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Trends in Aggregate Fish Biomass and Production on Georges Bank

by

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ABSTRACT

The Georges Bank ecosystem has undergone dramatic structural changes in biomass and species dominance. Sharp declines in the biomass of both pelagic and demersal fish populations occurred with rapid increases in fishing effort by distant water fleets in this region. We corrected nominal effort series for changes in vessel size, gear type and country of origin in an attempt to provide a measure of the intensity of the perturbation resulting from large scale changes in exploitation patterns on Georges Bank. We noted a fourfold increase in standardized effort over the period 1960-72. Declines in catch per standard day fished, and relative biomass indices derived from research vessel surveys indicate marked decreases in all components of the system during the period 1960-76. Decreases in fishing effort were effected with the implementation of extended jurisdiction to 200 miles in 1977; however, several major stocks had effectively collapsed by that time.

We noted fundamental changes in the production levels on Georges Bank during the period 1960-76. Declines in overall production can be attributed largely to the collapse of the herring population by 1976-77 under heavy exploitation. Recent increases in biomass of elasmobranchs and principal pelagic species (herring and mackerel) have resulted in further shifts in system structure. The biomass of piscivores is currently high and this shift may act synergistically with increasing exploitation rates to cause further declines in biomass of commercially desirable species.

SPECIAL SESSION ON CHANGES IN FISH POPULATIONS

INTRODUCTION

Georges Bank is a highly productive marine ecosystem characterized by an extensive history of exploitation. Structural features of this system, including patterns of energy flow and utilization, changes in biomass, production and species composition, and effects of exploitation, have been extensively studied (see reviews by Cohen and Grosslein 1987; Sissenwine 1987; Fogarty et al. 1987). Sharply increased levels of exploitation with the advent of distant water fleets on Georges Bank resulted in major perturbations to the system (Brown et al. 1976; Clark and Brown 1977, 1979). Estimated fish biomass declined by over fifty percent during the first decade of exploitation by the international fleet (Brown et al. 1976).

In this paper, we describe trends in aggregate fish biomass and production on Georges Bank with changes in fishing intensity. Our analyses are based on commercial catch and effort data for NAFO Division 5Z (Figure 1) for the period 1960-85, and research vessel survey information during 1963-88. We update the analyses of Brown et al. (1976) and Clark and Brown (1977, 1979) and evaluate the effects of harvesting on the structure of the Georges Bank ecosystem. Changes in ecosystem structure in response to exploitation have been observed in several other systems including the North Sea (Hempel 1978) and the Great Lakes (Holling 1973; Christie and Spangler 1987).

The general resilience of ecosystems to sustained disturbances such as exploitation, however, is not known. Many multispecies models implicitly assume that the system will revert to its original configuration following a reduction in exploitation rates. However, selective harvesting practices can alter species composition and affect predator-prey and competitive interactions among different components of the system. Here, we explore the consequences of large scale changes in exploitation patterns on fish populations on Georges Bank.

Historical Development of the Georges Bank Fisheries

Fisheries exploitation on Georges Bank dates back to the early 1700s when Nantucket-based whaling originated. Offshore groundfish fisheries, principally the handline fishery for Atlantic cod (***Gadus morhua***), developed between 1720 and 1750 but subsided afterwards due to the French and Indian Wars and the American Revolution (German 1987). Georges Bank fisheries revived in the 1820s with New England schooner fleets pursuing cod, Atlantic halibut (***Hippoglossus hippoglossus***), and Atlantic mackerel (***Scomber scombrus***). As inshore finfish stocks became depleted, landings and effort on the offshore grounds increased; by 1880, nearly 500 full- and part-time vessels were engaged in the summer Georges Bank mackerel fishery while 163 vessels participated in the year-round cod fishery. Technological improvements (e.g., purse seines, line trawls, otter trawls) and increased market demand for iced, fresh fish stimulated rapid growth and diversification of the Georges Bank fishery (Bourne 1987). Landings of Georges Bank haddock (***Melanogrammus aeglefinus***) rose markedly during the late 1870s and early 1880s, as did catches of hake (***Merluccius bilinearis*** and ***Urophycis spp.***), cusk (***Brosme brosme***), and pollock (***Pollachius virens***).

In the early part of the twentieth century, steam and diesel-powered vessels and freezing and refrigeration technology transformed the character of the offshore fisheries forever. Coupled with increased use of otter trawls and power-driven fishing equipment, these developments significantly enhanced the mobility, profitability, and collective fishing power of the Georges Bank fishing fleets. By the early 1920s, haddock had become the mainstay of the demersal fishery, accounting for about two-thirds of the USA groundfish catch from the Bank (Lange and Palmer 1985). Haddock landings doubled between 1916 and 1925 (23,000 to 41,000 metric tons) and peaked at 115,000 tons in 1929. Flounder catches also increased in the 1920s due to the introduction of filleting techniques and heightened awareness that important winter flounder (***Pseudopleuronectes americanus***) and yellowtail flounder (***Limanda ferruginea***) grounds existed on the southern flank of the Bank. By 1930, there were more than 320 otter trawlers in the Georges Bank fleet (Herrington 1935), with mixed-species catches becoming more common. Also, at this time, extensive beds of sea scallops (***Placopecten magellanicus***) were discovered on Georges Bank prompting the development of a large-vessel, dredge fishery offshore (Serchuk et al. 1979).

Between 1930 and 1960, the Georges Bank fishery was relatively stable, except for the intervention of World War II (Hennemuth and Rockwell 1987). In general, fishery growth did not exceed resource capacities and new species became increasingly marketed as demand broadened in response to fluctuations in species abundance. Although there were little, if any, fishery restrictions during this period, attention was raised over the large quantities (as much as 70-90 million fish) of small haddock (< 35 cm or < 0.7 kg) discarded in the Georges Bank fishery (Herrington 1935; Graham and Premetz 1955). As a result of these concerns (and the drop in haddock catch to only 28,000 tons in 1934), intensive research and port sampling programs were established by the U.S. Bureau of Fisheries to investigate changes in haddock landings and abundance (Schuck 1951). These programs were subsequently expanded in the 1940s and 1950s to encompass other species, and a comprehensive North Atlantic fishery statistics collection system implemented in 1944 (Rounsefell, 1948). Both initiatives were refined in later years but proved invaluable in providing the foundation for research and management activities under the International Commission for the Northwest Atlantic Fisheries (ICNAF), established in 1949, and the USA Magnuson Fishery Conservation and Management Act (MFCMA), enacted in 1976.

Prior to 1960, Georges Bank was fished almost exclusively (except for sea scallops) by the United States. During the 1960s and early 1970s, however, the nature of the fishery changed dramatically as distant water fleets from the Soviet Union, Poland, German Democratic Republic, Federal Republic of Germany, Japan, and other countries fished the Bank. Although these fleets initially exploited Georges Bank herring

(*Clupea harengus*), effort was soon directed towards groundfish and flounders, and later mackerel and squids (*Illex illecebrosus* and *Loligo pealei*). Total yield from Georges Bank increased sharply from 240,000 tons in 1960 to about 780,000 tons in 1965 (Figure 2) due to substantial increases in the groundfish component (principally haddock and silver hake). The subsequent sharp decline in groundfish landings was offset by a simultaneous increase in catches of pelagic species (principally herring and later, mackerel) between 1967 and 1973. The collapse of the herring and mackerel stocks during the mid-1970s, coupled with restricted effort imposed on distant water fleets after USA implementation of extended jurisdiction in 1976, resulted in a sharp decline in total yield from over 920,000 tons in 1973 to 300,000 - 330,000 tons during 1976-1981. After 1981, declining groundfish stocks contributed to further declines in total yield to less than 220,000 tons in 1985.

The significant decline in Northwest Atlantic fishery resources that accompanied the rapid expansion and extremely high fishing effort of the 1960s and 1970s was a major impetus for extending USA fisheries jurisdiction to 200 nautical miles in 1977 (ie., the MFCMA). Since 1978, however, abundance of groundfish and flounders on Georges Bank has continued to decline to record-low levels (Northeast Fisheries Center 1987), while pelagic stocks (primarily mackerel and herring) and nontarget species (skates and spiny dogfish) have increased (U.S. Department of Commerce 1988).

History of Regulation

Prior to the first meeting of ICNAF in 1951, no legal basis existed for the management of offshore fishery resources in the Northwest Atlantic (Clark et al. 1982). Under ICNAF, minimum cod-end mesh size regulations (114 mm) were implemented for the haddock fishery in 1953, expanded to the Georges Bank cod fishery in 1955, and eventually applied to most other Northwest Atlantic trawl fisheries (Hennemuth and Rockwell 1987). In 1974, the minimum mesh size was increased to 130 mm. Total allowable catch limits (TACs) were introduced by ICNAF in 1970 for haddock, followed by TACs on yellowtail flounder in 1971, and Georges Bank herring in 1972 (Grosslein et al. 1979). Beginning in 1972, TACs were subdivided into national allocations and, by 1974, TACs for 54 species-stocks had been established with 14 of these on Georges Bank. A limitation on total fishing effort from the Gulf of Maine to the Middle Atlantic region was proposed to ICNAF in 1973 to reduce fishing mortality to allow stocks to rebuild, but was not accepted. Rather a "two tier" catch quota system was developed and implemented in 1974 wherein the total allowable catch [all species] for each country (i.e., the "second tier") was less than the sum of its directed-fisheries TACs (i.e., the "first tier"). Essentially, this was a first attempt to address multispecies management by recognizing that the total fishing mortality tolerable within the ecosystem was less than the sum of the directed fisheries mortalities over all species (Hennemuth 1979). Fishing mortality on one stock would, because of by-catch, generate fishing mortality on other stocks. By having the "second tier" catch lower than the "first tier", national fleets were stimulated to direct their fishing effort to those resources of most value and in which by-catches would be relatively low so that "second tier" quotas would not be exceeded (Anthony 1988). Implicitly, the "two tier" system accounted for biological interactions and the need to restore biomass levels on an ecosystem-wide basis.

The United States withdrew from ICNAF at the end of 1976 and Canada terminated its membership at the end of 1977. Both countries independently established management programs for resources within their extended [and at the time, overlapping] fisheries management zones. Since 1977, USA Georges Bank fisheries have been managed under Fishery Management Plans (FMPs) developed by the New England Fishery Management Council, one of eight regional management authorities created in 1976 by the MFCMA. To date, three different FMPs have regulated USA fisheries for demersal species on Georges Bank: the Atlantic Groundfish FMP (which regulated cod, haddock, and yellowtail flounder fisheries from March 1977 to March 1982); the Interim FMP for Atlantic Groundfish (which regulated the same three fisheries from April 1982 to September 1986), and the FMP for the Northeast Multispecies Fishery (which, since September 1986, has regulated USA fisheries taking cod, haddock, yellowtail flounder, winter flounder, American plaice [*Hippoglossoides platessoides*], redfish [*Sebastes spp.*], witch flounder [*Glyptocephalus cynoglossus*], and pollock. Management measures implemented under each of these FMPs have varied but have included: annual and quarterly catch quotas; weekly and/or trip landings restrictions [by vessel size and gear type]; minimum mesh sizes; closed seasons and areas; by-catch limits; fishery closures; minimum landing sizes; small mesh/large mesh fishing areas and seasons; and record-

The current FMP (New England Fishery Management Council 1985) utilizes indirect controls on fishing mortality (i.e., minimum landings sizes, minimum mesh sizes, small mesh/large mesh fishing areas, and area closures) to:

> "control fishing mortality on juveniles (primarily) and on adults (secondarily) of selected finfish stocks *in order to maintain sufficient spawning potential so that year classes replace themselves on a long-term average basis*; and to similarly reduce fishing mortality for the purpose of rebuilding those stocks where it has been demonstrated that the spawning potential of the stock is insufficient to maintain a viable fishery resource; and further to promote the collection of data and information on the nature, behavior and activity of the multi-species fishery, and on the management program."

Operationally, no formal distinction is made in the FMP among the various stocks of individual species within the management region (Eastern Maine through Southern New England).

In addition to the Northeast Multispecies FMP, three other federal management plans are presently in effect for other Georges Bank fisheries (FMP for American Lobster; FMP for the Atlantic Sea Scallop Fishery; and the Preliminary Management Plan [PMP] for the Hake Fisheries of the Northwestern Atlantic [which only controls foreign fishing activities]).

Since 1978, Canadian fisheries on Georges Bank have been regulated under a management system based on single-species annual catch quotas. Additional measures have also been implemented including: minimum mesh sizes, spawning closure areas for haddock, limited entry, catch allocations by gear and tonnage class, and catch reporting requirements.

In October 1984, the International Court of Justice delimited a maritime boundary between the USA and Canada in the Gulf of Maine-Georges Bank area. This decision effectively partitioned the management and utilization of many of the Georges Bank fishery resources (often across generally accepted stock boundaries) between the two nations. As a consequence, fishing activity by each country has been subsequently restricted to its own portion of Georges Bank, and management of transboundary stocks on the Bank has been performed separately and independently by each country (Serchuk and Wigley 1986).

METHODS

DATA SOURCES

Commercial Fisheries

Catch and effort data from 1960 through 1985 were obtained from ICNAF Statistical Bulletins (ICNAF 1962 - 1972) and from data files provided by the NAFO Secretariat. To maintain consistency through time, catches for all years were aggregated by species groups corresponding to those which were presented in the 1960 Statistical Bulletin. Species categories (Table 1) were thus defined as follows: cod, haddock, redfish, silver hake, other groundfish, flounders, herring, other pelagics, other fish, as well as all species combined. A data base which included only records assigned to Division 5Z (or Subdivisions 5Ze and 5Zw) was constructed for each year excluding 1962 and 1981 because of apparent discrepancies in tonnage class codes (1962) and reported effort (1981). The data base was collapsed over months and all records relating to fisheries targeting large pelagic fishes (swordfish, tunas, and sharks), lobsters, and bivalves were eliminated using combinations of gear and main species designations (Tables 1 and 2).

Factors incorporated in the effort standardization analyses were gear, tonnage class, and country. To reduce the number of levels of each factor, and to provide a more balanced statistical design, several gears, countries, and tonnage classes which occurred occasionally were either eliminated or combined as illustrated in Tables 2 and 3. The combinations resulted in 9 gear groups, 8 country groups, and 5 tonnage class categories.

Standardized fishing effort was estimated for all groundfish and small pelagic components of the Georges Bank fishery and for a subset which only included effort associated with groundfish fisheries. The secondary subset was defined by eliminating all records for midwater trawls and purse seines and those which contained menhaden as the main species (Tables 1 and 2).

A standard category was chosen for each factor as follows: gear - otter trawl, bottom (side); tonnage class - 3; and, country - USA. Fishing effort units used in the analyses were expressed as days fished, although it is recognized that the definition of a day fished for the USA fleet (24 hr of fishing time) differs from that applied by all other countries ("ICNAF days").

Research Vessel Survey Data

The Northeast Fisheries Center has conducted stratified random trawl surveys in the offshore waters of the Northwest Atlantic since autumn 1963 and spring 1968. Detailed descriptions of sampling design, methodology and applications of the survey are provided by Grosslein (1969), Clark (1979), and Almeida et al. (1986).

Species-specific data from the surveys were aggregated into four categories for analysis: (1) *Principal groundfish*, including those species of major importance in the Georges Bank commercial fishery; (2) *Other groundfish*, those species comprising the remainder of the demersal component of the system; (3) *Principal pelagics*, including mackerel and sea herring; and (4) *Elasmobranchs*, including dogfish and skate species. A complete listing of each of the species groups is given in Table 4.

ANALYTICAL PROCEDURES

Effort Standardization

Relative harvesting efficiency varies markedly among different vessel size classes and fishing gears. To account for these differences, we standardized nominal fishing effort following the general approach outlined by Robson (1966). Effort standardization coefficients were derived by estimating the parameters of the multiplicative model:

$$U = \alpha_i \beta_j \delta_k (qB) \epsilon_{ijk}$$

where U is catch per unit effort; α_i, β_j, and δ_k represent gear, tonnage class and country effects respectively, q is the catchability coefficient, B represents population biomass and ϵ_{ijk} is a log-normally distributed random variable with mean 1.0 and constant variance. Because the population biomass is not directly known, the term qB is replaced by the mean catch per unit effort (μ) and all coefficients are estimated relative to an arbitrarily defined standard. The standard cell was defined as described previously. Least squares estimates of the model coefficients were made under the constraints: $\Sigma\alpha_i = \Sigma\beta_j = \Sigma\delta_k = 0$ for the linearized model:

$$\log_e U = \log_e \mu + \log_e \alpha_i + \log_e \beta_j + \log_e \delta_k + \epsilon'_{ijk}$$

where ϵ'_{ijk} is a normally distributed random variable with zero mean. Retransformation of the model coefficients to linear scale was made after correction for bias by adding one half of the variance of the estimate before taking the antilogarithm. Standardized effort for each country-gear-tonnage class category was estimated by multiplying nominal effort by the product of the coefficients for each of the factors.

Research Vessel Surveys

Estimates of stratified mean catch per tow (kg) for the species groups defined above were made after transformation to natural logarithms. Retransformation and bias correction was made for each group estimate as outlined by Bliss (1967). Autumn survey data were used for the principal groundfish and other groundfish groups. Spring survey data were utilized for the principal pelagics and elasmobranchs because of seasonal changes in availability.

The abundance index time series was then modelled using an autoregressive integrated moving average (ARIMA) model (Box and Jenkins 1976) as proposed by Pennington (1985, 1986). A detailed description of this method using NEFC bottom trawl survey data is given in Fogarty et al. (1986). The time series modeling objective was to filter the effects of measurement error in the survey data from 'true' variations in population levels. The measurement error comprises within-survey and between-survey variations caused by changes in availability or catchability. In general, the length of the survey time series is not sufficiently long to allow empirical identification of the full ARIMA model. Pennington (1985) advocated an *a priori* specification of a first order moving average model for the $\log_e$ transformed survey data:

$$\log_e(C_{t+1}/C_t) = a_t - \Theta a_{t-1}$$

where C_t is the stratified mean catch per tow in year t, Θ is the first order moving average parameter and a_t is a random error term (residual) at time t. This model is equivalent to an exponential smoothing model for the end points of the series. The moving average parameter used for all groups was 0.4 (Pennington 1985, 1986).

Surplus Production

Brown et al. (1976) developed estimates of surplus production for the aggregate fish biomass on the Northeast Continental Shelf from Cape Hatteras to Nova Scotia. We updated this analysis for the Georges Bank region to provide a reference point of observed current levels of production in the system relative to historical production rates. The generalized production model of Pella and Tomlinson (1969) can be expressed as:

$$1/B(dB/dt) = a - bB^{m-1} - qf$$

where B_t is aggregate biomass in year t, a and b are model coefficients representing density-independent and density-dependent effects, m is a shape parameter, q is the catchability coefficient, and f is standardized fishing effort. To estimate the parameters of this model, we assumed that catch per unit effort was directly proportional to biomass ($U \approx qB$) giving:

$$1/U(dU/dt) = d(\log_e U)/dt = a - (b/q^{m-1})U^{m-1} - qf$$

This model can be directly evaluated by numerical integration without recourse to assumptions regarding equilibrium conditions. We made the simple finite difference approximation:

$$d(\log_e U)/dt \approx \log_e(U_{t+1}/U_t)$$

and estimated parameters of the model by least squares. The shape parameter was set to 2.0 (equivalent to the Schaefer model) to allow direct comparison with the analysis of Brown et al. (1976).

RESULTS

Standardization of Fishing Effort

Results from the linear model for the demersal plus pelagic and the demersal only analyses are given in Tables 5 and 6. For both data sets, gear, tonnage class, and country effects were highly significant ($P < 0.01$). Coefficients for the gear, tonnage class, and country effects, converted to linear scale, are given Table 7. Relative to the side trawl standard, gear coefficients are highest for the pelagic gears (midwater trawls and purse seine) and lowest for fixed gear (gill nets and traps). Tonnage class coefficients generally increase with vessel size with the class 6+7 category approximately twice the class 3 standard. Country coefficients are variable with FRG, Italy/Spain, and Poland accounting for the greatest differences relative to the USA standard. It should be noted, however, that effort units for the USA differ from those of all other countries in the NAFO data base and that USA days fished, if reported in units similar to other countries, would be 2-3 times greater than are presently listed. Thus, differences in fishing power between the various countries and the USA standard would be

Trends in Nominal and Standardized Fishing Effort

Nominal fishing effort on Georges Bank for the combined demersal and pelagic gear components increased rapidly during the 1960s, peaking at about 65,000 days in 1968 (Figure 3). Total effort declined subsequently to 30-40,000 days between 1975 and 1982 before increasing to over 50,000 days fished during 1983-1985. Trends in standardized effort differ considerably from nominal effort, particularly during the mid-1970s, due to the combined effects of gear, country, and tonnage class coefficients relative to the USA tonnage class 3 side trawler standard. Standardized effort (Figure 4) increased from about 25,000 days in 1960 to about 100,000 days fished in 1969 and remained relatively high through 1975 before declining sharply in 1976 and 1977. Standardized effort remained at about 25,000 days during 1977-1979 before increasing to 40,000 days in 1985.

Nominal effort trends for the demersal fishery (excluding purse seine and midwater trawl gear) follow those for the total fishery with peak levels in 1968 followed by a gradual decline and subsequent increase (Figure 3). Standardized effort for this component, however, differs considerably from the overall standardized effort pattern with the major difference occurring during the mid-1970s. This difference may be explained by the increase in the amount of off-bottom gear, as indicated by trends in pelagic catches (Figure 2) and nominal effort (Figure 3), but is compounded here by the relatively high coefficients for purse seine (7.69) and midwater trawls (1.76) relative to the standard (Table 7). Standardized effort for both components are almost identical after 1977 when effort was exerted primarily by USA vessels fishing with bottom trawls.

Standardized CPUE for the combined demersal and pelagic gear components increased sharply from 5.7 tons per day fished in 1960 to 11.7 tons per day in 1965 (Figure 5) but declined steadily thereafter to an average of 7.5 tons during 1970-74. The combined CPUE index decreased gradually from this level until 1982 when the decline began to accelerate to a record low level of 2.9 tons per day in 1985. CPUE for the demersal component followed the same pattern as the combined index between 1960 and 1970, but began to oscillate with a temporary increase in 1973 followed by a sharp decline in 1975. The index increased gradually through 1980, but has since declined to an historic low level in 1985.

Trends in Biomass from Survey Data

The aggregate biomass index for principal groundfish and flounders peaked in 1963 (43.8 kg/tow) but declined afterwards, reaching a record-low in 1979 (4.1 kg/tow) [a reduction of 91% from 1963] (Table 8, Figure 6). During this period, large declines in abundance of haddock, silver hake, redfish, and yellowtail flounder occurred. Combined groundfish biomass increased during 1980-1983 (6.9 to 20.4 kg/tow), primarily due to a large increase in the pollock stock, but has subsequently declined to its lowest level since 1980.

Biomass of other groundfish was relatively high in 1963 (6.6 kg/tow) but declined during 1964-1971 (Table 8, Figure 7). Biomass stabilized between 1972 and 1978, and then markedly increased, attaining a record-high in 1985 (7.2 kg/tow). Biomass has since returned to levels observed in the early 1960s.

Biomass of principal pelagics was low throughout most of the survey time series reflecting declines in the Atlantic mackerel stock during 1972-1978 (although only a small fraction of the mackerel stock is found on Georges Bank) and the collapse of the Georges Bank herring stock in 1977 (Table 8, Figure 8). Since 1983, however, pelagic biomass has increased to record-high levels (1.9 kg/tow in 1988) due to significant rebuilding of the mackerel stock and the resurgence of the herring population on Georges Bank. Evidence for some recovery of this population has been obtained based on bottom trawl and ichthyoplankton surveys and by-catch rates in groundfish fisheries directed at silver hake (M.D. Grosslein and M.J. Fogarty, unpublished information).

Elasmobranch biomass, low but stable during 1968-1980, has dramatically increased reaching new record-high levels in almost every year since 1981 (Table 8, Figure 9). During the 1980-1988 period, elasmobranch biomass increased over 12-fold, due to sharp and sustained increases in spiny dogfish and skate populations.

Surplus Production

The surplus production model approach provides a useful framework for interpreting changes in biomass and production in response to harvesting for the Georges Bank system. It is recognized however, that the extreme simplicity of this model places important limitations on the interpretation of the results. Accordingly, we stress the qualitative *implications of the analysis.*

The curtailment of large-scale fishing activity of the distant water fleet on Georges Bank with imposition of the MFCMA in 1977 resulted in fundamental changes in the character of the Georges Bank fishery. Aggregate yield increased with increasing fishing effort steadily through 1973. In recognition of the fundamental changes in the production system with the decline of the herring population and the enactment of the MFCMA, we fit the production model to catch and effort data for period 1960-75 only (Figure 10).

Fishing effort by 1975 was slightly above the level required for maximum equilibrium yield under the general production model with the shape parameter set to 2.0 (equivalent to the Schaefer model) but, by 1976, yield and effort began a sharply declining trajectory (Figure 10). The decline in yield and standardized fishing effort in 1976 is attributable to the collapse of the herring population; marked decreases in abundance of herring were evident by 1972 (Anthony and Waring 1980) and the population had effectively collapsed by 1976-77. Directed effort on the herring population declined by 1974 as a result of poor catch rates (Anthony and Waring 1980). Dramatically decreased abundance levels of the pelagic component (both herring and mackerel) in the mid-1970s resulted in fundamental changes in the production levels of the system. The relationship between yield and fishing effort has changed markedly since 1977, relative to the 1960-76 period, indicating both a change in the characteristics of the fishery and in overall production (Figure 10).

DISCUSSION

Large-scale escalation of fishing effort on Georges Bank with the arrival of the distant water fleets resulted in major perturbations to the biomass of both groundfish and pelagic species. The nearly four-fold increase in standardized fishing effort during the period 1960-72 was accompanied by sharp declines in aggregate fish biomass as measured by commercial catch rates and biomass indices derived from research vessel surveys. Fundamental changes in the nature of the production system resulted from the dramatic decline in biomass of pelagic species.

Changes in standardized fishing effort between 1960 and 1972 exhibit the same relative increase described by Brown et al. (1976) for the Subarea 5-Statistical Area 6 region. After 1972, fishing effort remained relatively high on Georges Bank until 1977 when restrictions imposed by USA implementation of extended jurisdiction sharply curtailed fishing activity by distant water fleets. The sharpest decline in effort resulting from these restrictions occurred in the pelagic gear component which had been used principally by distant water fleets fishing for herring and mackerel. Since 1977, effort on Georges Bank has been expended almost entirely by USA and Canadian vessels using demersal gear (primarily otter trawls). Thus, trends in nominal and standardized effort, and standardized CPUE for the combined pelagic and demersal component since 1977 are essentially the same as those for the demersal *component* alone.

The doubling of CPUE between 1960 and 1965 occurred during a period of increasing effort and yield, although a five-fold increase in the catch of finfish and squids was accomplished with a 2.5-fold increase in estimated standardized fishing effort. This suggests that the abundance of principal groundfish and pelagics was increasing, although results from bottom trawl surveys suggest a declining trend for both species groups since 1963. However, increases in biomass of herring and haddock did occur between 1960 and 1963 before the survey time series began. Thus, the large 1960 year class of herring (Anthony and Waring 1980) and the 1963 year class of haddock (Clark et al. 1982) likely contributed to the substantial increase in stock biomass suggested by the CPUE index at least through 1963. It is also likely, however, that a substantial increase in the estimated CPUE during the early 1960s resulted from a learning function as suggested by Brown et. al (1976) since fisheries prosecuted by the distant water fleets were in a development stage during this period. Had a learning adjustment been applied to the effort estimates in our model, the resulting increase in estimated effort would have been considerably greater and the increase in CPUE correspondingly less.

The decline in CPUE since the late 1960s reflects the overall decline in abundance of principal groundfish and pelagics, including haddock, silver hake, herring, and mackerel, as indicated by the bottom trawl surveys. The secondary increase in CPUE which occurred after 1977, particularly for the demersal gear component, coincided with increased abundance of several stocks of groundfish and flounders, including haddock, cod, pollock, and yellowtail flounder, following recruitment of several relatively strong year classes between 1975 and 1980 (Clark et. al 1982, 1984; Serchuk and Wigley 1986; Mayo et al. 1989). The decline in CPUE since 1982 is associated with increased fishing mortality on these stocks (U.S. Department of Commerce 1988).

Parallel declines in research vessel survey indices were noted during this period. The aggregate biomass index for principal groundfish and flounders declined precipitously during 1963-66, reflecting the decrease in haddock abundance. Other groundfish also decreased during the period of exploitation by the international fleet as a result of incidental by-catch and reduction fisheries for many of the species in this category. Survey biomass indices for dogfish and skates remained at relatively low levels throughout the period of fishing activity by the distant water fleet; these species were also harvested incidentally and taken for reduction. Following the enactment of the MFCMA, relative biomass levels of principal groundfish and flounders and other groundfish rebounded. The principal groundfish and flounders category, however, has not reached historical levels. We note however, that the high biomass levels for this group during the early 1960s largely reflect haddock abundance, particularly the dominant 1963 year class. The aggregate biomass indices for this period are not necessarily representative of average conditions. The biomass indices of the other groundfish category, now exceed levels noted during the 1960s. The most striking changes in relative biomass indices have been noted for the elasmobranchs and the principal pelagics. Skates and dogfish species have increased by a factor of twelve since 1980. The herring and mackerel biomass indices have increased substantially since 1983 with the apparent resurgence of the Georges Bank herring population and extremely high biomass levels of mackerel. Current estimates of the mackerel population exceed 1.8 million tons (W.J. Overholtz, personal communication).

These historical changes in components of the Georges Bank system indicate marked alterations in the production rates of Georges Bank fish populations. These considerations profoundly affect the interpretation of analyses of surplus production based on aggregate biomass. In particular, these results indicate that species with widely divergent production rates cannot be aggregated for the purposes of developing total surplus production estimates. Atlantic herring accounted for nearly one-half of the total landings from Georges Bank during the late 1960s. By the early 1970s, however, clear indications of overharvesting of this population had been obtained (Anthony and Waring 1980). Estimated spawning stock biomass levels of Georges Bank herring declined from 1.4 million tons in 1966 to less than 400 thousand tons in 1972 (Anthony and Waring 1980). The production to biomass ratio for herring is low relative to many demersal species (Grosslein et al. 1980), indicating that this species would evince sharper declines in production with increased harvesting than many demersal species. Grosslein et al. (1980) also noted that the recruitment to production ratio for herring is high relative to demersal species, indicating that population growth rates are highly dependent on recruitment. Similar observations were made for mackerel relative to demersal species.

Production rates and recruitment dynamics appear to differ fundamentally for herring and mackerel relative to groundfish and flounder species. Accordingly, we recommend that these species must be treated separately from demersal species in analyses of aggregate surplus production. Available published catch and effort information for the individual components of the Georges Bank fishery did not allow adequate separation of the demersal and pelagic species in the present analysis.

We also note that the recent increase in biomass of piscivores, including dogfish and large skates, may result in further changes in biomass and overall production. Atlantic mackerel are also important predators of the early life stages of a number of commercially important groundfish, including gadoids. Both groups are currently subjected to very low fishing mortality rates. Increased predation mortality could exacerbate the declines in principal groundfish and flounders noted since the early 1980s. The joint effects of increased directed harvesting on these stocks (standardized effort has nearly doubled since 1977) and predation mortality could further alter the structure of the system.

LITERATURE CITED

Almeida, F.P., M.J. Fogarty, S.H. Clark, and J.S. Idoine. 1986. An evaluation of precision of abundance estimates derived from bottom trawl surveys off the Northeastern United States. ICES C.M. 1986/G:91, 19 p.

Anthony, V.C. 1988. The New England fisheries in the 21st century. In Proceedings: National Resources for the 21st Century. American Forestry Association, Washington, D.C.

Anthony, V.C. and G.T. Waring. 1980. The assessment and management of the Georges Bank herring population. Rapp. P-verbaux des Reun. Cons. Int. Explor. Mer Vol. 177:72-111.

Bliss, C.I. 1967. Statistics in Biology; Statistical Methods for Research in the Natural Sciences, Vol. 1. McGraw-Hill, New York, 558 p.

Bourne, D.W. 1987. The fisheries, p. 406-408. In R.H. Backus (ed.) Georges Bank. The MIT Press, Cambridge, Massachusetts. 593 p.

Box, G.E.P., and G. Jenkins. 1976. Time series analysis: forecasting and control (Revised Edition), Holden-Day, Oakland, California. 575 p.

Brown, B.E., J.A. Brennan, E.G. Heyerdahl, M.D. Grosslein, and R.C. Hennemuth. 1976. The effect of fishing on the marine finfish biomass of the Northwest Atlantic from the Gulf of Maine to Cape Hatteras. Int. Comm. Northwest Atl. Fish., Res. Bull. 12:49-68.

Christie, W.J. and G.R. Spangler (eds.). 1987. International symposium on stock assessments and yield prediction. Can. J. Fish. Aquatic. Sci. 44 Suppl. 2. 499 p.

Clark, S.H. 1979. Application of bottom trawl survey data to fish stock assessment. Fisheries 4:9-15.

Clark, S.H., and B.E. Brown. 1977. Changes in biomass of finfish and squids from the Gulf of Maine to Cape Hatteras, 1963-1974, as determined from research vessel survey data. Fish. Bull., U.S. 75(1):1-21.

Clark, S.H., and B.E. Brown. 1979. Trends in biomass of finfishes and squids in ICNAF Subarea 5 and Statistical Area 6, 1964-1977, as determined from research vessel survey data. Investigación Pesquera 43(1):107-122.

Clark, S.H., W.J. Overholtz, and R.C. Hennemuth. 1982. Review and assessment of the Georges Bank and Gulf of Maine haddock fishery. J. Northw. Atl. Fish. Sci. 3:1-27.

Clark, S.H., M.M. McBride, and B. Wells. 1984. Yellowtail flounder assessment update-1984. NMFS, NEFC Woods Hole Laboratory Ref. Doc. 84-39, 30 p.

Cohen, E.B. and M.D. Grosslein. 1987. Production on Georges Bank compared with other shelf ecosystems, p. 383-391. In R.H.Backus (ed.) Georges Bank. The MIT Press, Cambridge, Massachusetts. 593 p.

Fogarty, M.J., M.P. Sissenwine, and M.D. Grosslein. 1987. Fish Population Dynamics, p. 494-507. In R.H. Backus (ed.) Georges Bank. The MIT Press, Cambridge, Massachusetts. 593 p.

Fogarty, M.J., J.S. Idoine, F.P. Almeida, and M. Pennington. 1986. Modelling trends in abundance based on research vessel surveys. ICES C.M. 1986/G:92, 13 p.

German, A.W. 1987. *History of the early fisheries: 1720-1930*, p. 409-424. In R.H. Backus (ed.) Georges Bank. The MIT Press, Cambridge, Massachusetts. 593 p.

Graham, H.W., and E.D. Premetz. 1955. First year of mesh regulation in the Georges Bank haddock fishery. U.S. Fish. Wildl. Serv., Spec. Sci. Rep. Fish. 142, 20 p.

Grosslein, M.D. 1969. Groundfish survey program of BCF, Woods Hole. Comm. Fish. Rev. 31:22-35.

Grosslein, M.D., B.E. Brown, and R.C. Hennemuth. 1979. Research, assessment, and management of a marine ecosystem in the Northwest Atlantic - A case study, p. 289-357. In J. Cairns, Jr., G.P. Patil, and W.E. Waters (eds.) Environmental Biomonitoring, Assessment, Prediction, and Management - Certain Case Studies and Related Quantitative Issues. International Co-operative Publishing House, Fairland, Maryland. 560 p.

Grosslein, M.D., R. Langton, and M.P. Sissenwine. 1980. Recent fluctuations in pelagic fish stocks in the Northwest Atlantic, Georges Bank region in relation to species interactions. Rapp. P-verbaux des Reun. Cons. Int. Explor. Mer 177:374-405.

Hempel, G. (ed.). 1978. North Sea fish stocks-recent changes and their causes. Rapp. P-Verbaux des Reun. Cons. Int. Explor. Mer Vol. 172, 449 p.

Hennemuth, R.C. 1979. Man as Predator. p. 507-532. In G.P Patil and M. Rosenzweig (eds.) Contemporary Quantitative Ecology and Related Ecometrics. International Co-operative Publishing House, Fairland, Maryland. 695 p.

Hennemuth, R.C., and S. Rockwell. 1987. History of fisheries conservation and management, p. 430-446. In R.H. Backus (ed.) Georges Bank. The MIT Press, Cambridge, Massachusetts. 593 p.

Herrington, W.C. 1935. Modifications in gear to curtail the destruction of undersized fish in otter trawling. U.S. Dept. Commerce, Bur. Fish., Invest. Rep. 24, 48 p.

Holling, C.S. 1973. Resilience and stability of ecological systems. Ann. Rev. Ecol. Syst. Vol. 4:1-24.

ICNAF. 1962-1972. Fishery Statistics for the years 1960-1970. ICNAF Stat. Bull., Vols. 10-20.

Lange, A.M.T., and J.E. Palmer. 1985. USA historical catch data, 1904-82, for major Georges Bank fisheries. NOAA Tech. Mem. NMFS-F/NEC-39, 21 p.

Mayo, R.K., J. McGlade, and S.H. Clark. 1989. Exploitation and biological status of pollock, *Pollachius virens* (L.) in the Scotian Shelf, Georges Bank, and Gulf of Maine area. J. Northw. Atl. Fish. Sci., Vol. 9 (In press).

New England Fishery Management Council. 1985. Fishery Management Plan for the Northeast Multi-Species Fishery. New England Fishery Management Council, Saugus, Massachusetts.

Northeast Fisheries Center. 1987. Status of mixed species demersal finfish resources in New England and scientific basis for management. Nat. Mar. Fish. Serv., Woods Hole Lab. Ref. Doc. No. 87-08, 105 p.

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

Pennington, M. 1986. Some statistical techniques for estimating abundance indices from trawl surveys. Fish. Bull., U.S. 84:519-526.

Pella, J.J. and P.K. Tomlinson. 1969. A generalized stock production model. Bull. Inter-Amer. Trop Tuna Comm., 13(3):419-496.

Robson, D.S. 1966. Estimation of the relative fishing power of individual ships. Int. Comm. Northw. Atl. Fish. Res. Bull. 3:5-14.

Rounsefell, G.A. 1948. Development of fishery statistics in the North Atlantic. U.S. Dept. Interior, Fish and Wildl. Serv., Spec. Sci. Rep. 47, 27 p.

Schuck, H.A. 1951. Studies of Georges Bank haddock, Part I: Landings by pounds, numbers, and sizes of fish. Fish. Bull., U.S. 52:151-176.

Serchuk, F.M., and S.E. Wigley. 1986. Assessment and status of the Georges Bank and Gulf of Maine Atlantic cod stocks. Nat. Mar. Fish. Serv., Woods Hole Lab. Ref. Doc. No. 86-12, 84 p.

Serchuk, F.M., P.W. Wood, J.A. Posgay, and B.E. Brown. 1979. Assessment and status of sea scallop (*Placopecten magellanicus*) populations off the northeast coast of the United States. Proc. Natl. Shellfish Assoc. 69:161-191.

Sissenwine, M.P. 1987. Fish and squid production, p. 347-350. In R.H. Backus (ed.) Georges Bank. The MIT Press, Cambridge, Massachusetts. 539 p.

U.S. Department of Commerce. 1988. Status of fishery resources off the northeastern United States for 1988. NOAA Tech. Mem. NMFS-F/NEC-63, 135 p.

Table 1. Species groupings used in analyses of commercial fishing effort.

Species Group	Species Included	Species Group	Species Included
COD	Atlantic cod	**FLOUNDERS**	American plaice
			Witch flounder
			Yellowtail flounder
HADDOCK	Haddock		Atlantic halibut
			Winter flounder
REDFISH	Atlantic redfishes		Summer flounder
	Beaked redfishes		Windowpane flounder
			Flatfishes (NS)
SILVER HAKE	Silver hake		
		ATLANTIC HERRING	Atlantic Herring
OTHER GROUNDFISH	Red Hake		
	Pollock		
	Goosefish	**OTHER PELAGICS**	Atlantic mackerel
	Atlantic searobins		Atlantic butterfish
	Atlantic tomcod		Atlantic menhaden
	Cunner		Atlantic saury
	Cusk		Bay anchovy
	Lumpfish		Bluefish
	Northern kingfish		Swordfish
	Northern puffer		All tunas
	Ocean pout		Pelagic fish (NS)
	Sand lances		
	Sculpins	**OTHER FISH**	All other finfish, molluscs, crustaceans, and other invertebrates
	Scup		
	Tautog		
	White Hake		
	Atlantic Wolffish		
	Wolffishes		
	Groundfish (NS)		

Note: Main species deleted from all analyses included: swordfish, tuna, lobster, molluscs, and invertebrates.

Main species further deleted from demersal effort analyses: menhaden.

Table 2. Gear groupings used in effort standardization analyses.

Gear Code	Gear Group	Gears Included	
08	**Otter Trawl, Bottom**	OTB	Otter Trawl, Bottom
11	**Otter Trawl, Bottom (Side)**	OTB-1	Otter Trawl, Bottom (Side)
12	**Otter Trawl, Bottom (Stern)**	OTB-2	Otter Trawl, Bottom (Stern)
13	**Midwater Trawls**	OTM	Midwater Trawl
		OTM-1	Midwater Trawl (Side)
		OTM-2	Midwater Trawl (Stern)
		PTM	Midwater Pair Trawl
16	**Miscellaneous Trawls**	PTB	Pair Trawl, Bottom
		SND	Danish Seine
		SSC	Scottish Seine
31	**Purse Seine**	PS	Purse Seine
41	**Gill Nets**	GNS	Set Gillnets
		GND	Drift Gillnets
51	**Line Gear**	LL	Longlines
		LLS	Set Lines
		LLD	Drift Lines
		LHP	Hand Lines
		LTL	Troll Lines
60	**Fixed Gear**	FIX	Traps
		FPN	Uncovered Pound Nets
		FPO	Covered Pots
		FWR	Weirs

Note: Gear deleted from all analyses include:
beach seine, squid jiggers, all dredge gear,
harpoons, miscellaneous or unknown gear.

Gear further deleted from demersal effort analyses include:
purse seines and all midwater trawls.

Table 3. Country groupings and tonnage class categories used in effort standardization analyses.

Country Code	Country Group	Countries Included	Tonnage Class Code	Tonnage Classes Included
01	**Bulgaria Group**	Bulgaria	2	2
		Romania		
		USSR	3	3
02	**Canada**	Can-MQ	4	4
		Can-M		
		Can-Q	5	5
		Can-N		
			6	6 and 7
10	**FRG**	FRG		
11	**GDR**	GDR		
13	**Italy Group**	Italy		
		Spain		
14	**Japan**	Japan		
16	**Poland**	Poland		
22	**USA**	USA		

Note: The following countries were deleted from all analyses:
Cuba, France (M), Norway, UK, and Ireland.

Table 4. Species included in aggregate groups from bottom trawl surveys.

Principal Groundfish	
Haddock	*Melanogrammus aeglefinus*
Atlantic Cod	*Gadus morhua*
Pollock	*Pollachius virens*
Redfish	*Sebastes* spp.
Silver Hake	*Merluccius bilinearis*
Red Hake	*Urophycis chuss*
Yellowtail Flounder	*Limanda ferruginea*
Summer Flounder	*Paralichthys dentatus*
Winter Flounder	*Pseudopleuronectes americanus*
American Plaice	*Hippoglossoides platessoides*
Witch Flounder	*Glyptocephalus cynoglossus*
Other Groundfish	
White Hake	*Urophycis tenuis*
Ocean Pout	*Macrozoarces americanus*
American Goosefish	*Lophius americanus*
Cusk	*Brosme brosme*
Windowpane Flounder	*Scophthalmus aquosus*
Northern Sea Robin	*Prionotus carolinus*
Striped Sea Robin	*Prionotus evolans*
Armored Sea Robin	*Peristedion miniatum*
Hookeared Sculpin	*Artediellus uncinatus*
Longhorned Sculpin	*Myoxocephalus octodecemspinosus*
Mailed Sculpin	*Triglops ommatistius*
Sea Raven	*Hemitripterus americanus*
Wolffish	*Anarhichas lupus*
Principal Pelagics	
Atlantic Mackerel	*Scomber scombrus*
Sea Herring	*Clupea harengus*
Elasmobranchs	
Spiny Dogfish	*Squalus acanthias*
Smooth Dogfish	*Mustelus canis*
Little Skate	*Raja erinacea*
Winter Skate	*Raja ocellata*
Thorny Skate	*Raja radiata*
Barndoor Skate	*Raja laevis*
Clearnose Skate	*Raja eglanteria*
Leopard Skate	*Raja garmani*
Smoothtailed Skate	*Raja senta*

Table 5. Analysis of variance results from NAFO fishing effort standardization analyses using general linear models procedure.

NAFO EFFORT STANDARDIZATION

GROUNDFISH, FLOUNDERS, AND SMALL PELAGICS

USA, TON CLASS 3, SIDE TRAWL, 1985, STANDARD

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
GR	9	8 12 13 16 31 41 51 60 100
TC	5	2 4 5 6 9
CTY	8	1 2 10 11 13 14 16 100

NUMBER OF OBSERVATIONS IN DATA SET = 2284

DEPENDENT VARIABLE: LCPE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	19	1112.02597015	58.52768264	66.40	0.0	0.357853	54.0523
ERROR	2264	1995.46440229	0.88138887		ROOT MSE		LCPE MEAN
CORRECTED TOTAL	2283	3107.49037244			0.93882313		1.73687938

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
GR	8	861.10267539	122.12	0.0	8	520.94293545	73.88	0.0
TC	4	163.65682172	46.42	0.0001	4	72.35030277	20.52	0.0001
CTY	7	87.26647304	14.14	0.0001	7	87.26647304	14.14	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		1.74165657 B	38.61	0.0	0.04510667
GR	8	-1.15191868 B	-3.86	0.0001	0.29873368
	11	0.00000000 B	.	.	.
	12	0.01850614 B	0.37	0.7082	0.04943396
	13	0.55877237 B	6.05	0.0001	0.09243346
	16	-0.18752497 B	-1.61	0.1069	0.11626742
	31	2.02997233 B	14.05	0.0	0.14445693
	41	-0.94837323 B	-7.35	0.0001	0.12904469
	51	-0.85879639 B	-11.86	0.0001	0.07244141
	60	-1.35429063 B	-11.80	0.0001	0.11473396
TC	2	-0.29853892 B	-5.66	0.0001	0.05272674
	3	0.00000000 B	.	.	.
	4	0.06697164 B	1.18	0.2397	0.05694176
	5	0.09083301 B	0.84	0.3997	0.10783597
	6	0.73768292 B	5.16	0.0001	0.14303737
CTY	1	0.02288599 B	0.17	0.8614	0.13110943
	2	0.41529675 B	7.03	0.0001	0.05904394
	10	0.63311345 B	3.12	0.0018	0.20296041
	11	0.07508477 B	0.44	0.6567	0.16888780
	13	0.65964367 B	3.03	0.0025	0.21780000
	14	-0.49946957 B	-2.96	0.0031	0.16852113
	16	0.24125988 B	1.32	0.1858	0.18228953
	22	0.00000000 B	.	.	.

Table 6. Analysis of variance results from NAFO fishing effort standardization analyses using general linear models procedure.

NAFO EFFORT STANDARDIZATION

GROUND FISH & FLOUNDERS - PELAGICS EXCLUDED

USA, TON CLASS 3, SIDE TRAWL, 1985, STANDARD

GENERAL LINEAR MODELS PROCEDURE

CLASS LEVEL INFORMATION

CLASS	LEVELS	VALUES
GR	7	8 12 16 41 51 60 100
TC	5	2 4 5 6 9
CTY	8	1 2 10 11 13 14 16 100

NUMBER OF OBSERVATIONS IN DATA SET = 2067

DEPENDENT VARIABLE: LCPE

SOURCE	DF	SUM OF SQUARES	MEAN SQUARE	F VALUE	PR > F	R-SQUARE	C.V.
MODEL	17	681.09781174	40.06457716	49.47	0.0	0.291005	55.9362
ERROR	2049	1659.40813589	0.80986244		ROOT MSE		LCPE MEAN
CORRECTED TOTAL	2066	2340.50594763			0.89992357		1.60883981

SOURCE	DF	TYPE I SS	F VALUE	PR > F	DF	TYPE III SS	F VALUE	PR > F
GR	6	444.28057702	91.43	0.0	6	262.90571818	54.11	0.0
TC	4	162.61062501	50.20	0.0	4	49.04987179	15.14	0.0001
CTY	7	74.20660971	13.09	0.0001	7	74.20660971	13.09	0.0001

PARAMETER		ESTIMATE	T FOR H0: PARAMETER=0	PR > |T|	STD ERROR OF ESTIMATE
INTERCEPT		1.69291314 B	38.45	0.0	0.04402400
GR	8	-1.12828528 B	-3.94	0.0001	0.28643551
	11	0.00000000 B	.	.	.
	12	0.00744660 B	0.16	0.8764	0.04785984
	16	-0.17727716 B	-1.59	0.1121	0.11153803
	41	-0.93633885 B	-7.56	0.0001	0.12384947
	51	-0.84529155 B	-12.13	0.0001	0.06966609
	60	-1.34195494 B	-11.91	0.0001	0.11265941
TC	2	-0.27368818 B	-5.27	0.0001	0.05195316
	3	0.00000000 B	.	.	.
	4	0.10265792 B	1.84	0.0657	0.05574427
	5	0.12676699 B	1.18	0.2387	0.10756533
	6	0.56088141 B	3.64	0.0003	0.15406761
CTY	1	0.45111017 B	3.12	0.0018	0.14435733
	2	0.45504167 B	7.97	0.0001	0.05711377
	10	0.77767215 B	3.13	0.0018	0.24884844
	11	0.16793431 B	0.83	0.4094	0.20352074
	13	0.68563154 B	3.28	0.0011	0.20930988
	14	-0.11854460 B	-0.64	0.5195	0.18401548
	16	0.66119443 B	3.16	0.0016	0.20924061
	22	0.00000000 B	.	.	.

Table 7. Standardization coefficients for gear, tonnage class, and country effects (linear scale) derived from NAFO effort standardization analyses.

Demersal Gear Only			Demersal and Pelagic Gear Combined		
Factor		Standardization Coefficient	Factor		Standardization Coefficient
GEAR	8	0.337138	GEAR	8	0.330451
	*11	1.000000		*11	1.000000
	12	1.008629		12	1.019924
	16	0.842774		13	1.756010
	41	0.395079		16	0.834631
	51	0.430476		31	7.693734
	60	0.262998		41	0.390609
				51	0.424785
				60	0.259835
TC	2	0.761596	TC	2	0.742933
	*3	1.000000		*3	1.000000
	4	1.109835		4	1.071000
	5	1.141738		5	1.101472
	6	1.773136		6	2.112586
COUNTRY	1	1.586499	COUNTRY	1	1.031981
	2	1.578812		2	1.517463
	10	2.244841		10	1.922660
	11	1.207612		11	1.093459
	13	2.028987		13	1.980525
	14	0.903378		14	0.615531
	16	1.979977		16	1.294176
	*22	1.000000		*22	1.000000

Table 8. Fitted abundance indices and 80% confidence intervals for aggregate species groups from Georges Bank.

Year	Mean	Confidence Interval Lower	Confidence Interval Upper	Mean	Confidence Interval Lower	Confidence Interval Upper
	Principal Groundfish			Other Groundfish		
1963	43.796	-	-	6.598	-	-
1964	36.092	-	-	5.799	-	-
1965	27.200	-	-	5.972	-	-
1966	18.692	13.913	25.113	5.987	4.944	7.250
1967	14.390	10.710	19.333	4.396	3.630	5.324
1968	11.258	8.380	15.126	3.772	3.115	4.568
1969	9.438	7.025	12.680	3.392	2.801	4.107
1970	8.879	6.609	11.929	3.322	2.744	4.023
1971	7.892	5.874	10.603	2.976	2.457	3.604
1972	8.299	6.177	11.150	3.588	2.963	4.344
1973	7.649	5.693	10.277	3.380	2.791	4.093
1974	6.653	4.952	8.939	2.797	2.310	3.387
1975	7.472	5.562	10.039	3.099	2.559	3.752
1976	8.523	6.344	11.451	3.266	2.697	3.955
1977	6.344	4.722	8.524	3.109	2.568	3.765
1978	4.598	3.422	6.178	2.645	2.185	3.204
1979	4.106	3.056	5.517	2.739	2.262	3.317
1980	6.853	5.101	9.207	3.593	2.967	4.351
1981	10.588	7.881	14.225	4.381	3.618	5.306
1982	17.694	13.170	23.772	5.212	4.304	6.311
1983	20.407	15.189	27.417	6.247	5.158	7.565
1984	17.382	12.937	23.353	6.806	5.620	8.242
1985	17.381	12.934	23.357	7.209	5.952	8.731
1986	15.971	11.869	21.489	6.967	5.747	8.445
1987	15.077	11.118	20.445	6.505	5.339	7.925
1988	15.180	10.704	21.528	5.915	4.716	7.419
	Principal Pelagics			Elasmobranchs		
1968	.451	-	-	9.638	-	-
1969	.305	-	-	9.523	-	-
1970	.391	-	-	9.060	-	-
1971	.272	.140	.531	8.968	5.893	13.648
1972	.472	.242	.919	10.375	6.817	15.790
1973	.550	.283	1.072	11.921	7.833	18.142
1974	.391	.201	.761	14.956	9.827	22.761
1975	.127	.065	.247	14.791	9.719	22.510
1976	.191	.098	.373	14.783	9.714	22.498
1977	.170	.087	.330	11.103	7.295	16.897
1978	.203	.104	.396	11.194	7.355	17.035
1979	.212	.109	.413	9.800	6.439	14.914
1980	.228	.117	.444	14.414	9.471	21.937
1981	.241	.124	.470	32.787	21.544	49.898
1982	.203	.104	.395	63.325	41.610	96.372
1983	.242	.124	.471	67.744	44.514	103.099
1984	.390	.200	.760	66.702	43.827	101.517
1985	.773	.397	1.508	117.469	77.161	178.835
1986	1.135	.581	2.219	111.413	73.051	169.920
1987	1.127	.567	2.243	162.543	105.401	250.663
1988	1.914	.870	4.214	179.395	109.149	294.850

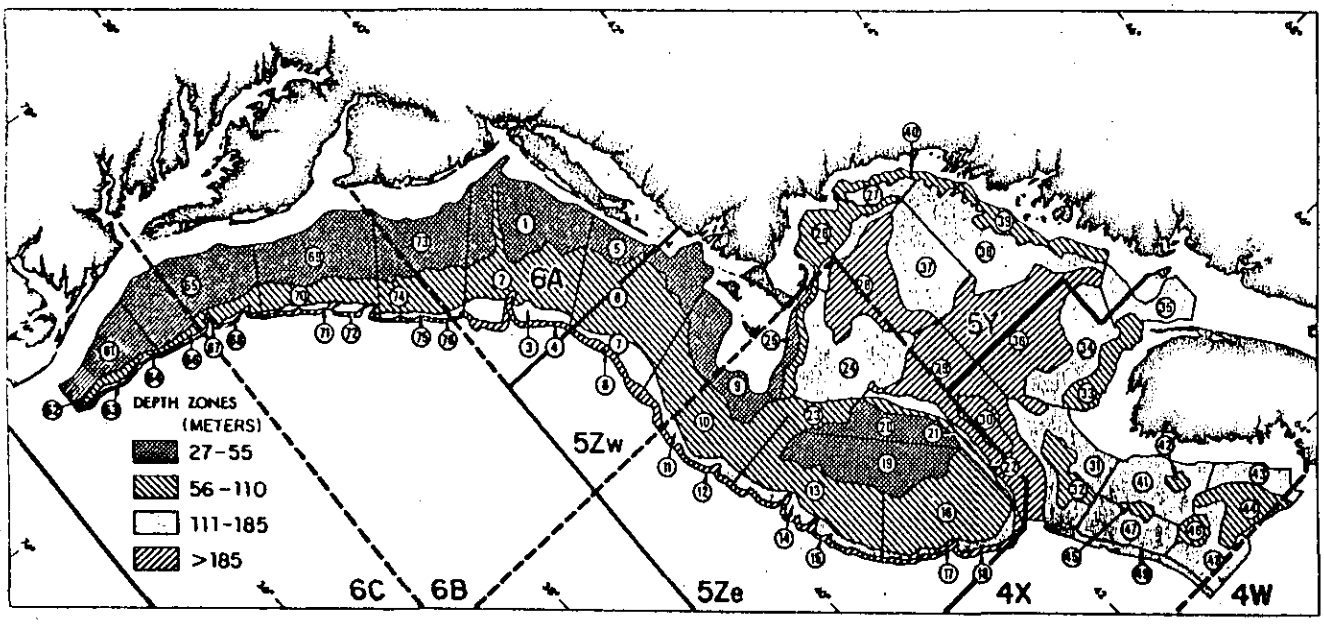

Figure 1. The Georges Bank region off the northeastern coast of the United States. NAFO statistical areas and NEFC bottom trawl survey sampling strata are also indicated.

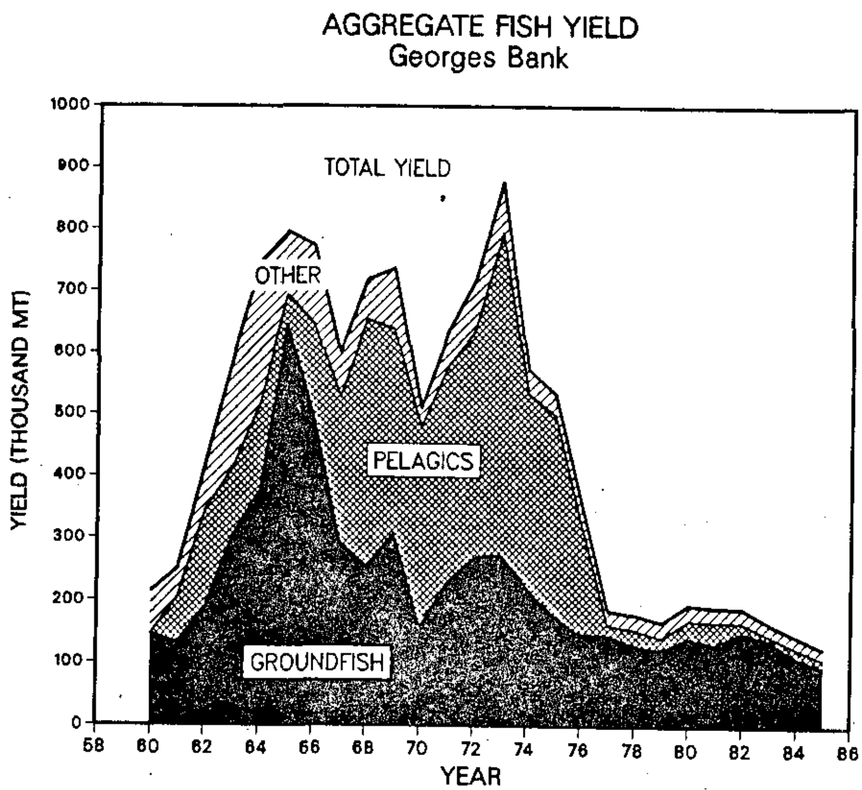

Figure 2. Total nominal catches from Georges Bank (NAFO Div. 5Z) fisheries, 1960 - 1985. Aggregate yields are presented by fishery components: groundfish, pelagic, and 'other'.

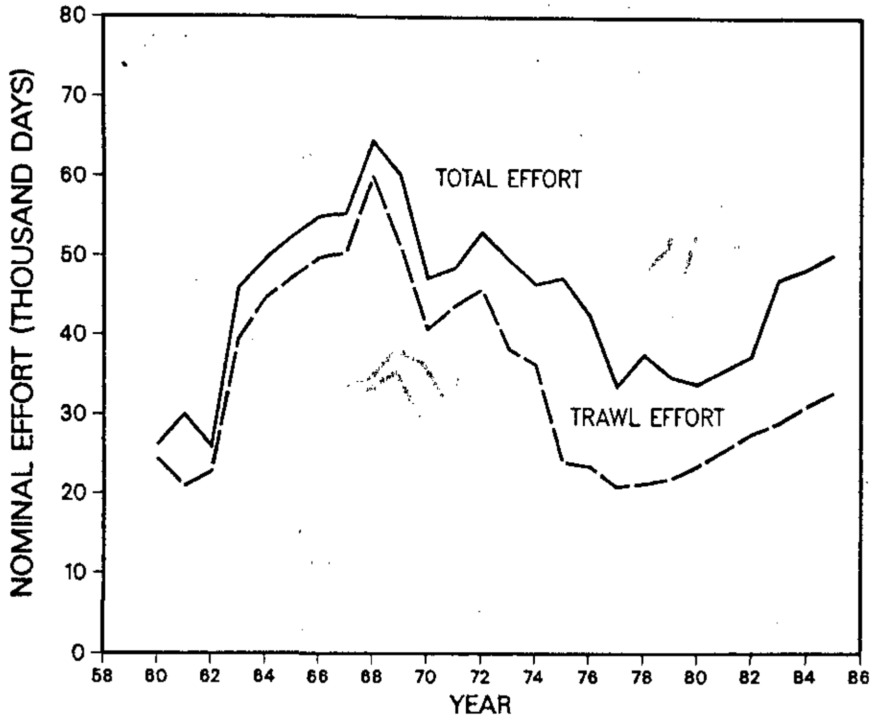

Figure 3. Total nominal fishing effort (days fished) on Georges Bank (NAFO Div. 5Z), 1960 - 1985. Total nominal trawl effort is also presented. Effort data for 1962 and 1981 have been excluded because of statistical discrepancies.

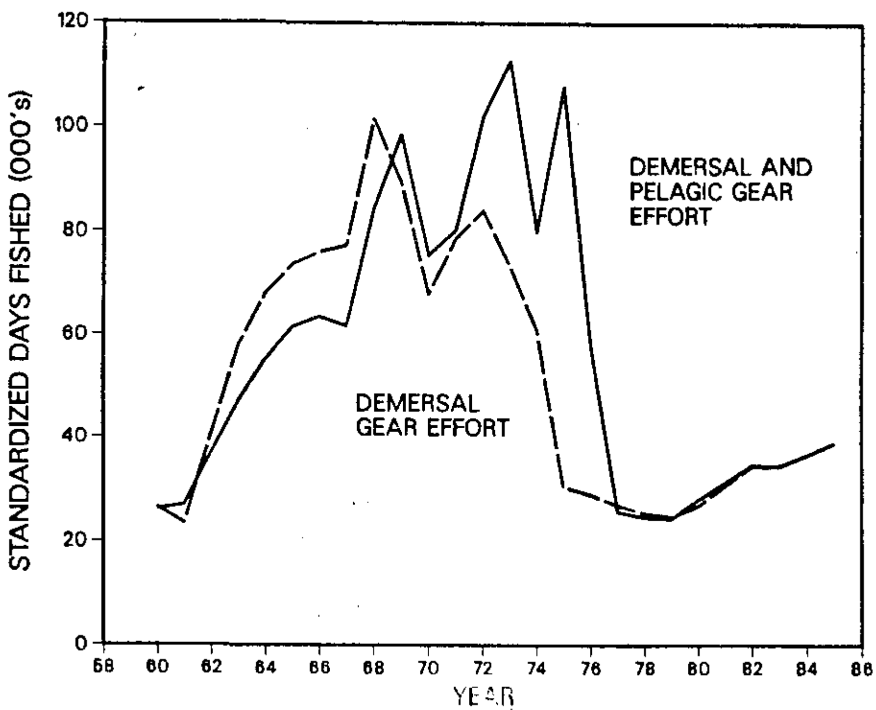

Figure 4. Total standardized fishing effort (days fished) on Georges Bank (NAFO Div. 5Z), 1960 - 1985. Both total effort and demersal gear effort are presented. Standardized effort was not calculated for 1962 and 1981 due to statistical discrepancies in nominal effort in these two years.

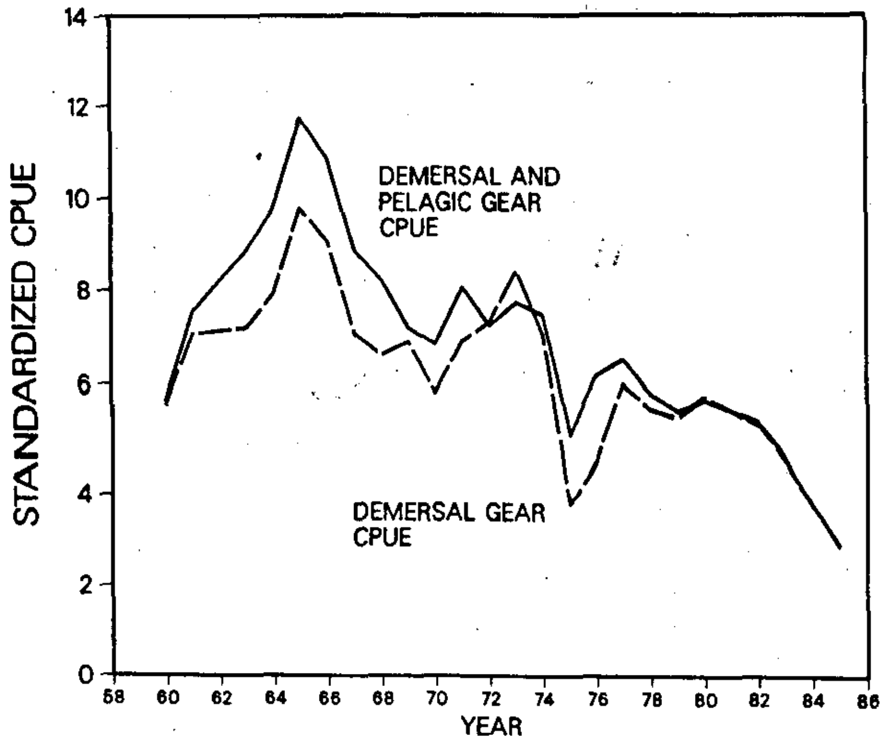

Figure 5. Total standardized CPUE (nominal catch per standardized day fished, in tons/day) on Georges Bank (NAFO Div. 5Z), 1960 - 1985. CPUE values are presented for all gear (demersal and pelagic) and for demersal gear alone. CPUE values were not calculated for 1962 and 1981 due to statistical discrepancies in nominal effort in these two years.

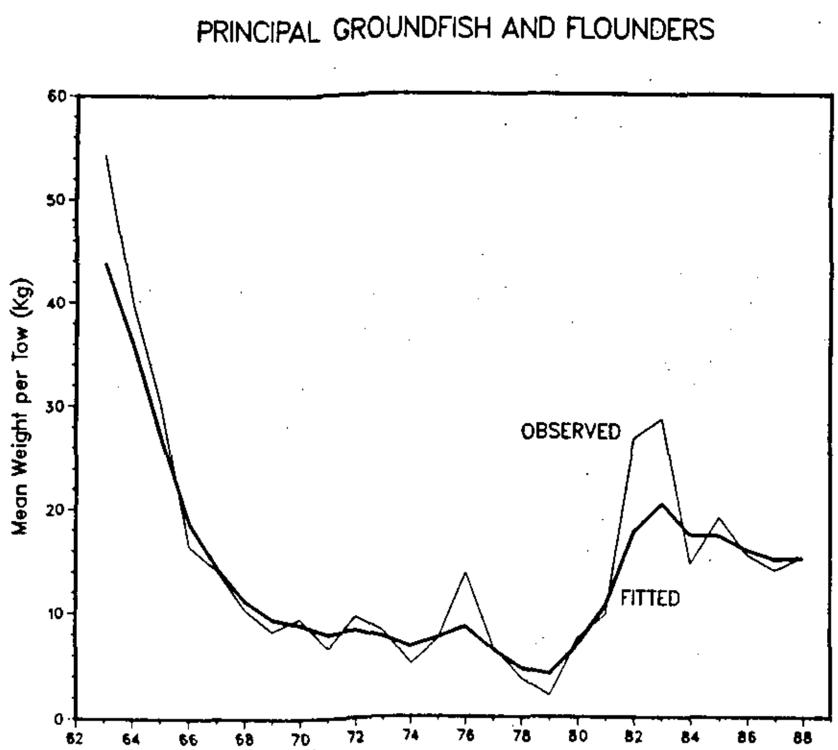

Figure 6. NEFC bottom trawl survey (autumn) biomass indices (kg/tow) for *'principal groundfish and flounders'* on Georges Bank (NEFC offshore sampling strata 5 - 25), 1963 - 1988.

OTHER GROUNDFISH AND FLOUNDERS

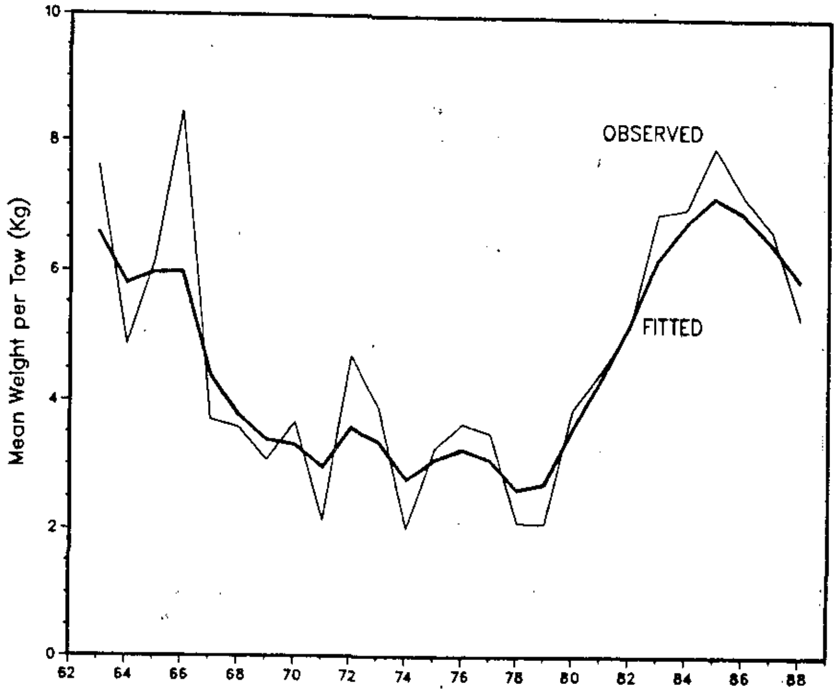

Figure 7. NEFC bottom trawl survey (autumn) biomass indices (kg/tow) for *'other groundfish'* on Georges Bank (NEFC offshore sampling strata 5 - 25), 1963 - 1988.

PRINCIPAL PELAGICS

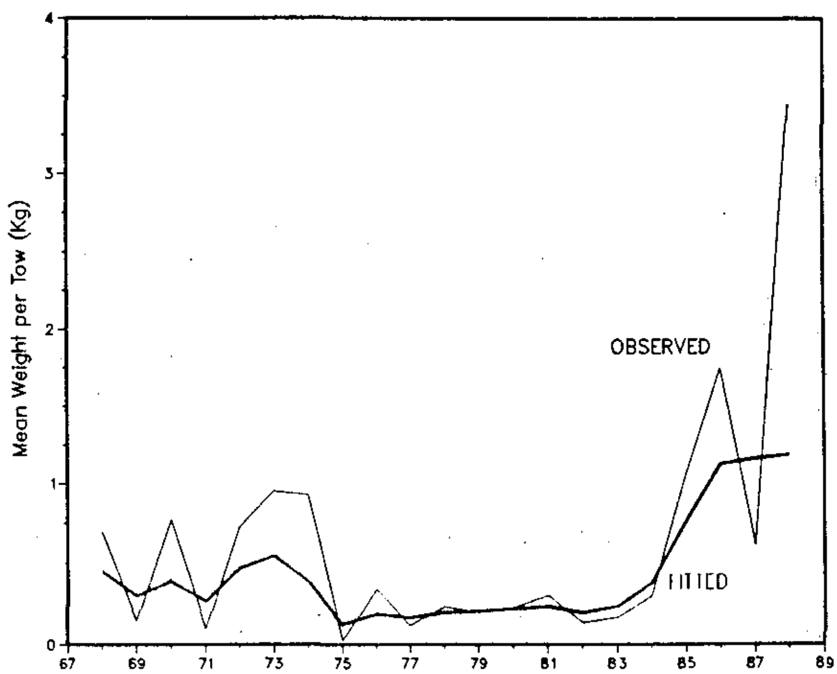

Figure 8. NEFC bottom trawl survey (spring) biomass indices (kg/tow) for *'principal pelagics'* (mackerel and herring) on Georges Bank (NEFC offshore sampling strata 5 - 25), 1968 - 1988.

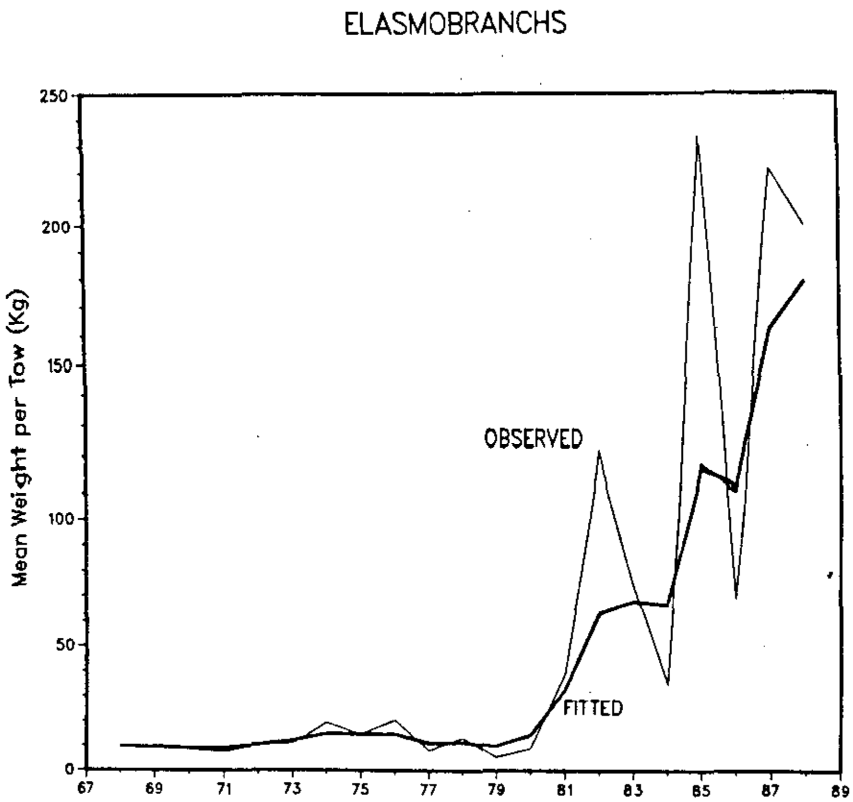

Figure 9. NEFC bottom trawl survey (spring) biomass indices (kg/tow) for *'elasmobranchs'* on Georges Bank (NEFC offshore sampling strata 5 - 25), 1968 - 1988.

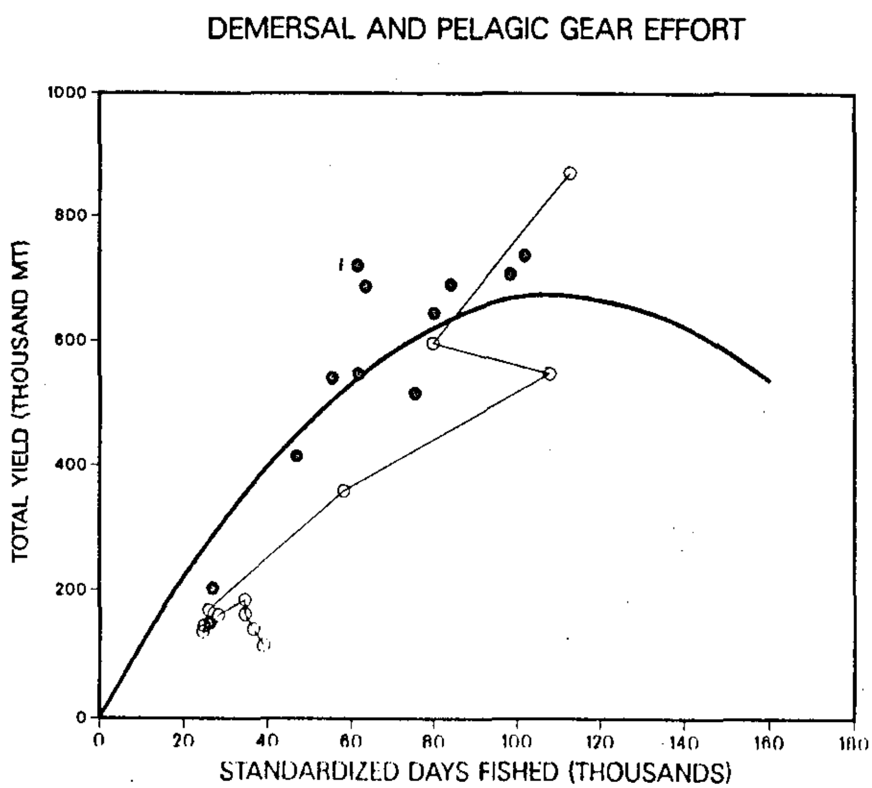

Figure 10. Yield/effort relationship for Georges Bank finfish and squid, 1960 - 1985, derived using a generalized stock production model.