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Aggregate Fish Biomass and Yield on Georges Bank, 1960–87

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Abstract

The Georges Bank ecosystem has undergone dramatic changes in biomass and species dominance under exploitation. Sharp declines in the biomass of both pelagic and demersal fish populations have occurred associated with rapid increases in fishing effort by distant water fleets. 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. A fourfold increase was noted in standardized effort over the period 1960–72. Declines in catch-per-standard day fished, and relative biomass indices derived from research vessel surveys indicated 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 collapsed by that time.

Fundamental changes were noted 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.

Introduction

Georges Bank is a highly productive marine ecosystem with 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 associated with the advent and expansion of distant water fisheries on Georges Bank in the early-1960s resulted in major perturbations to the system (Clark and Brown, 1977; 1979). Between 1961 and 1973, total finfish and squid landings from Georges Bank nearly quadrupled, while fishing effort increased sixfold. Virtually all of the principal demersal and pelagic resources within the region became intensively exploited and overfished. As a consequence, marked reductions in abundance (50–90%) occurred for several important species and total finfish biomass declined by over 50% (Brown *et al*., 1976).

Changes in ecosystem structure in response to exploitation have been observed in several large regions including the North Sea (Hempel, 1978) and the Great Lakes (Holling, 1973; Christie and Spangler, 1987). However, the general resilience of ecosystems to sustained perturbations (e.g. exploitation) is still not known. It is often implicitly assumed that these systems will revert to their 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. Beddington (1984) noted that changes in system structure induced by harvesting may not be reversible and that exploited ecosystems may exhibit multiple stable states.

In this paper, we describe trends in aggregate fish biomass and yield on Georges Bank, and explore the consequences of large scale changes in exploitation levels on the fish populations. The analyses are based on commercial catch and effort data for NAFO Div. 5Z (Fig. 1) for the period 1960–87, 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.

History of exploitation and regulation of Georges Bank fisheries

Offshore groundfish fisheries developed on Georges Bank between 1720 and 1750, primarily for

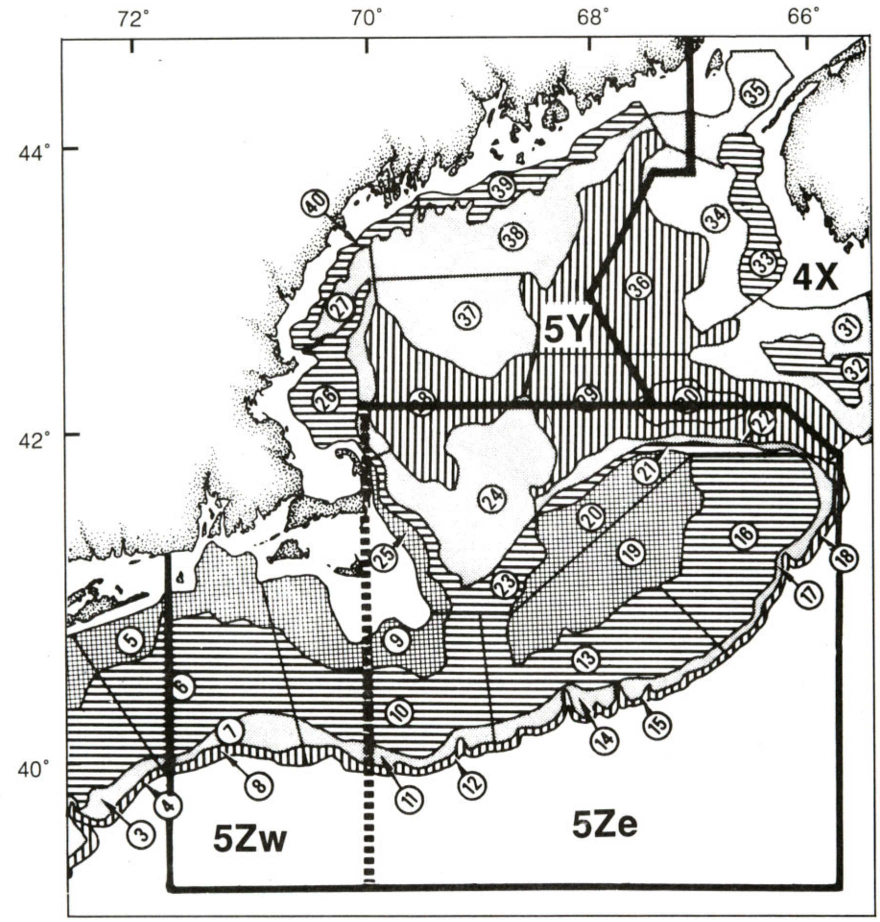

Fig. 1. The Georges Bank region off the northeastern coast of the United States. NAFO areas (Div. 4X, 5Y and Subdiv. 5Ze and 5Zw) and NEFC bottom trawl survey sampling strata (numbered shaded areas) are indicated.

Atlantic cod (*Gadus morhua*), but expanded during the early–1800s to include Atlantic halibut (*Hippoglossus hippoglossus*) and Atlantic mackerel (*Scomber scombrus*) (German, 1987). 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*) increased 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. 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). Flounder catches also increased during the 1920s due to the introduction of filleting techniques and awareness that significant winter flounder (*Pleuronectes americanus*) and yellowtail flounder (*Pleuronectes ferrugineus*) stocks existed on the southern flank of the Bank.

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, although attention was raised over the large quantities of small haddock discarded in the Georges Bank fishery (Herrington, 1935; Graham and Premetz, 1955). As a result of these concerns (and a sharp drop in haddock catches), intensive research and port sampling programs were established by the U.S. Bureau of Fisheries in the 1930s to investigate changes in haddock landings and abundance (Schuck, 1951). These programs were expanded in the 1940s and 1950s to encompass other species, and a comprehensive North Atlantic fishery statistics collection system was 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 by the USA. During the 1960s and early-1970s, however, the nature of the fishery changed dramatically with the arrival of distant water fleets from the Union of Soviet Socialist Republics (USSR), Poland, German Democratic Republic (GDR), Federal Republic of Germany (FRG), Japan and other countries. Although these fleets initially exploited Atlantic herring (*Clupea harengus*), effort was soon directed towards abundant stocks of groundfish and flounders. Total yield from Georges Bank increased sharply from 240 000 tons in 1960 to about 780 000 tons in 1965 (Fig. 2) due to substantial increases in the groundfish component (principally haddock and silver hake). Subsequently, groundfish landings sharply declined and fishing effort was redirected to pelagic species (principally herring, and later, mackerel) and squid (*Illex illecebrosus* and *Loligo pealei*). 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 1977–1981. After 1981, declining groundfish stocks contributed to further reductions in total yield to less than 220 000 tons in 1985 and 1986.

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 (i.e. the MFCMA). Since 1978, however, abundance of groundfish and flounders on Georges Bank has continued to decline to record-low levels (Northeast Fisheries Center, MS 1987), while pelagic stocks (primarily mackerel and herring) and non-target species (skates and spiny dogfish) have increased (U.S. Department of Commerce, 1988).

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 (TAC) limits 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 TAC (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.

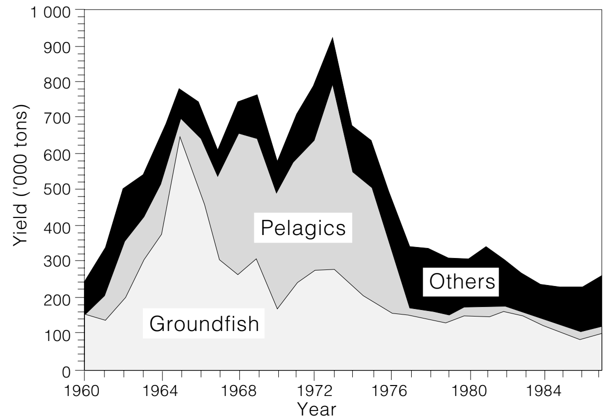

Fig. 2. Total nominal catches from Georges Bank (NAFO Div. 5Z) fisheries, 1960–87. Aggregate yields are presented by fishery components: groundfish, pelagic and 'other'.

The USA 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 harvesting 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-keeping/reporting requirements (Serchuk and Wigley, 1992). 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, behaviour 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 USA 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 subsequently been restricted to its own portion of Georges Bank, and management of transboundary stocks on the Bank is performed separately and independently by each country (Serchuk and Wigley, 1992).

Materials and Methods

Data sources

Catch and effort data from 1960 through 1987 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 presented in the 1960 ICNAF Statistical Bulletin. Species categories (Table 1) were thus defined as: cod, haddock, redfish, silver hake, other groundfish, flounders, herring, other pelagics, other fish, and all species combined. A database which included only records assigned to Div. 5Z (or Subdiv. 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). All records relating to fisheries targeting large pelagic fishes (swordfish, tunas, and sharks), lobsters, and bivalves were eliminated using combinations of main species and gear designations (Tables 1 and 2).

Standardized fishing effort was derived for all groundfish and small pelagic components of the Georges Bank fisheries and for a subset which only included effort associated with demersal fishing. The secondary subset was defined by first eliminating all records for midwater trawls and purse seines and those listing menhaden as the main species (Tables 1 and 2). We then examined the impact of several qualification levels ranging from 30 to 70%

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
Haddock	Haddock		Yellowtail flounder
			Atlantic halibut
Redfish	Atlantic redfishes		Winter flounder
	Beaked redfishes		Summer flounder
			Windowpane flounder
Silver hake	Silver hake		Flatfishes (NS)
Other Groundfish	Red hake	**Atlantic herring**	Atlantic herring
	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 include: swordfish, tuna, lobster, molluscs (NS) and invertebrates (NS).

Main species further deleted from demersal effort analyses: menhaden.

on changes in effort relative to catch. As the qualification level increases, elimination of "non-directed" effort can only be achieved by greatly reducing catches of non-pelagic species due to non-linearity in the catch/effort *vs.* qualification level relationship. Therefore, only those records in the secondary subset in which the catch of non-pelagic species represented 50% or more of the total catch were included for analysis of demersal catch and effort. Both data sets were then aggregated over months.

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 gear types, countries and tonnage classes appearing infrequently in the data set were either eliminated or combined as illustrated in Tables 2 and 3. The combinations resulted in 9 potential gear groups, 8 country groups and 5 tonnage class categories. Catches associated with gear and country categories excluded from the effort standardization analyses were subsequently incorporated when estimates of standardized fishing effort and catch per unit effort (CPUE) were expanded to total catch. A standard category was chosen for each factor as follows: gear - otter trawl, bottom (side); tonnage class - 3; and, country - USA. Units of fishing effort used in the analyses were expressed as hours fished; since effort for the USA fleet is reported as days fished (equivalent to 24 hr of fishing time), USA effort was multiplied by a factor of 24 to furnish effort units consistent with all other fleets.

The Northeast Fisheries Science Center has conducted stratified random bottom 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.* (MS 1986). Species-specific data from 1963–1988 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, in-

TABLE 2. Gear groupings used in effort standardization analyses.

Gear code	Gear group	Gears included	
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
71	**Dredges**	DRB	Dredge (boat)
		DRH	Dredge (hand)

Note: Gear deleted from all analyses includes: beach seine; squid jiggers; all traps, pound nets, pots and weirs; all dredge gear; harpoons; and all miscellaneous or unknown gear.

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

cluding dogfish and skate species. Stratified mean weight-per-tow (kg) indices were then calculated for each aggregate group inclusive of strata 5 through 25. A complete listing of the species within each of the groups is given in Table 4.

Effort standardization

Relative harvesting efficiency varies markedly among different vessel size classes and fishing gears. To account for these differences, nominal fishing effort was standardized using a general linear model approach (e.g. Robson, 1966; Gavaris, 1980; Kimura, 1981; 1988) based on the multiplicative model:

$$U_{ijkl} = \alpha_i \beta_j \delta_k (qB) \exp(\varepsilon_{ijkl})$$

where U_{ijkl} is the CPUE for the i^{th} gear, j^{th} tonnage class, k^{th} country, and l^{th} observation; α_i, β_j, and δ_k represent gear, tonnage class and country effects respectively, q is the catchability coefficient, B represents mean population biomass and ε_{ijkl} is a normally distributed random variable with mean 0 and constant variance. Because the population biomass is not directly known, the term qB is replaced by the mean CPUE (μ) and all coefficients are estimated relative to an arbitrarily defined standard (described previously). Least squares estimates of the model coefficients were made under the constraints: $\Sigma \log_e \alpha_i = \Sigma \log_e \beta_j = \Sigma \log_e \delta_k = 0$ for the linearized model:

$$\log_e U_{ijkl} = \log_e \mu + \log_e \alpha_i + \log_e \beta_j + \log_e \delta_k + \varepsilon_{ijkl}$$

Retransformation of the model coefficients to linear scale was made after correction for bias following Granger and Newbold, (1977). Interactions among all main effects in the model were tested, and several interactions were found to be statis-

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

Country code	Country group	Countries included	Tonnage code	Tonnage classes	GRT range
01	**Bulgaria (BUL)**	Bulgaria	2	2	0–49.9
		Romania			
		USSR	3	3	50–149.9
		Cuba			
			4	4	150–499.9
02	**Canada (CAN)**	Can-MQ			
		Can-M	5	5	500–999.9
		Can-Q			
		Can-N	6	6 and 7	1000 & over
10	**Federal Republic of of Germany (FRG)**	FRG			
		France (M)			
11	**German Democratic Republic (GDR)**	GDR			
14	**Japan (JPN)**	Japan			
16	**Poland (POL)**	Poland			
19	**Spain (ESP)**	Spain			
		Italy			
22	**United States (USA)**	USA			

Note: The following countries were deleted from all analyses: Faroe Islands, Iceland, Norway, United Kingdom and Ireland.

tically significant. However, in each case, the proportion of the variance explained by the interaction terms was small relative to the main effects (<7%). Accordingly, only main effects models were considered in subsequent analyses. The large number of degrees of freedom in the model increased the probability of detecting significant interactions, but the practical significance of these interactions seemed to be minor.

Standardized effort for each country-gear-tonnage class category was estimated by multiplying nominal effort by the product of the coefficients for each factor. Estimated effort was then accumulated over all categories on an annual basis and the annual effort adjusted up to account for catches which were excluded from the standardization procedure. The annual adjustments generally represented less than 10% of the total annual landings.

We also examined models incorporating a year effect and a covariate based on research vessel surveys conducted by the Northeast Fisheries Science Center to account for the effects of learning (in the early years of the multinational fishery) and the effects of technological changes not directly quantifiable in the model (e.g. satellite navigation systems, etc.). Estimates of stratified mean catch per tow (kg) for each species group were made after the survey catch data were transformed to natural logarithms; retransformed values (with bias correction) were obtained using procedures outlined by Bliss (1967). Autumn survey data were used for the principal groundfish and other groundfish groups while spring data were used for principal pelagics and elasmobranchs to account for seasonal changes in availability. The general linear model with covariate term is:

$$\log_e u_{ijklm} = \log_e u + \log_e \alpha_i + \log_e \beta_j + \log_e \delta_k + \log_e \gamma P + \log_e I_1 + \varepsilon_{ijklm}$$

where γ is the coefficient for the survey biomass term (P) for the principal groundfish group, I_1 is the year effect coefficient, and all other terms are defined as before. Interaction terms were again tested and found to explain only a small fraction of the variance. Accordingly, the final model included only main effects.

Results

Standardization of fishing efort

Results from the linear model analyses for the demersal + pelagic groups and the demersals-only are given in Tables 5 through 7. Both analyses, the

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	*Pleuronectes ferrugineus*
Summer flounder	*Paralichthys dentatus*
Winter flounder	*Pleuronectes 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. Linear model for NAFO effort (hrs) data standardization for groundfish, flounders and small pelagic groups using USA, Ton Class 3, Side Trawl – standard data with No Year Effect.

Source	DF	Sum of squares	Mean square	F value	PR > F
Model	17	2 310.00	135.88	184.16	0.0
Gear	6	1 013.64	168.94	228.97	0.0
Ton Class	4	700.90	175.23	237.49	0.0
Country	7	595.46	85.07	115.29	0.0
Error	2 455	1 811.38	0.74		
Total	2 472	4 121.38			

TABLE 6. Linear model for NAFO effort (hrs) data standardization for directed groundfish and flounder fisheries using USA, Ton Class 3, Side Trawl – Standard data with No Year Effect.

Source	DF	Sum of squares	Mean square	F value	PR > F
Model	15	1 241.38	82.76	130.43	0.0
Gear	4	196.85	49.21	77.56	0.0
Ton Class	4	437.84	109.46	172.51	0.0
Country	7	606.69	86.67	136.59	0.0
Error	2 043	1 296.30	0.63		
Total	2 058	2 537.68			

TABLE 7. Linear model for NAFO effort (hrs) data standardization for directed groundfish and flounder fisheries using USA, Ton Class 3, Side Trawl, 1963 – Standard; Survey Index as covariate.

Source	DF	Sum of squares	Mean square	F value	PR > F
Model	38	1 357.34	35.72	61.41	0.0
Surv. Index	1	199.51	199.51	343.00	0.0
Year	22	133.13	6.05	10.40	0.0
Gear	4	202.71	50.68	87.13	0.0
Ton Class	4	295.07	73.77	126.82	0.0
Country	7	526.93	75.28	129.41	0.0
Error	2 005	1 166.22	0.58		
Total	2 043	2 523.57			

three-factor model (Tables 5 and 6) and the model which incorporated the survey index as a covariate (Table 7), accounted for approximately 50–55% of the total sums of squares. For each data set, the gear, tonnage class and country effects were highly significant ($P < 0.01$), and year was highly significant in the covariate model. The only interactions found to be significant ($P < 0.05$) were gear-country and then only between fixed gear fished by Canada and the USA. In general, the contribution of the interaction terms to the model sums of squares was minimal.

Coefficients for the gear, tonnage class and country effects, converted to a linear scale, are given in Table 8. Relative to the side trawl standard, gear coefficients were highest for pelagic gear (midwater trawls and purse seines) and lowest for fixed gear (gill nets and line gear). Tonnage class coefficients generally increased with vessel size, the class 6+7 category being approximately twice the class 3 standard. Country coefficients were variable with most country groups exhibiting a 2-to 4-fold difference in fishing power relative to the USA standard. Country coefficients were generally highest for the combined demersal + pelagic group analysis compared to the demersals-only analyses. The largest differences occurred in the FRG/France, GDR and Polish fleets, suggesting that higher catch rates were achieved by these countries in the pelagic fisheries. Between 1966 and 1976, pelagic species (principally herring and mackerel) accounted for over 80% of the total catch by these countries (Appendix 1).

Trends in nominal and standardized fishing effort and CPUE

Nominal fishing effort on Georges Bank for the combined demersal and pelagic gear components increased rapidly during the 1960s, peaking at about 947 000 hrs fished in 1965 (Table 9, Fig. 3). Total effort subsequently declined to less than 500 000 hrs in 1977 and 1978, before increasing to over 850 000 hrs in 1985. Total nominal effort declined slightly thereafter, but remained relatively high through 1987. Nominal effort trends for the demersal fishery follow those for the total fishery, with a peak level of 939 000 hr in 1965 followed by gradual decline and subsequent increase (Table 9, Fig. 3).

Trends in standardized effort differ considerably from nominal effort, particularly during the mid-1970s. Standardized effort (Table 9, Fig. 4) increased from about 616 000 hr fished in 1960 to about 2 400 000 hrs in 1969 and remained relatively high, increasing to a peak of over 3 000 000 hrs in

TABLE 8. Standardization coefficients for gear, tonnage class and country effects (linear scale) derived from NAFO effort data standardization analyses.

Demersal and pelagic gear			Demersal gear only			Demersal gear only w/survey		
Factor		Standardization coefficient	Factor		Standardization coefficient	Factor		Standardization coefficient
GEAR	11[a]	1.000	GEAR	11[a]	1.000	GEAR	11[a]	1.000
	12	1.021		12	0.970		12	1.065
	13	1.864		16	1.014		16	1.039
	16	0.953		41	0.413		41	0.447
	31	16.986		51	0.570		51	0.592
	41	0.351						
	51	0.516						
TON CLASS	2	0.720	TON CLASS	2	0.738	TON CLASS	2	0.744
	3[a]	1.000		3[a]	1.000		3[a]	1.000
	4	1.019		4	1.108		4	1.042
	5	0.972		5	1.062		5	0.993
	6	1.889		6	1.768		6	1.708
COUNTRY	1	4.088	COUNTRY	1	4.447	COUNTRY	1	3.648
	2	3.809		2	4.226		2	3.974
	10	4.017		10	3.551		10	3.028
	11	4.407		11	2.539		11	2.271
	14	1.663		14	2.122		14	1.962
	16	4.882		16	4.146		16	3.423
	19	4.264		19	4.423		19	4.077
	22[a]	1.000		22[a]	1.000		22[a]	1.000

[a]Denotes standard gear, tonnage class and country categories.

TABLE 9. Total catch (metric tons, live), nominal effort (hrs) and CPUE (tons/hr), and estimated standardized effort (hrs) and CPUE (tons/hr) derived from General Linear Models (GLM) for Georges Bank (NAFO Div. 5Z), 1960–1987[1].

	Demersal and small pelagic fishery					Demersal fishery only						
						(without survey index as covariate)					(with covariate added)	
Year	Total catch	Nominal effort	Nominal CPUE	Standard Effort	Standard CPUE	Total catch	Nominal effort	Nominal CPUE	Standard effort	Standard CPUE	Standard effort	Standard CPUE
1960	147 646	607 528	0.2430	616 208	0.2396	147 646	607 528	0.2430	628 541	0.2349	–	–
1961	204 670	517 627	0.3954	697 772	0.2933	133 372	502 246	0.2656	476 548	0.2799	–	–
1962	371 277	–	–	–	–	214 259	–	–	–	–	–	–
1963	414 411	698 108	0.5936	1 166 433	0.3553	310 756	649 020	0.4788	1 050 207	0.2959	960 925	0.3234
1964	540 108	799 251	0.6758	1 577 834	0.3423	404 763	711 375	0.5690	1 359 747	0.2977	1 325 530	0.3054
1965	716 238	946 743	0.7565	2 201 576	0.3253	671 209	939 265	0.7146	2 280 163	0.2944	2 357 651	0.2847
1966	688 117	931 664	0.7386	2 254 374	0.3052	540 582	863 428	0.6261	2 115 709	0.2555	2 895 930	0.1867
1967	545 758	792 021	0.6891	1 729 752	0.3155	315 893	646 700	0.4885	1 294 141	0.2441	1 668 625	0.1893
1968	689 547	794 644	0.8677	2 088 348	0.3302	292 579	568 448	0.5147	1 148 756	0.2547	1 732 244	0.1689
1969	708 457	753 560	0.9401	2 398 317	0.2954	371 741	574 676	0.6469	1 464 832	0.2538	1 945 758	0.1911
1970	516 986	629 448	0.8213	1 590 878	0.3250	195 811	494 735	0.3958	859 045	0.2279	1 103 990	0.1774
1971	649 293	692 419	0.9377	2 218 866	0.2926	300 944	568 851	0.5290	1 439 060	0.2091	1 755 734	0.1714
1972	741 558	772 478	0.9600	2 918 940	0.2541	375 331	606 055	0.6193	1 757 841	0.2135	1 715 208	0.2188
1973	879 822	706 430	1.2454	2 511 851	0.3503	342 305	590 345	0.5798	1 597 036	0.2143	1 595 149	0.2146
1974	607 416	702 114	0.8651	2 144 174	0.2833	281 183	612 661	0.4590	1 352 889	0.2078	1 885 828	0.1491
1975	550 607	762 818	0.7218	3 055 377	0.1802	104 918	582 053	0.1803	755 237	0.1389	798 116	0.1315
1976	361 337	575 528	0.6278	1 686 101	0.2143	115 092	500 667	0.2299	695 764	0.1654	606 348	0.1898
1977	171 057	475 045	0.3601	738 798	0.2315	154 634	466 850	0.3312	688 171	0.2247	825 958	0.1872
1978	157 223	499 598	0.3147	707 588	0.2222	133 634	489 364	0.2731	624 523	0.2140	773 897	0.1727
1979	145 713	538 814	0.2704	588 869	0.2474	127 957	531 541	0.2407	582 323	0.2197	761 473	0.1680
1980	176 161	571 845	0.3081	767 239	0.2296	145 413	554 749	0.2621	631 577	0.2302	808 033	0.1800
1981	187 820	–	–	–	–	151 476	–	–	–	–	–	–
1982	184 629	702 785	0.2627	857 745	0.2152	169 434	687 414	0.2465	824 583	0.2055	1 044 790	0.1622
1983	156 592	756 616	0.2070	830 749	0.1885	150 457	745 931	0.2017	812 176	0.1853	943 002	0.1596
1984	134 891	804 254	0.1677	869 060	0.1552	121 597	792 322	0.1535	846 472	0.1437	1 147 163	0.1060
1985	112 772	853 776	0.1321	949 373	0.1188	102 693	838 985	0.1224	907 611	0.1131	920 342	0.1116
1986	98 810	717 216	0.1378	787 517	0.1255	84 062	706 275	0.1190	759 930	0.1106	779 195	0.1079
1987	108 464	829 505	0.1308	886 702	0.1223	93 026	816 350	0.1140	888 859	0.1047	952 641	0.0977

[1] Data for 1962 and 1981 were eliminated from analyses because of inconsistencies (see text for explanation).

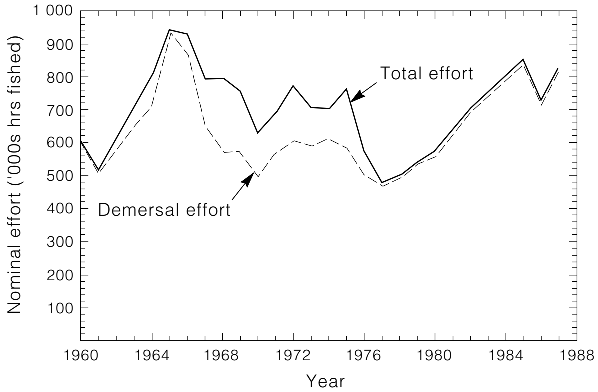

Fig. 3. Total nominal fishing effort and nominal effort on demersals on Georges Bank (NAFO Div. 5Z), 1960–87. Effort data for 1962 and 1981 have been excluded because of statistical discrepancies.

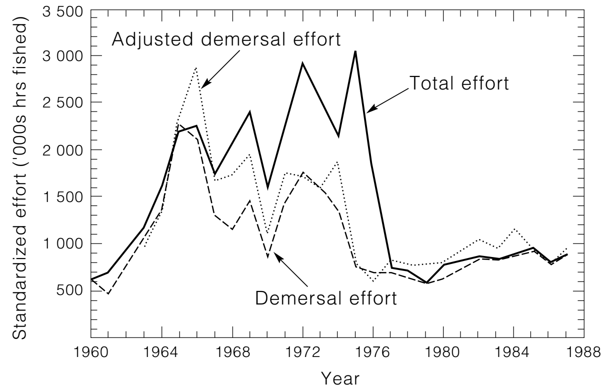

Fig. 4. Standardized effort on total fishing and demersal gear, and standardized demersal gear effort adjusted for survey biomass index on Georges Bank (NAFO Div. 5Z), 1960–87. Standardized effort was not calculated for 1962 and 1981 due to nominal effort discrepancies in the 2 years.

1975. Effort declined sharply in 1976 and 1977, and continued to decline to less than 600 000 hrs in 1979. Although total effort increased to about 950 000 hrs in 1985 and has generally remained above 800 000 hrs since 1982, recent effort levels have remained well below those recorded during the mid-1970s.

Trends in standardized effort for the demersal component were quite distinct from the overall standardized effort pattern, with major declines in effort evident throughout the late-1960s and continuing through the mid-1970s. This difference may be explained by increases in the amount of off-bottom gear, as indicated by trends in pelagic catches (Fig. 2) and nominal effort (Fig. 3), but is accentuated by the relatively high coefficients for purse seine gear (16.99) relative to the standard (Table 8). Standardized effort trends for both components are similar after 1977, when effort was primarily by USA vessels fishing with bottom trawls. When the survey index is included in the model as a covariate to account for changes in abundance, demersal effort remained at a relatively high level for a longer period during the late-1960s than indicated by the standard model (Table 9, Fig. 4). The covariate model also indicated slightly greater demersal effort during the late-1970s and early-1980s.

Standardized CPUE for the combined demersal and pelagic gear components increased from 0.24 tons/hr fished in 1960 to 0.36 tons/hr in 1963 (Table 9, Fig. 5) but declined gradually thereafter to about 0.18 tons/hr in 1975. After increasing to about 0.25 tons/hr in 1979, the combined CPUE index began to decline rapidly, reaching record low levels of about 0.12 tons/hr between 1985 and 1987. CPUE for the demersal component followed the same pattern as

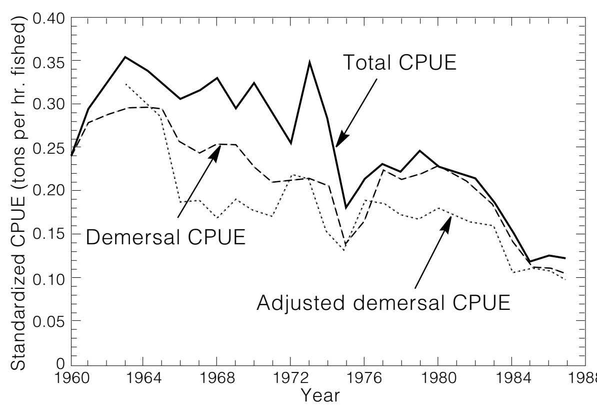

Fig. 5. Total standardized nominal catch-per-hr fished (CPUE), for all gear (demersal and pelagic), for demersal gear alone, and for demersal gear effort adjusted for survey biomass index on Georges Bank (NAFO Div. 5Z), 1960–87. CPUE values were not calculated for 1962 and 1981 due to nominal effort discrepancies in the 2 years.

the combined index, declining from a maximum of 0.30 tons/hr during 1963–65 to about 0.15 tons/hr in 1975 and 1976 (Table 9, Fig. 5). During the late-1970s, demersal CPUE increased steadily but declined after 1980 to about 0.10 tons/hr during 1985–87. However, when the survey index was incorporated as a covariate in the model, the decline in CPUE during the mid-1960s was even more pronounced, and the apparent increase in CPUE during the late-1970s less evident.

Yield-effort trajectory

During the initial phase of exploitation by the distant water fleets, aggregate yield increased sharply as total effort increased, and previously unexploited or lightly exploited species were harvested (Fig. 6A). However, by 1976, both yield and total effort had declined, reflecting reduced abundance of several important species including haddock and herring. With the implementation of extended jurisdiction in 1977, total standardized effort was reduced to pre-impact levels (Fig. 6A). The yield-effort trajectory for the period dominated by the distant water fleets reflects several distinct stanzas in fishery development ranging from an initial concentration on demersal species to a subsequent focus on pelagic species (primarily herring and mackerel). These shifts in target species appear to have been largely opportunistic and keyed to the occurrence of dominant year-classes.

Total fishing effort by the domestic fleet since implementation of extended jurisdiction has not approached levels observed during the peak of the distant water fisheries. Despite reduced effort levels under MFCMA, however, yield has remained at relatively low levels. The lower aggregate yield since 1977 reflects both the reduced abundance of principal groundfish and a difference in the species composition of the fishery. Fishing effort is currently more sharply focused on the traditionally exploited groundfish and flounder complex.

Standardized fishing effort in the demersal component of the fishery increased steadily from 1963 to 1966, peaking with concentration on the exceptional 1963 year-class of haddock (Fig. 6B). Directed effort on demersal species subsequently declined with the sharp decrease in haddock biomass. By 1976, effort levels in the demersal component had declined to pre-distant water fleet levels. Following the implementation of extended jurisdiction, the yield effort trajectory has remained within a more limited domain relative to its earlier history.

Trends in survey biomass estimates

The aggregate biomass index for principal groundfish peaked in 1964 (102.2 kg/tow) but declined thereafter, reaching a record-low of 17.1 kg/tow in 1974, an 83% reduction from the 1964 level (Fig. 7A). Sharp declines in abundance of haddock, silver hake, redfish and yellowtail flounder occurred during this period. The biomass index increased again to an average of 51.0 kg/tow during 1976–78, but subsequently declined to an average of 17.9 kg/tow during 1984–88, its lowest level since 1974. The biomass index for other groundfish remained relatively high during 1963–66, averaging 11.6 kg/tow, but declined during 1967–71 (Fig. 7B). The index increased steadily during the late–1970s, reaching peak levels of about 20 kg/tow in 1980 and 1985, but subsequently declined to levels observed in the mid-1960s.

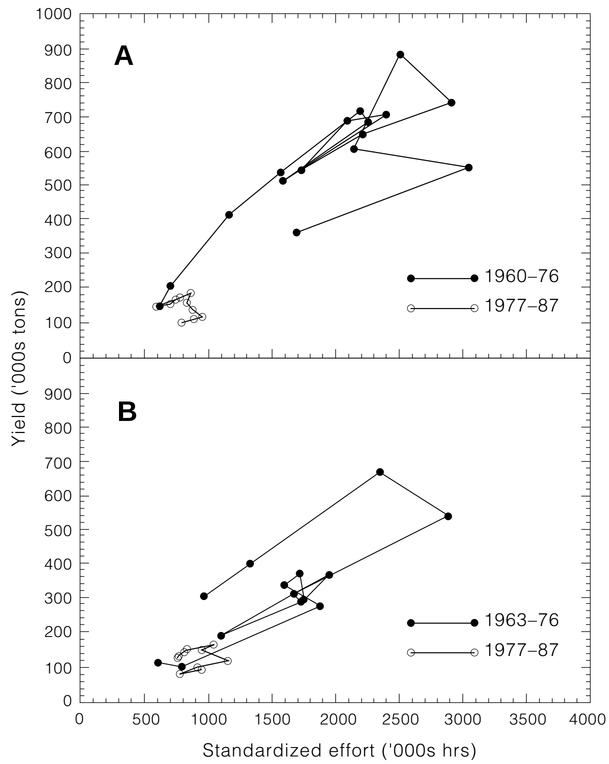

Fig. 6. Time trajectories of yield *vs* fishing effort for Georges Bank, 1960–76 and 1977–87. (**A**) Total pelagic and demersal catch *vs* standardized total effort, and (**B**) Demersal catch *vs* standardized demersal effort adjusted by NEFSC bottom trawl survey biomass indices from 1963 to 1987.

The aggregate biomass index for principal pelagics fluctuated during the late-1960s and early-1970s, but declined sharply after 1973 due to reduced abundance of Atlantic mackerel and the collapse of the Georges Bank herring stock in 1977 (Fig. 7C). Pelagic biomass has been increasing since 1985 due to significant rebuilding of the mackerel stock and the resurgence of the herring population on Georges Bank (Smith and Morse, MS 1990). Evidence of 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.

Elasmobranch biomass, which remained relatively low throughout most of the 1970s increased sharply during the 1980s (Fig. 7D). By 1988, elasmobranch biomass had increased by a factor of 2–5 over pre-1980 levels, due to sharp and sustained increases in spiny dogfish and skate populations.

Discussion

The arrival of distant water fleets on Georges

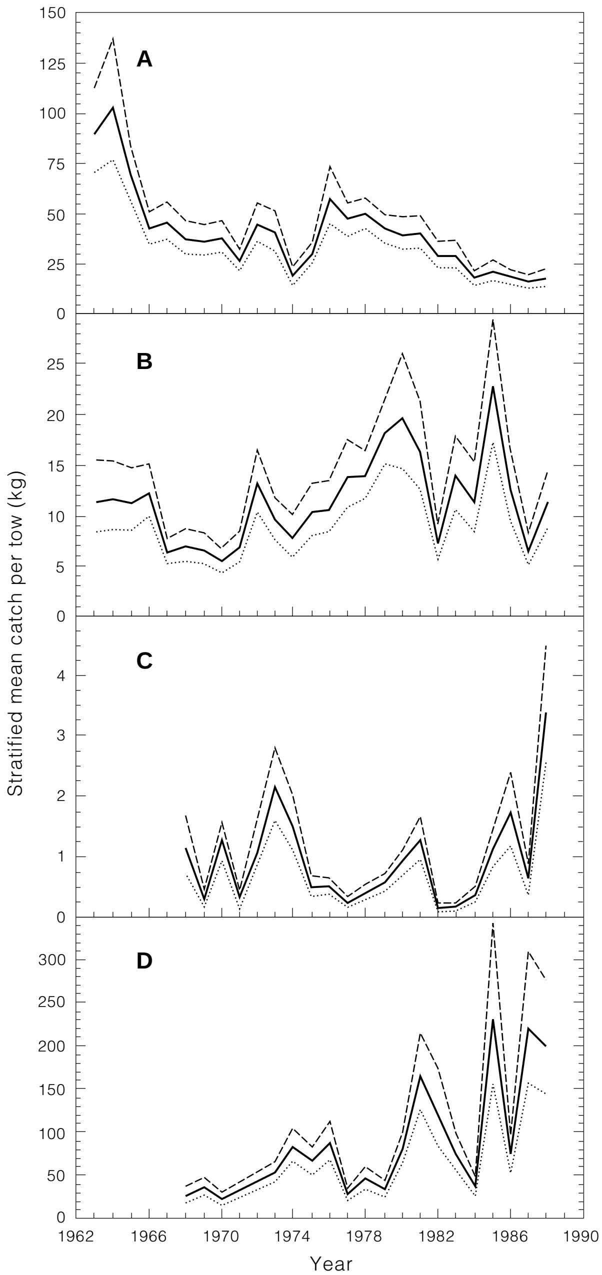

Fig. 7. NEFSC bottom trawl survey biomass indices and 95% confidence intervals for (**A**) 'principal groundfish', (**B**) 'other groundfish', (**C**) 'principal pelagics' (mackerel and herring), and (**D**) 'elasmobranchs' on Georges Bank (NAFO Div. 5Z; NEFSC offshore sampling strata 5–25), 1963–88. (**A**) and (**B**) from autumn surveys; (**C**) and (**D**) from spring surveys.

Bank in the early-1960s resulted in a large-scale escalation of fishing effort and caused major perturbations to the structure of the system. The nearly four-fold increase in standardized fishing effort during the period 1960–72 induced sharp declines in aggregate fish biomass as measured by commercial catch rates and research vessel biomass indices. Our estimates of trends in standardized fishing effort on Georges Bank between 1960 and 1972 parallel those provided by Brown *et al*. (1976) for the entire Subarea 5-Statistical Area 6 region. After 1972, fishing effort remained relatively high on Georges Bank until 1977 when extended jurisdiction sharply curtailed distant water fleet fishing activity. As a result, fishing effort on pelagic species (herring and mackerel) was sharply reduced, and from 1977 onward effort on Georges Bank has been directed toward the demersal component primarily by USA and Canadian otter trawlers. Thus, trends in nominal effort, standardized effort and standardized CPUE have been essentially the same since 1977 for the combined pelagic and demersal components as for the demersal component alone.

The sharp increase in CPUE between 1960 and 1965 occurred during a period of increasing effort and yield, although the five-fold increase in the catch of finfish and squids was accomplished with a 3.5-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 after 1964 for the principal groundfish. However, sharp increases in biomass of herring and haddock occurred between 1960 and 1963 prior to the beginning of the NEFSC survey time series. Thus, the large 1960 year-class of herring (Anthony and Waring, 1980) and the exceptional 1963 year-class of haddock (Clark *et al*., 1982) must have contributed to the substantial increase in stock biomass indicated by the CPUE index through at least 1964. It is also likely, however, that the increase in the estimated CPUE during the early 1960s resulted, to some extent, from increased fleet efficiency as suggested by Brown *et al*. (1976), since fisheries prosecuted by the distant water fleets were then in a development stage.

This increased fleet efficiency was modelled by Brown *et al*. (1976) using a learning function, which they defined as "… a monotonically increasing function of CPUE through a continuous time period which was not caused by changes in stock abundance…", applied over the first 3 years of a fleet's participation in the fishery. The rate of learning was determined by comparing observed CPUE with predicted values adjusted by independent abundance estimates derived from autumn bottom trawl surveys.

Our approach to adjusting the standardized demersal effort to account for changes in fleet efficiency differs from Brown *et al*. (1976) only in the application of the fishery-independent estimates of abundance as covariates in the General Linear Model. Our CPUE adjustments reflect differences in the change in commercial CPUE over time relative to the changes in the survey biomass index. Both approaches, however, suggest that the decline in biomass which followed the peak levels of the early-1960s was more severe than would be predicted without the adjustment for increased fleet efficiency. Our analysis further suggests that the apparent increase in CPUE during the late-1970s and early-1980s may have also been partially due to technological advancements, since significant improvements in vessel design, gear and electronics occurred throughout the USA fleet during this period.

The decline in CPUE since the mid-1960s reflects the overall decline in abundance of principal groundfish and pelagics, including haddock, silver hake, herring and mackerel. The secondary increase in CPUE which occurred during the late-1970s 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.*, MS 1982; MS 1984; Mayo *et al.*,1989; Serchuk and Wigley,1992). The decline in CPUE since 1982 is associated with increased fishing mortality on these same stocks (U.S. Department of Commerce, 1988).

Based on their standardized fishing effort estimates, Brown *et al.* (1976) computed a 65% decline in commercial CPUE in Subarea 5 and Statistical Area 6 between 1963 and 1972. Our results suggest declines of 50% for all finfish and 60% for the demersal component in Div. 5Z alone during a similar period. CPUE for both components, after increasing slightly between 1978 and 1982, declined to record-low levels after 1984, 65–70% below those in 1963.

Parallel declines in research vessel survey indices were noted during this period. The aggregate biomass index for principal groundfish declined precipitously during 1964–66, reflecting a major reduction in haddock abundance. Other groundfish species also decreased during the period as a result of large incidental by-catches and the reduction fisheries prosecuted by many of the international fleets. Survey biomass indices for dogfish and skates remained relatively low during the peak years of the distant water fisheries since these species were also harvested incidentally and taken for reduction.

In the years prior to and shortly after the enactment of the MFCMA, relative biomass levels of principal groundfish and other groundfish began to increase. Brown and Halliday (1983) suggested that the recovery of groundfish stocks during this period was related to reduced fishing pressure which resulted from a combination of more restrictive ICNAF TAC regulations and the extension of jurisdiction by coastal states. We can now see that the recovery on Georges Bank was short-lived, however, and soon reversed as effort by domestic vessels increased; biomass of principal groundfish declined throughout the 1980s, reaching an historic low level in 1988. We note, however, that the high biomass levels for this group during the mid-1960s largely reflect haddock abundance, particularly the dominant 1963 year-class, and that the aggregate biomass indices for this period do not necessarily represent average conditions. The most striking changes in relative biomass indices during the past three decades are those for elasmobranchs and the principal pelagics. Skate and dogfish species have increased 2-to 5-fold since the late-1970s. Herring and mackerel biomass indices have increased substantially since 1985, reflecting the apparent resurgence of the Georges Bank herring population and extremely high biomass levels of mackerel. Current estimates of the mackerel stock alone exceed 2 million tons (Northeast Fisheries Center, MS 1991).

Brown *et al*. (1976) modeled surplus production of aggregate fish biomass off the northeastern USA and noted that the maximum sustainable yield (MSY) of the aggregate was less than the sum of the MSYs for the component species. Any attempt to update this estimate of aggregate MSY is complicated by (1) the non-equilibrium behaviour associated with the rapid decline in the herring population (which accounted for nearly one half of the total yield in the early-1970s), (2) differences in the production to biomass ratios of the species currently dominating the system relative to historical patterns, and (3) changes in effort and catch composition induced by the imposition of extended jurisdiction in 1977. Accordingly, we have not attempted to update the production model of Brown *et al*. (1976).

The perturbation induced by dramatic increases in fishing effort on Georges Bank by the distant water fleets resulted in important changes in system structure and productivity. The production of commercially desirable species has remained at depressed levels despite overall reductions in fishing effort relative to the period of distant water fleet activity. In part, this reflects a sharper focusing of effort on the principal groundfish by the domestic fleet. However, the increasing biomass of piscivores of little commercial value, particularly dogfish, mackerel and large skates, may further depress production levels by increasing predation mortality on both the pre-recruits and recruited components of the principal groundfish populations. The synergistic effects of exploitation and predation can affect the stability and resilience of these populations and result not only in lower levels of production but increased probability of a population collapse. It is possible that the observed changes in system structure may not be reversible without manipulation of predator biomass to reduce the dominance of piscivores in the system. Reduction in fishing mortality rates alone on the commercially desirable species may not be sufficient to increase recruitment and overall production. These issues can only be fully addressed in the context of an Adaptive Management Experiment (Walters, 1977) in which deliberate changes in system structure are induced and the response of the system carefully monitored.

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APPENDIX 1. Catch (tons, live) by country group and species group, 1960-87.

Year	Country group	Principal groundfish	Other groundfish	Pelagics	Other fish	Total
1960	CAN	96	16 924	0	3 029	20 049
	USA	77 250	50 347	0	0	127 597
	Total	77 346	67 271	0	3 029	147 646
1961	BUL	69	524	67 928	0	68 521
	CAN	383	58	0	0	441
	USA	87 388	45 046	2 690	444	135 568
	OTH	0	0	140	0	140
	Total	87 840	45 628	70 758	444	204 670
1962	BUL	8 155	47 989	153 921	0	210 065
	CAN	5 969	535	0	0	6 504
	POL	143	0	391	1	535
	USA	101 065	26 214	2 706	24 188	154 173
	Total	115 332	74 738	157 018	24 189	371 277
1963	BUL	8 880	110 994	100 557	4 121	224 552
	CAN	16 659	1 153	274	0	18 086
	USA	103 655	64 180	2 824	1 114	171 773
	Total	129 194	176 327	103 655	5 235	414 411
1964	BUL	11 414	173 212	131 654	19 542	335 822
	CAN	19 362	2 071	2 555	124	24 112
	POL	50	0	35	638	723
	ESP	20	2	0	0	22
	USA	113 354	57 871	1 101	6 053	178 379
	OTH	713	334	0	3	1 050
	Total	144 913	233 490	135 345	26 360	540 108
1965	BUL	380 759	70 487	39 556	9 871	500 673
	CAN	26 065	2 474	3	20	28 562
	GDR	740	0	1 993	345	3 078
	POL	1 977	0	1 448	1 116	4 541
	ESP	69	0	0	0	69
	USA	136 216	24 113	1 813	17 173	179 315
	Total	545 826	97 074	44 813	28 525	716 238
1966	BUL	188 414	101 683	126 657	39 544	456 298
	CAN	34 123	5 230	1	97	39 451
	GDR	486	304	4 855	3	5 648
	POL	318	0	14 479	1 304	16 101
	ESP	9 486	45	0	0	9 531
	USA	134 684	20 124	1 543	4 626	160 977
	OTH	99	10	0	2	111
	Total	367 610	127 396	147 535	45 576	688 117
1967	BUL	76 730	38 866	138 443	15 636	269 675
	CAN	21 811	7 142	1 306	61	30 320
	FRG	0	24	28 261	3	28 288
	GDR	112	0	21 719	24	21 855
	POL	322	748	38 184	2 008	41 262
	ESP	16 085	165	0	0	16 250
	USA	107 552	25 211	1 940	3 381	138 084
	OTH	21	3	0	0	24
	Total	222 633	72 159	229 853	21 113	545 758
1968	BUL	52 128	35 234	164 487	32 997	284 846
	CAN	18 994	3 344	15 135	85	37 558
	FRG	50	3	71 097	0	71 150
	GDR	13	160	70 373	27	70 573

APPENDIX 1. Continued.

Year	Country group	Principal groundfish	Other groundfish	Pelagics	Other fish	Total
1968	POL	4 781	0	73 658	1 584	80 023
	ESP	17 636	380	0	0	18 016
	USA	96 146	25 725	1 793	3 243	126 907
	OTH	39	0	425	10	474
	Total	189 787	64 846	396 968	37 946	689 547
1969	BUL	95 066	76 360	157 977	51 333	380 736
	CAN	10 713	3 404	947	7	15 071
	FRG	17	6	62 086	0	62 109
	GDR	91	176	45 926	8 309	54 502
	POL	1 605	0	45 789	9 013	56 407
	ESP	14 798	226	0	0	15 024
	USA	86 253	18 078	3 832	3 659	111 822
	OTH	0	0	12 786	0	12 786
	Total	208 543	98 250	329 343	72 321	708 457
1970	BUL	34 981	10 261	98 523	25 156	168 921
	CAN	5 015	1 835	8	2	6 860
	FRG	3	941	82 718	0	83 662
	GDR	800	1 239	29 660	2 060	33 759
	JPN	241	366	3 487	6 596	10 690
	POL	709	0	95 819	5 168	101 696
	ESP	7 656	67	0	0	7 723
	USA	77 849	16 463	6 783	2 580	103 675
	Total	127 254	31 172	316 998	41 562	516 986
1971	BUL	96 211	36 438	133 903	42 882	309 434
	CAN	4 936	2 833	12 863	1	20 633
	FRG	3	148	55 568	5	55 724
	GDR	97	1 202	22 187	3 304	26 790
	JPN	146	1 259	3 705	9 771	14 881
	POL	378	130	112 791	10 390	123 689
	ESP	8 770	189	3	3 281	12 243
	USA	66 019	11 326	6 719	1 835	85 899
	Total	176 560	53 525	347 739	71 469	649 293
1972	BUL	116 584	68 929	161 524	79 447	426 484
	CAN	3 317	2 090	54	8	5 469
	FRG	233	73	28 817	166	29 289
	GDR	307	2 143	62 555	1 457	66 462
	JPN	232	770	2 999	8 538	12 539
	POL	176	424	102 493	10 518	113 611
	ESP	7 799	108	6	5 315	13 228
	USA	58 697	8 035	6 260	1 484	74 476
	Total	187 345	82 572	364 708	106 933	741 558
1973	BUL	114 604	64 002	204 883	35 672	419 161
	CAN	4 879	2 228	5 150	0	12 257
	FRG	1	288	35 879	867	37 035
	GDR	239	443	107 413	12 799	120 894
	JPN	253	70	4 093	6 302	10 718
	POL	751	1 808	150 556	16 875	169 990
	ESP	6 366	863	0	10 147	17 376
	USA	64 835	11 723	13 451	2 382	92 391
	Total	191 928	81 425	521 425	85 044	879 822
1974	BUL	110 315	21 663	138 679	39 354	310 011
	CAN	1 912	3 632	217	4	5 765
	FRG	105	40	27 676	13	27 834
	GDR	112	0	41 274	1 136	42 522
	JPN	98	264	6 253	7 264	13 879

APPENDIX 1. Continued.

Year	Country group	Principal groundfish	Other groundfish	Pelagics	Other fish	Total
1974	POL	598	140	78 637	9 966	89 341
	ESP	7 171	725	0	7 580	15 476
	USA	60 426	12 764	19 316	9 426	101 932
	OTH	603	53	0	0	656
	Total	181 340	39 281	312 052	74 743	607 416
1975	BUL	74 407	19 392	155 731	39 425	288 955
	CAN	3 339	4 955	4	0	8 298
	FRG	53	155	27 715	48	27 971
	GDR	60	96	55 791	2 182	58 129
	JPN	20	412	2 904	3 719	7 055
	POL	401	418	65 744	3 795	70 358
	ESP	4 126	240	22	2 881	7 269
	USA	59 901	7 421	12 372	1 963	81 657
	OTH	60	0	220	635	915
	Total	142 367	33 089	320 503	54 648	550 607
1976	BUL	52 913	18 818	79 818	21 525	173 074
	CAN	3 960	2 612	0	104	6 676
	FRG	92	1 007	13 222	1 123	15 444
	GDR	0	24	10 644	1 119	11 787
	JPN	10	19	7 669	2 680	10 378
	POL	303	1 039	42 119	7 060	50 521
	ESP	1 700	12	114	3 991	5 817
	USA	53 595	9 523	20 733	2 966	86 817
	OTH	23	10	276	514	823
	Total	112 596	33 064	174 595	41 082	361 337
1977	BUL	48 263	5 970	5 193	6 324	65 750
	CAN	9 431	3 889	417	30	13 767
	GDR	0	0	782	0	782
	JPN	5	26	650	2 222	2 903
	POL	0	39	51	180	270
	ESP	13	6	38	915	972
	USA	64 735	11 657	7 417	2 416	86 225
	OTH	11	12	334	31	388
	Total	122 458	21 599	14 882	12 118	171 057
1978	BUL	10 614	1 695	322	1 995	14 626
	CAN	19 468	5 324	0	6	24 798
	JPN	79	7	443	2 216	2 745
	ESP	10	9	30	979	1 028
	USA	74 606	14 976	21 909	2 535	114 026
	Total	104 777	22 011	22 704	7 731	157 223
1979	BUL	1 409	172	17	123	1 721
	CAN	11 318	3 244	0	14	14 576
	JPN	244	90	116	1 338	1 788
	POL	0	0	0	167	167
	ESP	94	53	19	988	1 154
	USA	83 739	19 491	17 384	5 693	126 307
	Total	96 804	23 050	17 536	8 323	145 713
1980	BUL	3	1	1	41	46
	CAN	18 594	6 321	1	40	24 956
	JPN	426	36	301	3 889	4 652
	POL	0	0	5	124	129
	ESP	259	86	22	3 491	3 858
	USA	95 695	16 947	25 970	3 906	142 518
	OTH	0	0	0	2	2
	Total	114 977	23 391	26 300	11 493	176 161

APPENDIX 1. Continued.

Year	Country group	Principal groundfish	Other groundfish	Pelagics	Other fish	Total
1981	CAN	14 380	6 010	0	0	20 390
	JPN	378	43	439	2 175	3 035
	POL	2	1	0	11	14
	ESP	498	307	223	9 625	10 653
	USA	92 163	15 138	33 020	13 407	153 728
	Total	107 421	21 499	33 682	25 218	187 820
1982	CAN	23 024	6 486	0	0	29 510
	JPN	93	81	246	1 433	1 853
	ESP	238	173	21	2 668	3 100
	USA	104 879	13 899	13 323	18 043	150 144
	OTH	0	0	0	22	22
	Total	128 234	20 639	13 590	22 166	184 629
1983	CAN	15 795	4 475	0	0	20 270
	JPN	69	50	122	1 094	1 335
	POL	0	0	141	2	143
	ESP	67	48	21	972	1 108
	USA	103 952	12 911	4 293	12 570	133 726
	OTH	0	0	0	10	10
	Total	119 883	17 484	4 577	14 648	156 592
1984	CAN	7 341	2 304	1	6	9 652
	JPN	19	22	36	641	718
	POL	1	2	134	5	142
	ESP	131	29	13	1 539	1 712
	USA	84 614	14 203	12 396	11 454	122 667
	Total	92 106	16 560	12 580	13 645	134 891
1985	CAN	14 263	1 813	1	5	16 082
	JPN	15	6	15	67	103
	POL	15	0	1 277	48	1 340
	ESP	159	168	0	1 328	1 655
	USA	63 454	12 543	8 406	9 119	93 522
	OTH	0	0	0	70	70
	Total	77 906	14 530	9 699	10 637	112 772
1986	CAN	12 300	2 423	11	3	14 737
	GDR	13	6	4 020	80	4 119
	JPN	6	1	8	64	79
	POL	12	1	1 756	7	1 776
	ESP	162	2	9	1 493	1 666
	USA	45 366	10 604	8 665	11 798	76 433
	Total	57 859	13 037	14 469	13 445	98 810
1987	CAN	16 630	3 003	17	1	19 651
	GDR	2	0	2 548	29	2 579
	POL	0	0	986	4	990
	USA	47 861	14 989	11 649	10 745	85 244
	Total	64 493	17 992	15 200	10 779	108 464