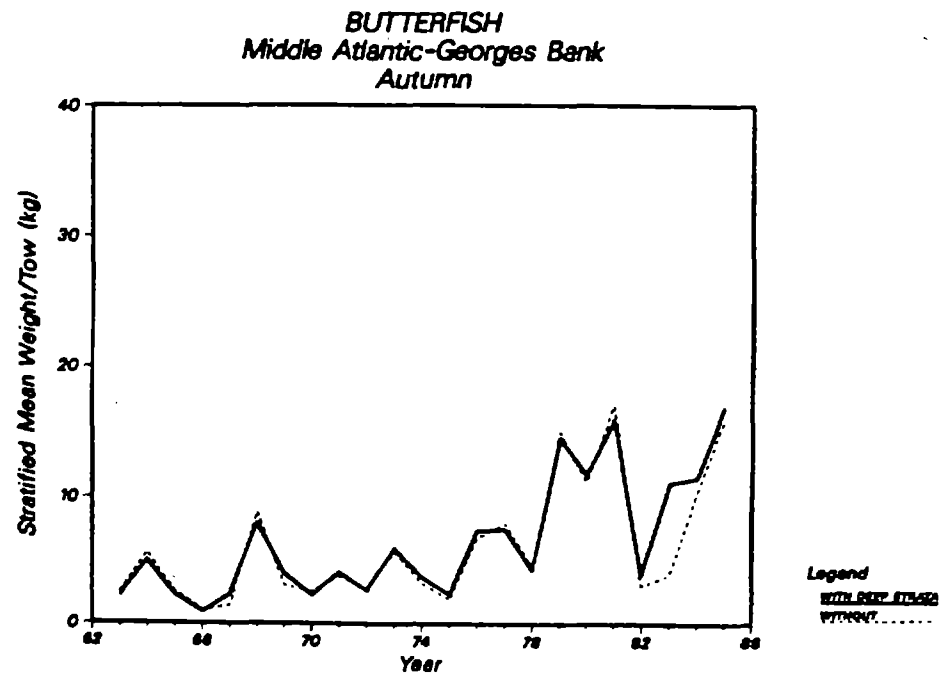
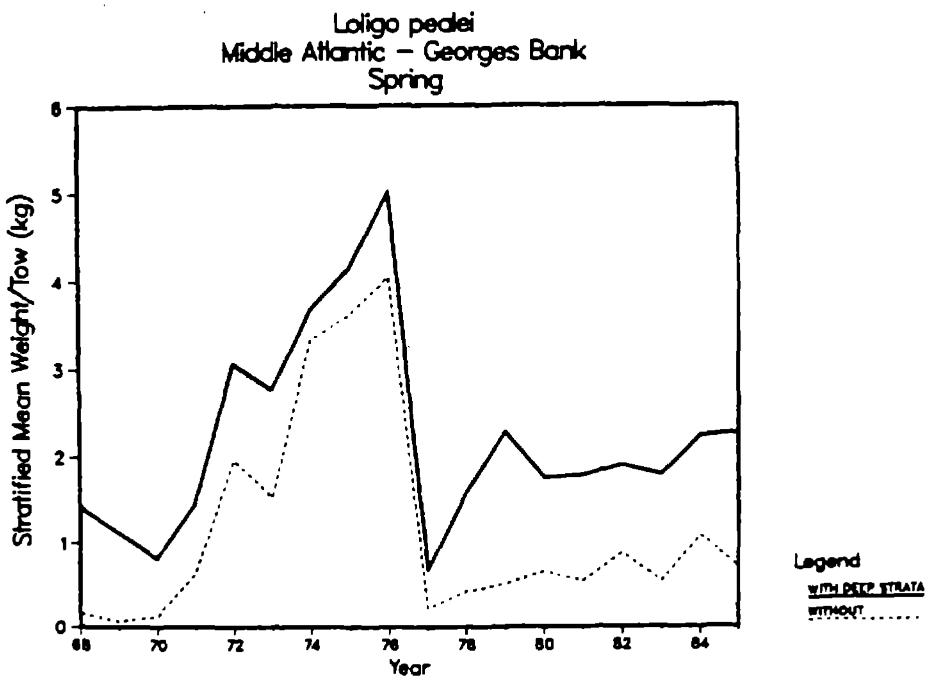


Figure 32. Comparison of stratified mean weight/tow (Delta distribution) with and without strata of depths greater than 110 m for butterfish.



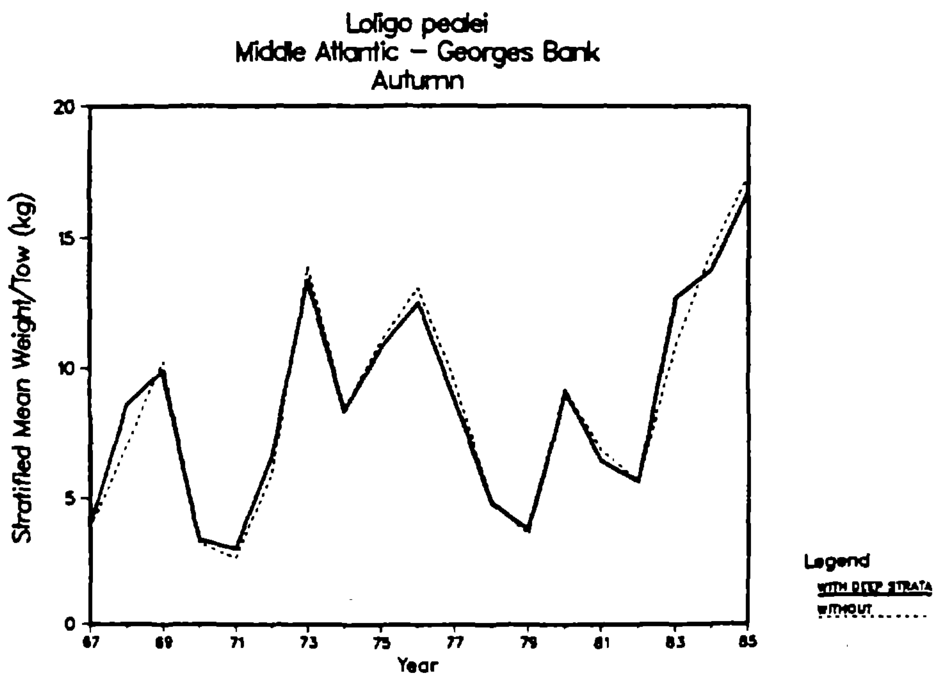


Figure 33. Comparison of stratified mean weight/tow (Delta distribution) with and without strata of depths greater than 110 m for longfin squid.

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