Northwest Atlantic Fisheries Organization

Serial No. N1999 NAFO SCR Doc. 91/107

SCIENTIFIC COUNCIL MEETING - SEPTEMBER 1991

Assessment and Management of the Georges Bank Cod Fishery

by

Fredric M. Serchuk and Susan E. Wigley

National Oceanic and Atmospheric Administration, Northeast Fisheries Center
National Marine Fisheries Service, Woods Hole, Massachusetts 02543 USA

1. INTRODUCTION

> *..."We left him at the seaside and returned to our ship where, in five or six hours absence, we had pestered our ship so with codfish that we threw numbers of them overboard again; and surely, I am persuaded that in the months of March, April, and May, there is upon this coast [Cape Cod] better fishing, and in as great plenty, as in Newfoundland. For the schools of mackerel, herrings, cod, and other fish that we daily saw as we went and came from shore, were wonderful..."* John Brereton, 1602

The early history of fishing in New England is the history of the fishery for Atlantic cod, *Gadus morhua*. Cod fishing was a principal occupation and source of food for the early colonists and dried salt cod subsequently became a major commodity in commerce and international trade. The earliest fisheries in the 1600s occurred in the local waters off Maine and Massachusetts but by the early 1700s New England vessels had begun to fish the offshore banks (Jensen and Murray 1965). The first trip of cod from Georges Bank was landed in 1748 in Marblehead, Massachusetts and cod catches from Georges Bank have been a major component of the USA groundfish fishery since the late 1800s (Goode and Collins 1887). The course of American history has been more influenced by cod more than any other fish (Ryan 1979) and a large wooden carving of the "Sacred Cod" has hung in the Massachusetts State House since 1784 as a symbol of the source of original wealth of Massachusetts and the Nation.

Although catches of cod have fluctuated over the centuries, cod is no less important now than in former times. Cod is presently the mainstay of the USA groundfish fishery on Georges Bank and, in the past two decades, has accounted for more catch [by weight] than any other groundfish species taken in the fishery. During 1988-1990, USA Georges Bank cod landings exceeded the total USA landings of haddock, redfish, winter flounder, and yellowtail flounder combined! Additionally, a significant recreational fishery for cod exists; USA recreational landings of cod from the Georges Bank stock have averaged about 6,000 tonnes (t) per year since 1980.

In this paper, an historical review of the Georges Bank cod stock and fishery is presented, and information provided on changes in the status of the stock, as reflected by indices of abundance and stock assessment results. The management history of the Georges Bank stock is also reviewed, with particular emphasis on the effectiveness of (1) international management activities during 1950-1976; and (2) USA and Canadian domestic management activities enacted under extended fisheries jurisdiction from 1977 onward.

2. *DISTRIBUTION AND STOCK STRUCTURE*

> *..."On the shores of the United States we find fish of different kinds each supplying a certain proportion of the inhabitants. These are restrained by some laws in nature to their own feeding ground; they do not invade the rights of others, nor are their rights infringed by any. The cod-fish which occupy the banks lying between the latitudes of 41 and 45, are very different on the different banks, and are kept so distinct, and are so similar on the respective banks that a man acquainted with the fishing business will separate those caught on one bank from those caught on another with as much ease as we separate the apple from the pear".* Hon. General Lincoln, 1791.

Cod occur in the Northwest Atlantic from Greenland to North Carolina (Wise 1958; Scott and Scott 1988), with the highest concentrations in USA waters occurring on Georges Bank and in the Gulf of Maine. Within USA waters, three or possibly four major groupings of cod have been generally recognized: (1) Georges Bank; (2) Gulf of Maine; and (3) one or two groups in the Southern New England-Middle Atlantic area (Wise 1963; Serchuk and Wigley 1986). Based on tagging studies (Smith 1902; Schroeder 1930; North American Council on Fishery Investigations 1932; 1935; Wise 1963), parasite infestations (Sherman and Wise 1961), spawning time data (Colton et al. 1979), and growth rate analyses (Penttila and Gifford 1976; Serchuk and Wood 1979), minimal interchange of cod occurs between the Gulf of Maine and Georges Bank groups, but extensive mixing prevails between cod on Georges Bank and in the Southern New England-Middle Atlantic region. A seasonal southwesterly movement of cod from the South Channel area of Georges Bank occurs in autumn followed by a northeasterly return in spring. Wise (1963) proposed that the autumn movement was not a migration of Georges Bank fish [as concluded by Schroeder (1930)] but rather a return of Southern New England-Middle Atlantic fish to their native grounds for winter spawning. The presence of ripe spawning individuals off the New Jersey coast (Smith 1902; Schroeder 1930; Wise 1958) and the occurrence of cod eggs and larvae as far south as North Carolina (Schroeder 1930; Berrien et al. 1978) seemingly suggest that cod in the Middle Atlantic may comprise a genetically distinct subpopulation, separate from the groupings further north. However, the origin and fate of Middle Atlantic cod eggs and larvae have yet to be delineated, and hence the existence of a Middle Atlantic subpopulation remains to be confirmed. Serchuk and Wood (1979) found strong affinities between Georges Bank and Southern New England-Middle Atlantic cod based on growth rates, research vessel survey catch and abundance patterns, recruitment trends, and commercial catch size/age distributions. Based on these findings, and the relative absence of juvenile cod in inshore and offshore research vessel surveys in the Southern New England-Middle Atlantic region, Serchuk and Wood (1979) hypothesized that either the southerly populations were not self-sustaining or that offspring from the southern spawning move north as ichthyoplankton or larval nekton, and return south several years later as adults.

Cod on Georges Bank (ICNAF/NAFO Div 5Z [eastern Georges Bank to Long Island, New York]; Figure 1) have been managed separately from cod in the Gulf of Maine (Div 5Y) since 1972. With the implementation of extended fisheries jurisdiction in 1977, the USA and Canada assumed separate responsibilities for the management of Georges Bank cod. Due to the pronounced demographic similarities between Georges Bank and Southern New England-Middle Atlantic cod, the two groups have been treated as a single 'Georges Bank' stock unit (Div 5Z and Subarea 6) by the USA since 1977. From 1983 through 1988, Canada similarly considered the 'Georges Bank' stock as encompassing the cod in Div 5Z and Subarea 6 (Bowen 1987; Hunt 1988). In 1989, Canada re-examined the definitions of management units for groundfish species on Georges Bank [in light of the separate USA and Canadian management systems and the delimitation in 1984 of a maritime boundary between the USA and Canada in the Gulf of Maine/Georges Bank area], and concluded that the 'Georges Bank' cod stock could be partitioned into two management units: (1) eastern Georges Bank cod [unit areas 5Zj and 5Zm; Figure 1]; and (2) central and western Georges Bank cod [the remainder of Div 5Z and Subarea 6] (Hunt 1989). As such, from 1989 onwards, Canada has treated the cod on Georges Bank as being comprised of two separate units (CAFSAC 1989; Halliday and Pinhorn 1990).

3. *COMMERCIAL FISHERY LANDINGS*

> *..."The successful result of a trip to George's Bank for codfish is largely dependent upon the exertions of each individual; men are, therefore, required for that fishery in whose natures is combined hardihood, doggedness of purpose, and bravery."* G.B.Goode and J.W.Collins, The George's Bank Cod Fishery, 1887.

Technological innovations and changes in consumer preferences have strongly influenced commercial landings of cod from Georges Bank (Jensen 1972). Prior to the early 1900s, most of the catch was taken by handlining from schooners and longlining from dories. Although labor intensive, a skillful schooner crew of 8-12 men, under favorable conditions, might catch between 20,000-30,000 pounds of cod in a day (Goode and Collins 1887). The dory-schooner fishery for cod on Georges Bank reached its heyday during the last quarter of the nineteenth century; in 1880, more than 12,000 t of cod were taken by the 163 vessels engaged in the Georges Bank fishery.

By the early 1900s, however, the character of the Georges Bank cod fishery had markedly changed. With the introduction of steam and diesel-powered vessels, otter trawling, power equipment, and low-cost ice making and refrigeration technology, the Georges Bank fishing fleet became much more mobile and efficient. In response to increased consumer demand for fresh fish, the focus of the cod fishery switched from providing salt cod to landing iced, fresh product (German 1987).

A continuous record of reliable commercial landings statistics of Georges Bank cod is available from 1893 onward. Historically, the fishery can be divided into five time-periods (Figure 2):

(1) an early era from 1893-1914 in which record-high landings (> 60,000 t) in 1895 and 1906 were followed by about 10 years of sharply reduced catches. The elevated landings in 1906 and 1907 probably reflects the introduction of otter trawling for cod using steam-powered vessels (Jensen and Murray 1965; Jensen 1972).

(2) a later period from 1915-1940 in which annual landings fluctuated between 20,000-40,000 t and during which cod was generally taken as a by-catch in the Georges Bank haddock fishery (Figure 3). The development, after World War I, of a packaged fish trade for quick-frozen haddock fillets resulted in a substantial increase in Georges Bank haddock landings and the preeminence of haddock over cod in the marketplace (Sette and Fiedler 1929; Jensen 1967).

(3) the 1940-1960 period when landings trended downward, reaching a record-low of 8,100 tons in 1953. During these years, fishing activity for cod on Georges Bank diminished due to the menace of World War II submarines and a redirection of fleet effort towards the relatively more abundant haddock resource.

(4) the 1960-1976 period in which Canadian and distant-water fleet fisheries for Georges Bank cod developed (Table 1; Figure 4). Fishing effort for cod strikingly increased during this period and resulted in a five-fold increase in landings between 1960 and 1966 (11,000 to 53,000 t). However, landings sharply declined afterward reaching only 20,000 t in 1976.

(5) the most recent period beginning in 1977 with the implementation of extended fisheries jurisdiction by both the USA and Canada. Total cod landings (solely USA and Canadian) from Georges Bank doubled between 1977 and 1982 (27,000 to 57,000 t), declined to only 26,000 t in 1986, but have since increased to 42,500 t in 1990.

4. *RECREATIONAL FISHERY LANDINGS*

"It is not unusual for an angler to haul up a fish that weighs 40 or 50 pounds and many recreational fishermen struggle home with gunny sacks brimming with 100 pounds or more of cod after a day at sea."
Albert Jensen, Sport Fishing for Cod, 1974.

Recreational fisheries for cod in USA waters have existed for many decades but information on catches has only been collected during the past 30 years. Recreational catch estimates of cod are available from a set of national saltwater angling surveys conducted in 1960, 1965, 1970, and 1974, and from a newer series of marine recreational fishery statistics surveys conducted annually since 1979. The latter series of surveys is considered the most reliable since a standardized statistical design is employed involving a combination of household telephone interviews and on-site, field surveys.

Estimated recreational cod catches [including those reportedly caught and subsequently released alive] have ranged between 3,450 t [1986] and 16,300 t [1970] (Table 2; Figure 5). The highest estimates were derived prior to 1979 but must be considered tentative due to methodological weaknesses and differences in survey procedures in these years (United States Department of Commerce 1979: p. 21). Between 1981 and 1985, annual recreational cod landings exhibited little variability; apart from 1984, annual catches ranged between 8,000-9,000 t, and averaged 8,500 t per year. Recreational catches declined in 1986 and 1987 to less than 4,000 t, but have since increased to between 5,500 t and 7,500 t. Although data on the distribution of recreational cod landings by stock area are not available, it is likely that annual catches from the Georges Bank cod stock have been between 4,000-6,000 t.

Most of the recreational catch of cod (> 70%) is taken beyond 3 miles from the coast [i.e., in 'federal' waters']. More than 95% of the catch is taken by party/charter and private/rental boats, with landings in Massachusetts exceeding those from any other state.

5. *STOCK ASSESSMENT AND MANAGEMENT*

"Of all the various fisheries formerly prosecuted directly off the coast of New England, north of Cape Cod, the depreciation in that of the Cod appears to be of the greatest economical importance."
Spencer F. Baird, Conclusions as to Decrease of Cod-Fisheries on the New England Coast, 1874.

"Cod, though heavily exploited, nevertheless support the most stable and continuous of all Georges fisheries. Their biology apparently buffers them against strong population changes under the pressure of fishing."
R.C. Hennemuth and S. Rockwell, History of Fisheries Conservation and Management, 1987.

Early Evaluations (before 1965) - Prior to the development in the 1930s and 1940s of formalized systems for the collection of comprehensive fishery statistics (North American Council on Fishery Investigations 1932, 1935; Rounsefell 1948), changes in the stock abundance of cod (and other species) could generally only be evaluated anecdotally or from trends in catches, by port or fishing ground. Anecdotal reports in the early 1870s of a short supply of cod in the inshore region of the Gulf of Maine prompted the first study of the effects of human activity on fishery resources (Baird 1874). Although Baird's conclusion that cod had declined due to reduced prey abundance [alewives and herring] caused by the building of dams was [in hindsight] incorrect (Graham,1970), his efforts led to the establishment the US fisheries research laboratory at Woods Hole in 1875 where scientific programs were initiated to investigate fluctuations in commercial fish stocks and their causes (Baird 1873). The earliest programs relating to cod focused on artificial culture and stocking of fry to enhance natural production and on determining the distribution and migration of cod via tagging (Smith 1902). These and subsequent investigations [especially the studies by Fish (1928) and Schroeder (1930)] provided baseline information on the life history aspects of cod off the New England coast.

The first scientific inquiry of the effect of fishing on the abundance of fish stocks on Georges Bank was conducted in 1913, as part of a study to evaluate the impacts of otter-trawling (Alexander et al., 1915). Based on analysis of trends in catch per effort (CPUE) during 1891-1914 of cod, haddock, and hake, no evidence was found that any of the demersal stocks on Georges Bank were being overfished. Nonetheless, for Georges Bank cod, the study indicated that line trawl CPUE had declined by 45% between 1908 and 1914, and that CPUE in 1914 was a record-low (Figure 6).

The study by Alexander et al. (1915) raised concerns that expansion of the Georges Bank otter-trawl fishery might result in substantial discards of small fish. Size composition data collected from otter trawlers fishing Georges Bank in 1913 revealed that 30-40% [by weight] of the cod and haddock captured were too small to market, and that the average size of fish landed by otter trawlers was smaller than that by line trawlers. However, the study recommended against increasing the cod-end mesh size [which was then 2.5 inches] as a way to allow greater escapement of small fish since it was felt that (1) meshes tended to close as fish were caught by the trawl; (2) fish in the cod-end blocked escape; (3) fish did not escape until haulback when escapement was minimal; and (4) greater numbers of fish would be gilled with larger meshes. The study also discounted, as feasible regulatory methods, a ban on otter trawling or restrictions on the number of vessels or trawls in the fishery. Instead, area restrictions for otter trawlers were proposed but were not supported by the fishing industry and hence never implemented (Herrington 1935).

Between World War I and II, Georges Bank cod landings ranged between 20,000 - 40,000 t, but most scientific attention during the period was focused on Georges Bank haddock. Haddock landings had dropped from over 120,000 t in 1929 to 28,000 t in 1934 (Figure 3) at a time when the USA otter-trawl fleet had grown to 323 vessels (Herrington 1932). Discarding of tremendous quantities of small fish was implicated as a major cause for the reduced landings. Sea sampling observations and mesh size experiments in the early 1930s indicated that up to 75% of the haddock caught by otter trawlers on Georges Bank were nonmarketable [< 35 cm, < 0.7 kg], but that the capture of undersized fish (including cod) could be markedly reduced by use of larger cod-end mesh sizes. It was recommended that industry adopt a minimum mesh size of at least 4¾ inches [121 mm] and that a mesh size of 5 to 5¼ inches [127-133 mm] would be even more beneficial (Herrington 1935). Although some fishermen adopted larger mesh sizes voluntarily, complete noncompulsory use of larger meshes was not attained since larger meshes allowed small quantities of marketable-sized fish to escape (Graham 1970). Nearly 20 years elapsed before minimum mesh regulations (4.5 inch, 114 mm) were formally implemented in the Georges Bank haddock and cod fisheries (in 1953 and 1955, respectively) under the International Commission for the Northwest Atlantic Fisheries (ICNAF) founded in 1949. During the intervening period, annual discards of haddock exceeded 2,200 t (Graham 1952) and, although no estimates are available, large quantities of Georges Bank cod must also have been discarded.

Between 1930 and 1965, cod abundance on Georges Bank generally trended downward. CPUE indices of cod [available from a 'Boston-based haddock study fleet' of large otter-trawlers fishing Georges Bank (Hennemuth 1969; Brown 1971; Brown and Heyerdahl 1972)], peaked in 1937, 1945 and 1961 but declined during 1938-1940, 1946-1952, and 1962-1965 (Figure 7). Apart from the early to mid-1940s when offshore fishing effort was reduced due to World War II, fishing effort was relatively stable throughout the 35-year time period, fluctuating between 7,000 and 13,000 standard fishing days.

Despite a 50% decline in Georges Bank cod landings between 1930 and 1950 (Figure 3), research effort on cod was quite limited during these two decades (Jensen 1968). However, the research and sampling programs initially established in the early 1930s to study haddock were expanded in the 1940s and 1950s to encompass other species, including cod (Rounsefell 1948). These and succeeding programs subsequently proved invaluable in providing the scientific foundation for research and management activities for cod under ICNAF and under the USA Magnuson Fishery Conservation and Management Act (MFCMA) enacted in 1976 (Fogarty et al. 1989). Through these initiatives, it finally became possible to relate changes in cod landings with changes in stock abundance and fishing effort (Sette 1928; North American Council on Fishery Investigations 1932).

ICNAF-Era Assessments (1965 - 1976) - Beginning in the early 1960s, comprehensive commercial fishery weighout, interview, and catch sampling systems were established and computerized at the Northeast Fisheries Center at Woods Hole, Massachusetts (Mayo 1977; Burns et al. 1983). These developments, along with the implementation [in 1963] of a standardized research vessel bottom-trawl survey program (Grosslein 1969; Clark 1979; Azarovitz 1981) provided a basis for conducting assessments evaluating trends in landings, fishing effort, stock abundance, and recruitment of cod on Georges Bank. A chronology of the Georges Bank cod assessments is provided in Table 3, which highlights principal findings and conclusions.

The first formal assessment of cod in Subarea 5 was conducted in 1971 (Brown 1971;ICNAF 1971), 10 years after the Canadian and distant-water fleet fisheries for cod had developed on Georges Bank. Peak Canadian landings of cod occurred in 1965 and 1966, while foreign catches had peaked during 1965-1969 (Table 1; Figure 4). However, there were still great concern about the effects of the heightened fishing intensity on biomass levels and stock productivity. Based on analysis of trends in commercial effort, CPUE, and research survey abundance indices, the 1971 assessment indicated that maximum sustained yield [MSY] was between 30,000-40,000 t, and noted that annual landings of Subarea 5 cod had exceeded 40,000 t since 1965.

In 1972, a more complete assessment of the Georges Bank stock (Div 5Z) indicated that cod abundance had remained stable between 1963-71 (Table 4, Figure 8) and that the elevated catches during 1965-69 were primarily due to increased fishing effort (Brown and Heyerdahl 1972; ICNAF 1972). Results from a generalized production model suggested that MSY for Georges Bank cod was about 35,000 t, with effort at MSY estimated to be 30,000 standard days fished. Fishing effort had exceeded this level during the mid-1960s but had declined to below 30,000 days in 1970 and 1971. Based on trends in cod CPUE [from the 'Boston-based haddock study fleet'], average cod abundance during 1964-1971 appeared to be lower than in the 1931-1963 period (Brown and Heyerdahl 1972).

Although no new assessments were conducted from 1973 through 1975, ICNAF established a 35,000 t TAC in 1973 for Division 5Z cod. This TAC corresponded to the estimated MSY level and was recommended on the basis that the stock seemed to be exploited at a reasonable level, and that the TAC would prevent a rapid expansion of effort on the stock (ICNAF 1973). Discouraging additional effort in the cod fishery was an important concern since Georges Bank haddock had already collapsed from overfishing. Equally, the magnitude and severity of the impacts caused by the high fishing effort in the 1960s on the total finfish biomass in Subareas 5 and 6 were beginning to be well-understood (Brown et al. 1976; Clark and Brown 1977, 1979).

The 35,000 t TAC for Georges Bank cod was maintained during 1974-1976, but annual catches never exceeded 29,000 t in these years (Table 1). In 1974, the minimum cod-end mesh size in the Subarea 5 cod trawl fishery was increased to 130 mm [5.1 in], and seasonal and area closures were introduced prohibiting large vessels (> 44.2 m; 145 ft) from demersal fishing within prescribed regions of Georges Bank. These latter restrictions were supplemental to the seasonal/area closures of haddock spawning grounds on Georges Bank which had been instituted annually since 1970. Apart from protecting haddock, closure of the haddock grounds was also expected to result in reduced catches of Georges Bank cod since both species were generally caught together in the Georges Bank otter trawl fishery (Serchuk and Wood 1979).

The 1976 Georges Bank cod assessment was the last one conducted under the aegis of ICNAF, but proved to be critically important since it served as the scientific basis for many of the management actions taken in 1977 under USA extended fisheries jurisdiction. While the 1976 assessment still indicated that cod abundance was stable, catch curve analysis of survey data indicated that during 1970-1974 [when commercial catches had averaged 26,500 t] fishing mortality (F) was 0.36, slightly above F_{max}=0.30 (Penttila and Gifford 1976). Results from a preliminary VPA suggested that F-values during the late 1960s [when Div 5Z catches averaged 41,500 t] ranged between F=0.55-0.65 (ICNAF 1976). Yield per recruit analyses indicated that, given average recruitment, fishing at F_{max} would generate a commercial catch of 24,000 t while fishing at $F_{0.1}$ would result in a catch of 15,000 t. Although two very strong year classes [1971 and 1975 cohorts] were evident in the stock (Table 5, Figure 9), and despite apparent stability in both catches and stock abundance, the ICNAF Assessment

Subcommittee recommended that the 1977 TAC for the Georges Bank cod stock be set at 15,000 t, corresponding to the $F_{0.1}$ catch. A 20,000 t TAC was subsequently established after USA industry advisors expressed concern that any lower TAC might produce adverse economic impacts.

In principle, the decision by ICNAF in 1976 to set TACs for 1977 on the basis of $F_{0.1}$ (Pinhorn and Halliday 1990) was appropriate since many stocks had continued to decline when managed by ICNAF at F_{max} (ICNAF 1976, p. 76). However, the Georges Bank cod stock was not one of these. The Subcommittee recommendation [and the agreed-upon 20,000 t TAC] called for a catch in 1977 lower than any since 1961, at a time when recruitment of the strong 1975 year class was expected to occur in the fishery. In hindsight, the seeds of pending turmoil had been sown which would soon blossom, under USA extended jurisdiction, into a countless array of troublesome problems.

Management and Assessment Under Extended Jurisdiction (1977 - 1990) - In 1977, extended fisheries jurisdiction took effect in both the United States and Canada. Although the jurisdictional claims of both countries overlapped (thereby creating a disputed zone on Georges Bank), both countries [under an interim fisheries agreement] adopted the TACs (and TAC allocations) set by ICNAF for 1977, as well as the existing ICNAF minimum mesh size and haddock spawning area closure measures.

In the USA, under provisions of the MFCMA, the New England Fishery Management Council (NEFMC) had been established and assumed management responsibility of cod, haddock and yellowtail flounder stocks in Subareas 5 and 6. The NEFMC developed a Fishery Management Plan for Atlantic Groundfish [FMP] to rebuild the stocks of these 'seriously depleted' species (NEFMC 1977). Regulations were enacted on an emergency basis in March 1977 that specified a minimum mesh size restriction [130 mm], minimum fish sizes [40.6 cm for cod], closed spawning areas [same as under ICNAF], and commercial and recreational fishery catch quotas (Optimum Yields, or 'OYs') for 1977 [for Georges Bank cod: 20,000 t commercial; 10,000 t recreational]. The emergency regulations remained in effect until June 1977 when final regulations were enacted via implementation of the FMP itself. The final regulations deleted the recreational quotas but all other provisions pertaining to cod were retained.

The decision to manage the recreational cod fishery under the FMP (or at least account for the recreational catch in determining optimum yield) had been made in late 1976 when the Plan was being developed. At the time, the only data that existed were the catch estimates from the 1960, 1965, 1970 and 1974 recreational surveys (Table 2, Figure 5). Although the accuracy of these estimates was unknown, these data were used to derive recreational landings by stock unit for each of the survey years, and to subsequently estimate recreational harvests in the years between surveys (NEFMC 1977; Serchuk et al. 1977). The estimated recreational catches were incorporated into a surplus production analysis which indicated an overall MSY of 50,000 t for the Georges Bank cod stock (NEFMC 1977) and also used in an initial VPA conducted in late 1977 (Serchuk et al. 1977). Both analyses, however, were not very reliable due to the poor and limited quality of the recreational data. This was particularly true for the VPA and noted (along with other sources of uncertainty) in the assessment itself (Serchuk et al. 1977). In retrospect, the inclusion of the existing recreational data in the assessment analyses conducted during Plan development and during 1977-1978 (Serchuk et al. 1978) was extremely premature and overly-ambitious. Although the recreational cod quota was eliminated in June 1977 because it was deemed arbitrary (i.e., set at the estimated 1974 catch level of 10,000 t of Georges Bank cod) and because of doubts as to whether it could be caught, there was little scientific basis for specifying such a quota in the first place.

In July 1977, a Reciprocal Fishing Agreement between the USA and Canada was signed which allocated 3,350 t of the 1977 Georges Bank cod quota to Canada (i.e., the allocation that would have occurred under ICNAF). As a result, the USA quota was reduced to 16,650 t (Pierce 1982). By 22 August, 80% of the USA quota had been taken and the USA directed cod fishery was closed [the Canadian fishery for Georges Bank cod had closed on 9 August]. Incidental fisheries continued, however, under various by-catch limitations. On 3 November, via a 45-day emergency amendment to the FMP, the 1977 Georges Bank quota was raised to 21,650 t. This allowed

further incidental [and rather large] catches of cod but when the amendment expired on 18 December, the entire USA groundfishery was closed, effective 24 December, for the remainder of the year.

Equally vexing problems concerning the management of the haddock and yellowtail flounder fisheries had to be faced by the NEFMC in 1977 and afterward (Anthony 1990). Between 1977 and 1982, the Council was caught up with one problem after another - while struggling at the same time to (1) revise the management program on the basis of new assessment information; (2) resolve various allocation issues; (3) define management objectives; and (4) cope with increased dissension and dissatisfaction within the fishing industry regarding the supposed benefits of management actions. Nearly 50 changes were made to the FMP management regulations during the 1977-1982 period. For Georges Bank cod, management measures in these years varied but included annual and quarterly fishery catch quotas, Canadian and recreational catch allocations, weekly and/or trip landings restrictions [by vessel size class and gear type], fishery closures [both total and by vessel gear/size class], changes to the minimum mesh and minimum fish sizes, and data reporting requirements.

The 1978 Georges Bank OY, which had been set in April 1978 at 22,000 t for the USA commercial fishery, was increased to 26,000 t in July 1978 to allow 4,000 t for Canada. Management on a 'fishing year basis' (October-September) was instituted in October 1978 to allow more timely use of the USA botttom-trawl survey data in setting annual OYs. The 1978/79 OY for Georges Bank cod was initially set at 26,000 t but was revised upwards in July 1979 to 34,960 t [30,960 t USA; 4,000 t for Canada]. In both 1979/80 and 1980/81, the OY was set at 35,000 t [29,620 t USA; 5,380 t Canada]. All of the OYs, however, were exceeded as total commercial landings in the 1978-1981 period ranged between 35,000 and 48,000 t. Actual catches were probably much higher (especially during 1978 and 1979) since high discarding and misreporting/underreporting of landings occurred as a consequence of many of the management restrictions (i.e., closures, trip limits, by-catch restrictions, etc).

The increased OYs during 1978-1981 were predicated, in part, on assessment results which indicated that the Georges Bank stock had increased in size since 1975. The 1979-1982 assessments (based largely on analyses of survey indices and USA commercial effort and CPUE data) all indicated that stock biomass was at a relatively high level, despite near-record high annual landings (Serchuk et al. 1979, 1980, 1982; Serchuk and Wood 1981). Stock size had been maintained through a succession of above-average year classes [1975, 1977, 1978, and 1980 cohorts] (Figures 8 and 9), seemingly moderate fishing mortality rates [i.e., 0.30-0.40; Table 6], and proportional harvesting of the stock relative to its age/size distribution. However, there were indications that fishing effort had increased since 1977 and concern was raised that annual catches in excess of 40,000 t could well lead to stock size reductions (Serchuk and Wood 1981). Also noted was the uncertain validity of the results derived from analysis of the commercial data due to discards and underreported catches.

During 1979, the NEFMC concluded that the existing management program was not working as envisaged, and that the management environment was unsatisfactory for making informed long-term management decisions. Industry support of the FMP had broken down due to the mis-match between Council actions and events in the fishery, as well as to the lack of adequate enforcement of management regulations. A wide credibility gap developed among fishermen, scientists, and managers. The industry was puzzled by the stringency of catch controls at a time when apparently large numbers of cod [and haddock] were present in the sea. Scientists thought that managers understood that strict catch controls were necessary to use the good 1975 year classes of cod and haddock for stock rebuilding (Anthony 1990). Managers were caught in the cross-fire, and were also burdened by a slow administrative review process (Hennemuth and Rockwell 1987) and a constant preoccupation with short-term FMP adjustments. In 1978, the NEFMC had begun work to develop a more comprehensive management program [the Atlantic Demersal Finfish Plan (ADF)] that would account for fishery interactions, given the multispecies nature of the demersal trawl fishery (Marchesseault et al. 1980). However, progress in developing the ADF Plan was slow and the NEFMC, realizing in 1979 that the current management system was not succeeding, decided to develop an 'Interim Fishery Management Plan' [Interim Plan] to replace the existing FMP and serve as a short-term bridge to the ADF Plan. The Interim Plan was implemented on 31 March 1982 and was expected to foster a renewed spirit of industry support through a less restrictive management program which eliminated quotas, trip limits, and vessel class catch allocations. A suite of indirect control measures on fishing mortality was enacted that included: creation of large mesh [130 mm in 1982, 140 mm thereafter] and

small mesh fishing areas, maintenance of the haddock seasonal spawning area closures, minimum fish size regulations [for cod, 43 cm for commercially-caught fish, 38 cm for fish caught by recreational fishing vessels], and record-keeping requirements for fish dealers and processors (NEFMC 1981). The NEFMC believed that these measures would reduce the risk of recruitment overfishing, enhance fish spawning activity, and allow more accurate and reliable fishery data to be collected.

As the USA grappled with groundfish management during 1977-1984, new initiatives were enacted under extended jurisdiction in Canada (Pinhorn and Halliday 1990). In 1977, the Canadian Atlantic Fisheries Scientific Advisory Committee (CAFSAC) was formed to provide peer-reviewed scientific advice for the management of Canada's Atlantic fisheries. Assessments were vetted through CAFSAC and management advice provided in accordance with specific management objectives and strategies. Since Canada's long-term strategy was to control exploitation at moderate levels, annual advice on catch levels was generally given on the basis of $F_{0.1}$.

In 1977, as previously noted, Canada and the USA both adopted the TACs set by ICNAF for the Georges Bank groundfish stocks. Throughout 1977, fishing fleets from both countries had access to the other country's undisputed fishing zone under the Reciprocal Fisheries Agreement [which was intended to preserve the status quo based on traditional fishing patterns]. Although this agreement expired at the end of 1977, it was provisionally continued into 1978 pending enactment of a new interim plan. However, on 2 June 1978, Canada asserted that the USA was not enforcing the terms of the Agreement and that USA fishing patterns had not been maintained (Christie 1987). Subsequently, each country banned the other from fishing in its undisputed waters. This was the beginning of the end of cooperative management of transboundary fisheries resources between Canada and the USA. After June 1978, fish stocks on Georges Bank were managed separately and independently by each country, generally without reference to one another's actions. Although the USA and Canada signed two treaties in 1979 covering (1) submission of the maritime boundary dispute settlement to binding third-party settlement and (2) creation of an East Coast Fisheries Commission for the management and conservation of USA/Canada fisheries resources, the fisheries treaty was never ratified by the USA [due to opposition by the New England fishing industry] and thus never implemented. In October 1984, the maritime dispute between the USA and Canada was settled when the International Court of Justice (ICJ) delimited a maritime boundary between the two countries. Although jurisdictional claims were resolved by the ICJ boundary, the boundary had no biological basis with respect to the distribution of Georges Bank fish stocks. Consequently, the same stocks of fish [i.e., Georges Bank cod and haddock] continued to be managed one way in the USA and quite another way in Canada.

Although cooperative management of Georges Bank groundfish ended in 1978, cooperation between Canadian and USA scientists continued, uninterrupted by any national differences in fishery policies. Scientific data were routinely exchanged and cooperative research projects planned and conducted. Since 1979, USA-Canada Scientific Discussions have been held [generally annually] to review assessment and fisheries issues, discuss databases and sampling programs, and collaborate on joint research of interest to both nations. Through these and other interactions (i.e., USA/Canada ageing workshops; exchange of scientists on research vessel cruises; informal consultations between colleagues; etc), information needed for assessment purposes has been made available to both parties. In this respect, the independent assessments of Georges Bank cod conducted by Canada and the USA have been based on common data.

The first Canadian assessment of Georges Bank cod was conducted in 1983 (Hurley and O'Boyle 1983) and annual assessments have been performed ever since (Table 3). The 1985 assessment (Hunt and Waiwood 1985) was the first to indicate that stock abundance had declined sharply after 1982. USA autumn survey indices in 1982-1984 were among the lowest ever and USA CPUE indices, stable during 1978-83, had fallen sharply in 1984 (Table 7, Figure 10). Sequential population analysis (SPA) of combined USA/Canadian commercial catch-at-age data from 1978-1984 revealed that harvestable biomass (age 3+) had declined by nearly 35% between 1982 and 1985, with the 1985 stock size the lowest in the time series. Fishing mortality, which had averaged 0.44 during 1978-81, increased to $F=0.6$ ($> 2X F_{max}$) during 1983-84. It finally seemed possible that the Georges Bank stock could be overfished.

The 1986 USA and Canadian assessments (Serchuk and Wigley 1986; Hunt and Gavaris 1986) corroborated the results of the 1985 assessment, and indicated that stock biomass had declined still further. The USA assessment indicated that F increased from 0.48 in 1981 to 0.82 in 1985, while stock biomass (3+) had declined from 90,000 to 46,000 t. The autumn 1985 USA survey weight-per-tow index was a record-low (Figure 8), as was the 1985 USA commercial CPUE (Figure 10). USA fishing effort on cod had increased sharply in 1985, due to redirection of fishing activity away from other groundfish stocks [i.e., haddock and yellowtail flounder which were in relatively poorer condition], and loss of access to fishing grounds as a result of the ICJ boundary decision. After the USA assessment had been vetted at the Fall 1986 Northeast Fisheries Center Stock Assessment Workshop [the peer-review forum, established in 1985, for USA Northwest Atlantic stock assessments], it was concluded that there had been a *"significant decline in stock abundance"* and that *"the stock appears to be growth overfished and perhaps in danger of recruitment overfishing"* (NEFC 1986). The 1986 Canadian assessment noted that since *"the $F_{0.1}$ yield for this stock is less than 15,000 t, which is exceeded by the current USA catch, any improvement in stock status will require bilateral management by the USA and Canada"* (Hunt and Gavaris 1986).

The assessments conducted in 1985-86 indicated that management of cod under the NEFMC's Interim Plan had been ineffective. Although more accurate and reliable fisheries data were acquired under the Interim Plan, analysis of this information indicated that resource conditions has gotten worse, not better. This was true, not only for the Georges Bank cod stock, but for the entire demersal species complex (NEFC 1987; Figure 11). Commercial CPUE, both in the cod fishery and in the total Georges Bank trawl fishery, declined by 50% between 1982-86 and had reached record-low levels (Figures 10 and 11).

In August 1985, the NEFMC completed the long-awaited ADF Plan, now re-titled the Fishery Management Plan for the Northeast Multispecies Fishery (Multispecies Plan), and submitted it to the USA National Marine Fisheries Service for approval. The management unit covered by the plan encompassed the multispecies finfish fishery that operated from eastern Maine through Southern New England, including all commercial and recreational harvesting sectors in New England (NEFMC 1985). Rather than dealing with just cod, haddock, and yellowtail flounder, the Multispecies Plan intended to address all species in the demersal finfish complex in New England waters including cod, haddock, yellowtail flounder, pollock, redfish, white hake, American plaice, winter flounder, witch flounder, and windowpane flounder. The basic conservation goal of the Plan was *"...to prevent stocks from reaching minimum abundance levels, defined as those levels below which there is an unacceptably high risk of recruitment failure"*. The objective of the Plan was:

> *"to control fishing mortality on juveniles (primarily) and on adults (secondarily) of selected finfish stocks within the management unit for the purpose of maintaining sufficient spawning potential so that year classes replace themselves in the stock on 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 effectiveness of the management program"* (NEFMC 1985, p. 6.1).

Similar to the Interim Plan, the Multispecies Plan contained no management measures to directly control fishing mortality (i.e, catch or effort limitations). Indirect controls were specified which included regulated mesh areas, minimum cod-end mesh size [140 mm when fishing in the large mesh area], minimum fish sizes [for cod: 43 cm during the first year of the plan, 48 cm thereafter], haddock and yellowtail flounder area closures, and seasonal/area and by-catch restrictions governing the 'exempted' (small mesh) fisheries. For the major stocks within the Plan management unit, minimum levels of spawning potential were identified that were required for long-term biological productivity. These were based on analysis of spawning stock biomass per recruit (SSB/R), expressed as a percentage of maximum spawning potential (% MSP) - since maximum SSB/R is obtained under conditions of no fishing mortality (Gabriel et al. 1989). For Georges Bank cod, the objective was to control fishing mortality to achieve 20% MSP (NEFMC 1985).

The Plan also established a Technical Monitoring Group (TMG) to monitor the multispecies fishery and report, at least annually, on the status of the resources and the operation of the fishery in relation to attainment of the conservation objective of the Plan.

The Multispecies Plan was initially rejected by the National Marine Fisheries Service but was resubmitted in April 1986 and conditionally approved and implemented [for a 1-year period] on 19 September 1986. During the first year, the NEFMC was to address the serious concern that the Plan allowed an unacceptably high level of juvenile mortality which threatened the spawning potential of the strong 1985 year classes of Georges Bank cod and haddock. Actions to protect these cohorts were considered critical since recent assessments had shown that both stocks had markedly declined while the Plan was being developed.

On 1 October 1987, Amendment #1 to the Multispecies Plan was approved and implemented. The Amendment was deemed to have appropriately addressed the deficiencies identified in 1986. However, most of the changes made were minor ones to the already existing measures. No new indirect [or direct] controls on fishing mortality were included in the Amendment (Anthony 1990).

The 1987 and 1988 assessments (Hunt 1987, 1988; Serchuk 1988) indicated that the condition of the Georges Bank cod stock was still deteriorating. Spawning stock biomass in 1987 was the lowest in the VPA/SPA time series while fishing mortality had increased to a new record-high. Fishing mortality was greatly in excess of $F_{0.1}$ and F_{max}, and far beyond that corresponding to the 20% MSP level. Because the fishery continued to be highly dependent on young fish (ages 2 and 3), rebuilding of the spawning stock had been precluded despite good recruitment. Concern was raised that the SSB was approaching a level where the probability of good recruitment might be low (NEFC 1989). Significant reductions in fishing mortality were required if the stock was to be rebuilt.

In June 1988, the TMG submitted its initial evaluation to the NEFMC on the effectiveness of the Multispecies Plan (TMG 1988). The TMG noted that: (1) almost all of the stocks covered under the Plan were at record-low levels of abundance; (2) most of the management measures in the Plan were either marginally effective or ineffective; (3) Plan regulations were difficult to enforce, unlikely to be enforced, or easy to circumvent; (4) incentives for compliance with the Plan did not exist; and (5) the difference in USA and Canadian management approaches [and regulations] were incompatible with achieving Plan objectives for the Georges Bank groundfish stocks. The TMG concluded that the overall management system (involving those who had created, administered, enforced, and been managed by the Plan) had not been very effective and appeared inadequate for dealing with resource maintenance and rebuilding needs (TMG 1988). A series of recommendations for strengthening the Plan and management measures were provided by the TMG. With regard to achievement of % MSP targets, it was recommended that *"the enforceability and design of management measures for controlling fishing mortality using catch, effort, or area controls should be explored in order to meet plan objectives"* (TMG 1988).

A similar evaluation of the lack of effectiveness of the Multispecies Plan in preventing overfishing and resource declines was rendered by the Massachusetts Offshore Groundfish Task Force in late 1990 (MOGTF 1990). To achieve recovery of the groundfish stocks to pre-1960 levels, the Task Force recommended that (1) direct controls be placed on fishing mortality; (2) wasteful fishing mortality [discarding] be reduced; (3) compliance with regulations be improved; (4) the biological basis for management be strengthened; (4) catch allocations be forthrightly addressed; (5) state regulations must support federal regulations; and (6) management council members be required to have strong conservation ethic.

Canada also recognized that management of Georges Bank cod had become problematical. In both 1987 and 1988, CAFSAC noted that the Canadian fishery had also become heavily reliant on incoming year classes and that stock rebuilding would not be possible *"... until coordinated management action by Canada and the USA reduces the level of fishing mortality"* (CAFSAC 1987, 1988).

In July 1989, the Canadian Minister of Fisheries and Oceans commissioned a task force to develop an action plan to deal with problems of the Scotia-Fundy groundfish industry and develop recommendations leading to long-term stability and prosperity in the groundfish industry. In December 1989, the Scotia-Fundy Groundfish Task Force issued its report (Haché 1989) and noted that: (1) Canadian and USA approaches to fisheries management significantly differed; (2) each country had pursued management strategies without regard for the impact of the other country's actions; and (3) that since 1978, cod catches on Georges Bank had generated fishing mortality levels two or three times the target. The Task Force concluded that this situation was *"not very satisfactory to orderly harvesting or stock conservation"* and recommended that *"discussions be pursued with the U.S. to develop compatible fishing approaches on Georges Bank including measures to ensure compliance, [although] reciprocal access was not to be considered"* (Haché 1989).

Although an agreement has subsequently been reached between the two countries on more effective enforcement of the ICJ boundary on Georges Bank, the issue of compatible fishing approaches has yet to be resolved. Canada established new management units in 1989 for Georges Bank cod and haddock, which geographically encompass all of the Canadian sector of Georges Bank [although a portion of these units still extend into the USA zone]. Since 1989, Canadian assessments have been focused, almost exclusively, on the status of cod in these new units (Hunt 1989, 1990).

In the USA, the Multispecies Plan is still operative and has been amended three additional times since October 1987. Although the most recent Plan Amendment [#4 in 1991] acknowledged that many stocks covered by the Plan were being overfished [i.e., the % MSP targets are not being met], the current Plan still lacks explicit rebuilding strategies for any of the stocks. This seems unfortunate since the 1990 USA cod assessment (Serchuk and Wigley 1990) suggests that, due to good recruitment from the 1985, 1987 and 1988 year classes, the Georges Bank cod stock has started to recover (Table 8, Figure 12).

However, the tides of management are changing. In July 1991, a legislative bill was introduced into the USA Congress to amend the MFCMA to provide for the restoration of New England groundfish stocks ('New England Groundfish Restoration Act of 1991'). Under this Act, a direct action plan would be established to double the spawning biomass of groundfish stocks within a 5-year period and negotiations would be initiated with Canada to improve the conservation of transboundary stocks. As well, enforcement of management regulations would be strengthened and innovative methods for reducing USA fishing effort [i.e., a vessel buyback program] would be authorized.

In August 1991, as a result of legal action brought against the National Marine Fisheries Service for failure to prevent overfishing of groundfish stocks [i.e., violation of the MFCMA which requires that 'conservation and management measures shall prevent overfishing'], a consent degree was signed that requires implementation (by 1 November 1992) of a new management plan designed to rebuild stocks of cod and yellowtail flounder within five years, and haddock within 10 years.

There is a growing resolve among managers, administrators, scientists, and the fishing industry that fishing mortality must be reduced to improve the health of the stocks.

6. SUMMARY

..."I used to get 2,000 to 3,000 pounds of [cod] fish on a tow, and I'd go fishing for eight days [on Georges Bank]. Now, a fisherman will get 500 to 1,000 pounds on a tow, and the trip takes twelve to thirteen days." 'Joe Brancaleone, 1989 (former fisherman and current member of the NEFMC). [Quoted in D. Cramer, Fished Out, 1989]

"If John Cabot [the English explorer who first crossed Georges Bank almost five centuries ago] were alive today, he would not recognize Georges Bank. Instead of a sea swarming with majestic cod, he would find dogfish. Instead of flounder, he would find skates. Instead of a fisherman's dream, he would find a nightmare." Congressman Gerry Studds [Massachusetts] on introducing the 'New England Groundfish Restoration Act' into the USA Congress, July 1991.

The Georges Bank cod stock is a valuable natural resource and has been a central component of the New England offshore fisheries for centuries. Throughout most of this period, the cod fishery was unregulated and growth in the fishery did not appear to exceed resource potential. During the 1960s and early 1970s, when other stocks had collapsed or declined markedly due to increased fishing pressure, the Georges Bank cod stock remained relatively stable. The stock seemed resilient to heavily exploitation - until the early and mid-1980s when (under extended fisheries jurisdiction), landings, fishing effort and fishing mortality attained record-high levels. Stock size declined by 50% between 1980 and 1986 despite good recruitment, as growth and spawning potential of good year classes were mortgaged for short-term yield. As a bellwether of the status of the entire groundfish complex on Georges Bank, the decline in cod raised serious concerns on the effectiveness of fisheries conservation programs in both the United States and Canada. Lack of compatible approaches between the two countries on the management of Georges Bank stocks exacerbated the situation and fostered, to some degree, competitive overfishing. Overlapping fisheries jurisdictional claims were not resolved until October 1984; shortly thereafter, independently-conducted USA and Canadian assessments began to reveal the impacts that 'supervised neglect' (Jensen 1973) was having on the Georges Bank cod stock.

Both the USA and Canada now recognize that cooperative and coordinated management actions are required to rebuild transboundary stocks (including Georges Bank cod) and prevent overfishing. The future of the groundfish fishing industries in both countries will critically depend on the success of these initiatives.

ACKNOWLEDGEMENTS

We thank R. Mayo and S. Clark [Northeast Fisheries Center, Woods Hole, Massachusetts] for their constructive comments and valuable advice during preparation of the manuscript.

7. REFERENCES

Alexander, A.B., H.F. Moore, and W.C. Kendall. 1915. Otter-trawl fishery. Rep. U.S. Comm. Fish. 1914, Appendix VI: 97 p.

Anthony, V.C. 1990. The New England groundfish fishery after 10 years under the Magnuson Fishery Conservation and Management Act. No. Amer. J. Fish. Mgmt. 10: 175-184.

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

Baird, S.F. 1873. Report of the Commissioner for 1871-1872. U.S. Comm. Fish and Fish. Part I.

Baird, S.F. 1874. Conclusions as to decrease of cod-fisheries on the New England coast. U.S. Comm. Fish and Fish., Part 2, Rep. Comm, 1872 and 1873: xi-xiv.

Berrien, P.L., M.P. Fahay, A.W. Kendall, Jr., and W.G. Smith. 1978. Ichthyoplankton from the RV *Dolphin* survey of continental shelf waters between Martha's Vineyard, Massachusetts and Cape Lookout, North Carolina, 1965-66. Tech. Series Rept. 15, Sandy Hook Lab., NEFC, NMFS, Highlands, New Jersey.

Bowen, D. (ed.). 1987. A review of stock structure in the Gulf of Maine area: A workshop report. CAFSAC Res. Doc. 87/21: 51 p.

Brown, B.E. 1971. A preliminary review of the status of the Subarea 5 cod stock. ICNAF Res. Doc. 71/125, Serial No. 2623: 14 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. ICNAF Res. Bull. 12: 49-68.

Brown, B.E., and R.G. Halliday. 1983. Fisheries resources of the Northwest Atlantic - Some responses to extreme fishing perturbations, p. 96-109. IN: Proceedings of the Joint Oceanographic Assembly 1982, General Assembly. Canadian National Committee/Scientific Committee on Oceanic Research, Ottawa.

Brown, B.E., and E.G. Heyerdahl. 1972. An assessment of the Georges Bank cod stock (Div. 5Z). ICNAF Res. Doc. 72/117, Serial No. 2831: 24 p.

Burns, T.S., R. Schultz, and B.E. Brown. 1983. The commercial catch sampling program in the northeastern United States, p. 82-95. IN: Doubleday, W.G. and D. Rivard (eds.) Sampling Commercial Catches of Marine Fish and Invertebrates. Can Spec. Pub. Fish Aquat. Sci. 66.

CAFSAC (Canadian Atlantic Fisheries Scientific Advisory Committee). 1987. Further advice on the management of groundfish stocks in 1988. CAFSAC Adv. Doc. 87/21: 44 p.

CAFSAC (Canadian Atlantic Fisheries Scientific Advisory Committee). 1988. Further advice on the management of groundfish stocks in 1989. CAFSAC Adv. Doc. 88/25: 30 p.

CAFSAC (Canadian Atlantic Fisheries Scientific Advisory Committee). 1989. Advice on the management of groundfish stocks in 1990. CAFSAC Adv. Doc. 89/12: 82 p.

Christie, D.R. 1987. The Georges Bank/Gulf of Maine boundary dispute between the United States and Canada, p. 469-473. IN: Backus, R.H. (ed.) Georges Bank. The MIT Press, Cambridge, Massachusetts. 539 p.

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

Clark, S.H., and B.E. Brown. 1977. Changes in biomass of finfishes and squids from the Gulf of Maine to Cape Hatteras, 1963-74, 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. Investigacion Pesquera 43(1): 107-122

Colton, J.B., W.G. Smith, A.W. Kendall, P.L. Berrien, and M.P. Fahay. 1979. Principal spawning areas and times of marine fishes, Cape Sable to Cape Hatteras. Fish. Bull. 76: 911-915.

Cramer, D. 1989. Fished out. Sanctuary (a publication of the Massachusetts Audubon Society), July/August 1989: 5-8.

Fish, C.J. 1928. Production and distribution of cod eggs in Massachusetts Bay in 1924 and 1925. Bull. U.S. Bur. Fish. 43 (Part II): 253-296.

Fogarty, M.J., R.K. Mayo, F.M. Serchuk, and F.P. Almeida. 1989. Trends in aggregate fish biomass and production on Georges Bank. ICNAF SCR. Doc. 89/78, Serial No. N1662: 23 p.

Gabriel, W.L., M.P. Sissenwine, and W.J. Overholtz. 1989. Analysis of spawning stock biomass per recruit: an example for Georges Bank haddock. No. Amer. J. Fish. Mgmt. 9: 383-391.

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.

Goode, G.B., and J.W. Collins. 1887. The George's Bank cod fishery, p. 187-198. IN: Goode, G.B., The Fisheries and Fishery Industries of the United States. Section V, History and Methods of the Fisheries, Vol. 1, Part II, The Cod, Haddock, and Hake Fisheries. Washington, D.C.

Graham, H.W. 1952. A regulation to increase the yield of the New England haddock fishery. Trans. Seventeenth North Am. Wildl. Conf., March 17-19 1952: 378-385.

Graham, H.W. 1970. Management of the groundfish fisheries of the Northwest Atlantic, p. 249-261. IN: Benson, N.G. (ed.), A Century of Fisheries in North America. Spec. Pub. No. 7, Am. Fish. Soc., Washington, D.C., 330 p.

Grosslein, M.D. 1969. Groundfish survey program of BCF Woods Hole. Comm. Fish. Rev. 31(8-9): 22-35.

Haché, J.-E. (Chairman). 1989. Report of the Scotia-Fundy Groundfish Task Force. Department of Fisheries and Oceans. Cat No. Fs 23-157/1989E, 86 p.

Halliday, R.G., and A.T. Pinhorn. 1990. The delimitation of fishing areas in the Northwest Atlantic. J. Northw. Atl. Fish. Sci. 10: 1-51.

Hennemuth, R.C. 1969. Status of the Georges Bank haddock fishery. ICNAF Res. Doc. 69/90, Serial No. 2256, 21 p.

Hennemuth, R.C., and S. Rockwell. 1987. History of fisheries conservation and management, p. 430-436. IN: Backus, R.H. (ed.) Georges Bank. The MIT Press, Cambridge, Massachusetts. 539 p.

Herrington, W.C. 1932. Conservation of immature fish in otter trawling. Trans. Am. Fish. Soc. 62: 57-63.

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

Heyerdahl, E.G. 1972. Estimates of future abundance levels of cod stocks in ICNAF Subarea 5 based on U.S. research survey cruise indices. ICNAF Res. Doc. 72/115, Serial No. 2830: 4 p.

Heyerdahl, E.G., and P.Wood. 1976. Data summaries prepared for Subarea 5 cod assessment; results of preliminary VPA analyses. ICNAF Working Paper 76/IV/70: 19 p + Addendum (2 p).

Hunt, J.J. 1987. Status of the Atlantic cod stock on Georges Bank, NAFO Division 5Z and Subarea 6, in 1986. CAFSAC Res. Doc. 87/94: 53 p.

Hunt, J.J. 1988. Status of the Atlantic cod stock on Georges Bank, NAFO Division 5Z and Subarea 6, in 1987. CAFSAC Res. Doc. 88/73: 50 p.

Hunt, J.J. 1989. Status of the Atlantic cod stock on Georges Bank in unit areas 5Zj and 5Zm, 1978-88. CAFSAC Res. Doc. 89/47: 26 p.

Hunt, J.J. 1990. Status of the Atlantic cod stock on Georges Bank in unit areas 5Zj and 5Zm, 1978-89. CAFSAC Res. Doc. 90/80: 37 p.

Hunt, J.J., and S. Gavaris. 1986. Status of the Atlantic cod stock on Georges Bank, NAFO Division 5Z and Statistical Area 6, in 1985. CAFSAC Res. Doc. 86/95: 49 p.

Hunt, J.J., and K.G. Waiwood. 1984. Status of the Atlantic cod stock on Georges Bank, NAFO Division 5Z and Statistical Area 6, in 1983. CAFSAC Res. Doc. 84/65: 32 p.

Hunt, J.J., and K.G. Waiwood. 1985. Status of the Atlantic cod stock on Georges Bank, NAFO Division 5Z and Statistical Area 6, in 1984. CAFSAC Res. Doc. 85/87: 47 p.

Hurley, P.C.F., and R.N. O'Boyle. 1983. An evaluation of the current 5Z cod population characteristics during 1960-82 with yield projected to 1984. CAFSAC Res. Doc. 83/77: 32 p.

ICNAF (International Commission for the Northwest Atlantic Fisheries). 1971-1976. Report of Assessment Subcommittee. ICNAF Redbooks (annual volumes, 1971-1976).

Jensen, A.C. 1967. A brief history of the New England offshore fisheries. U.S. Bur. Comm. Fish., Fish. Leafl. 594: 14 p.

Jensen, A.C. 1968. Atlantic cod...beef of the sea. Atl. States Mar. Fish. Comm., Mar. Resour. of the Atl. Coast, Leafl. 10: 4 p.

Jensen, A.C. 1972. The Cod. Thomas Y. Crowell Co., New York, 182 p.

Jensen, A.C. 1973. The Cod: A case of supervised neglect. Natural History 82(1): 44-51.

Jensen, A.C. 1974. Sport fishing for cod. N.Y. Fish and Game Jour. 23: 138-148.

Jensen, A.C., and H.E. Murray. 1965. The U.S. cod fishery in the Northwest Atlantic. Comm. Fish. Rev. 27(7): 1-11.

Marchesseault, G.D., R.P. Ruais, and D. Wang. 1980. History and status of the Atlantic Demersal Finfish Fishery Management Plan. NOAA Tech. Memorandum NMFS-F/NEC-2, 15 p.

Mayo, R.K. 1977. Historical description of the Northeast Fisheries Center statistical area data base. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 77-19: 8 p.

MOGTF (Massachusetts Offshore Groundfish Task Force). 1990. New England Groundfish in Crisis -- Again. The Report of the Massachusetts Offshore Groundfish Task Force, December 1990, 33 p.

NEFC (Northeast Fisheries Center). 1986. Report of Third NEFC Stock Assessment Workshop (Third SAW). NMFS, NEFC, Woods Hole Lab. Ref Doc. No. 86-14: 98 p.

NEFC (Northeast Fisheries Center). 1987. Status of mixed species demersal finfish resources in New England and scientific basis for management. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 87-08: 104 p.

NEFC (Northeast Fisheries Center). 1989. Report of Seventh NEFC Stock Assessment Workshop (Seventh SAW). NMFS, NEFC, Woods Hole Lab. Ref Doc. No. 89-04: 108 p.

NEFC (Northeast Fisheries Center). 1990. Report of Eleventh NEFC Stock Assessment Workshop, Fall 1990. NMFS, NEFC Ref Doc. No. 90-09: 121 p.

NEFMC (New England Fishery Management Council). 1977. Fishery Management Plan for Atlantic Groundfish. New England Fishery Management Council, Peabody, Massachusetts. 148 p.

NEFMC (New England Fishery Management Council). 1981. Interim Fishery Management Plan for Atlantic Groundfish. New England Fishery Management Council, Saugus, Massachusetts. 101 p.

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

North American Council on Fishery Investigations. 1932. Proceedings for 1921-1930, No. 1: 56 p.

North American Council on Fishery Investigations. 1935. Proceedings for 1931-1933, No. 2: 40 p.

Penttila, J.A., and V.M. Gifford. 1976. Growth and mortality rates of cod from the Georges Bank and Gulf of Maine areas. ICNAF Res. Bull. 12: 29-36.

Pierce, D.E. 1982. Development and evolution of fishery management plans for cod, haddock, and yellowtail flounder. Massachusetts Div. Mar. Fish. Publ. 13233-133-50-5-83-CR, 133 p.

Pinhorn, A.T., and R.G. Halliday. 1990. Canadian versus international regulation of Northwest Atlantic fisheries: Management practices, fishery yields, and resource trends, 1960-1986. N. Amer. J. Fish. Mgmt. 10: 154-174.

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.

Ryan, J.J. 1979. The cod family and its utilization. Mar. Fish. Rev. 41(11): 25-36.

Scott, W.B., and M.G. Scott. 1988. Atlantic Fishes of Canada. Can. Bull. Fish. Aquat. Sci. 219: 731 p.

Schroeder, W.C. 1930. Migrations and other phases in the life history of the cod off Southern New England. Bull. U.S. Bur. Fish. 46: 1-136.

Serchuk, F.M. 1988. Status and assessment of the Georges Bank and Gulf of Maine cod stocks, 1988. 7th Northeast Fisheries Center (Woods Hole, MA) Stock Assessment Workshop, Working Paper No. 1: 60 p.

Serchuk, F.M., S.H. Clark, and B.E. Brown. 1981. Implications of the 1981 Georges Bank and Gulf of Maine cod and haddock assessments for future management strategies. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 81-09: 7 p.

Serchuk, F.M., R.S. Rak, and J. Penttila. 1982. Status of the Georges Bank and Gulf of Maine Atlantic cod stocks - 1982. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 82-33: 46 p.

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

Serchuk, F.M., and S.E. Wigley. 1990. Revised assessment of the Georges Bank cod stock, 1990. 11th Northeast Fisheries Center (Woods Hole, MA) Stock Assessment Workshop, Working Paper No. 1: 42 p.

Serchuk, F.M., and P.W. Wood. 1979. Review and status of the Southern New England-Middle Atlantic cod, *Gadus morhua*, populations. August 1979. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 79-37: 77 p.

Serchuk, F.M., and P.W. Wood, Jr. 1981. Assessment and status of the Georges Bank and Gulf of Maine Atlantic cod stocks - 1981. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 81-06: 67 p.

Serchuk, F.M., P.W. Wood, and B.E. Brown. 1978. Atlantic cod (*Gadus morhua*): Assessment and status of the Georges Bank and Gulf of Maine stocks. January 1978. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 78-03: 25 p.

Serchuk, F.M., P.W. Wood, S.H. Clark, and B.E. Brown. 1977. Analysis of the Georges Bank and Gulf of Maine cod stocks. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 77-24: 26 p.

Serchuk, F.M., P.W. Wood,Jr., and D.M. Fried. 1980. Current assessment and status of the Georges Bank and Gulf of Maine cod stocks. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 80-07: 52 p.

Serchuk, F.M., P.W. Wood, R. Lewis, J.A. Penttila, and B.E. Brown. 1979. Status of the Georges Bank and Gulf of Maine cod stocks. February 1979. NMFS, NEFC, Woods Hole Lab. Ref. Doc. No. 79-10: 32 p.

Sette, O.E. 1928. Statistics of the catch of cod off the east coast of North America to 1926. Rept. U.S. Comm. Fish. for Fiscal Year 1927 with Appendices: 737-748.

Sette, O.E., and R.H. Fiedler. 1929. Fishery industries of the United States, 1927. Rept. U.S. Comm. Fish. for Fiscal Year 1928 with Appendices, Part I: 401-547.

Sherman, K., and J.P. Wise. 1961. Incidence of the cod parasite, *Lernaeocera branchialis*, in the New England area, and its possible use as an indicator of cod populations. Limnol. Oceanogr. 6: 61-67.

Smith, H.M. 1902. Notes on tagging of 4,000 adult cod at Woods Hole, Mass. Rept. U.S. Fish. Comm. 27: 193-208.

TMG (Technical Monitoring Group, New England Fishery Management Council). 1988. An assessment of the effectiveness of the Northeast Multispecies FMP with recommendations for plan and management system improvements. Report to the New England Fishery Council's Demersal Finfish Committee, 40 p.

U.S. Department of Commerce. 1979. Fisheries of the United States, 1978. NMFS, Current Fish. Stat. No. 7800, 120 p.

Wise, J.P. 1958. The world's southernmost indigenous cod. J. Cons. perm. int. Explor. Mer 23: 208-212.

Wise, J.P. 1963. Cod groups in the New England area. Fish. Bull. 63: 189-203.

Table 1. Commercial landings (metric tons, live) of Atlantic cod from Georges Bank and South (Division 5Z and Subarea 6), 1960 - 1990.

	Country						
Year	USA	Canada	USSR	Spain	Poland	Other	Total
1960	10834	19	-	-	-	-	10853
1961	14453	223	55	-	-	-	14731
1962	15637	2404	5302	-	143	-	23486
1963	14139	7832	5217	-	-	1	27189
1964	12325	7108	5428	18	48	238	25165
1965	11410	10598	14415	59	1851	-	38333
1966	11990	15601	16830	8375	269	69	53134
1967	13157	8232	511	14730	-	122	36752
1968	15279	9127	1459	14622	2611	38	43136
1969	16782	5997	646	13597	798	119	37939
1970	14899	2583	364	6874	784	148	25652
1971	16178	2979	1270	7460	256	36	28179
1972	13406	2545	1878	6704	271	255	25059
1973	16202	3220	2977	5980	430	114	28923
1974	18377	1374	476	6370	566	168	27331
1975	16017	1847	2403	4044	481	216	25008
1976	14906	2328	933	1633	90	36	19926
1977	21138	6173	54	2	-	-	27367
1978	26579	8904	-	-	-	-	35483
1979	32645	6011	-	-	-	-	38656
1980	40053	8094	-	-	-	-	48147
1981	33849	8508	-	-	-	-	42357
1982	39333	17862	-	-	-	-	57195
1983	36756	12132	-	-	-	-	48888
1984	32915	5761	-	-	-	-	38676
1985	26828	10441	-	-	-	-	37269
1986	17490	8508	-	-	-	-	25998
1987	19035	11843	-	-	-	-	30878
1988	26310	12725	-	-	-	-	39035
1989	25097	7897	-	-	-	-	32994
1990*	28193	14335	-	-	-	-	42528

* Provisional

Table 2. Estimated number (000's) and weight (metric tons, live) of Atlantic cod caught by marine recreational fishermen, by region, in 1960, 1965, 1970, 1974, and 1979 - 1990.

Year	North Atlantic [1,2]		Mid-Atlantic [2]		All Regions	
	No. of Cod (000's)	Wt. of Cod (mt)	No. of Cod (000's)	Wt. of Cod (mt)	No. of Cod (000's)	Wt. of Cod (mt)
1960	3998	11426	793	2590	4791	14016
1965	4970	13144	62	421	5032	13565
1970	3690	16188	154	104	3844	16292
1974	2155	8566	746	3802	2901	12368
1979	3083	3762	8	55	3091	3817
1980	2403	6376	36	9	2439	6385
1981	4440	7281	482	1367	4922	8648
1982	2663	4378	586	3633	3249	8011
1983	3511	7432	244	852	3755	8284
1984	2463	5061	102	330	2565	5391
1985	3611	8644	62	338	3673	8982
1986	1493	3261	56	187	1549	3448
1987	1890	3287	173	519	2063	3806
1988	2035	4740	837	2823	2872	7563
1989	3097	5561	350	1279	3447	6840
1990	2484	4753	228	717	2712	5470

[1] During 1960, 1965, and 1970 marine recreational fishery statistics surveys, 'North Atlantic' included Maine to New York; in subsequent surveys, 'North Atlantic' included only Maine to Connecticut (ie., excluding New York).

[2] For surveys conducted in 1979 and afterward, total weight caught was derived by multiplying the number of cod caught in each region by the mean weight of cod landed in whole form in each region (Type A catch) obtained from intercept (creel) survey sampling.

Table 3. Chronology of assessments conducted on Georges Bank cod.

Year	Area	Source	Results and Conclusions
1971	SA 5	Brown 1971 ICNAF 1971	Catch & effort increased greatly since 1964; some CPUE indices have decreased through 1970; research survey indices do not indicate any increases in stock size or recruitment; MSY is probably between 30-40 Kt; fishery is judged fully exploited at present and increases in effort should be avoided until a more complete assessment is made.
1972	Div 5Z	Brown & Heyerdahl 1972 ICNAF 1972	Survey indices peaked in 1963-64, declined to lowest levels in 1965-66, and remained steady at intermediate levels since 1967; USA CPUE indices have shown similar trends, but 1964-71 indices are lower than 1931-1963 mean; F_{max}=0.3; MSY is about 35 Kt; effort at MSY is 30,000 standard days fished, effort in mid-60s exceeded this level.
1973	Div 5Z	ICNAF 1973	The 1973 TAC for the stock was set at 35Kt, considered to be the long-term MSY; the 1972 catch was about 24Kt; No new evidence to change the TAC for 1974 from 35Kt; a new assessment should be carried out but presently the stock seems to be exploited at a 'reasonable level' and the TAC should prevent rapid expansion of effort.
1974	Div 5Z	ICNAF 1974	No new assessment available; 1973 catch was 28.5 Kt, less than 35 Kt TAC [considered as MSY]; USA commercial LFs show an increase in recruitment (R) from 1971 cohort; survey pre-recruit indices suggest that commercial stock size will increase in 1975 & 1976; catches from increased R will result in F_{MSY}, so maintain 35Kt TAC for 1975.
1975	Div 5Z	ICNAF 1975	No new assessment available; catches in 1965-75 averaged 34.3Kt and been < 30Kt since 1970; survey indices indicate a stable population since 1963; 1971 cohort is strong & subsequent cohorts are present but not as abundant; current F=0.35 > F_{max}; updated CPUE data give MSY of 32.5Kt but no firm basis to change 35Kt TAC for 1986.
1976	Div 5Z	Penttila & Gifford 1976 Heyerdahl & Wood 1976 ICNAF 1976	Survey data indicate a stable abundance level since 1963 with good R since 1970; 1975 cohort appears strong, equal to 1971 cohort; preliminary VPA indicates that F in late 1960s was between 0.55-0.65. If R remains stable, catch at F_{max} (0.3) would be 24 Kt; at $F_{0.1}$, catch would be 15Kt; it is recommended that the TAC for 1977 be set at 15Kt.
1977	Div 5Z & SA 6	Serchuk et al. 1977	VPA conducted using comm landings and estimated USA rec catches, 1960-76; survey age/length keys applied to commercial LFs in 1960-76 and #s at age raised to include rec catches. $F_{(3+)}$ increased from 0.35 in 1960-64 to 0.75 in 1971, and stabilized at 0.5-0.6 from 1973-76; SSB (3+) declined by 50% between 1965 and 1977 [110 to 65Kt]. SSB and total stock size would increase if F was reduced to F_{max} (0.30) or $F_{0.1}$ (0.18).
1978	Div 5Z & SA 6	Serchuk et al. 1978	Stock sizes at age and Fs in 1977 and 1978 were projected from 1960-76 VPA results using 1977 catch-at-age data and VPA/survey and F/effort relationships. Due to considerable discards of scrod in 1977 (from the strong 1975 cohort), four discard scenarios were evaluated based on $F87_{(3+)}$=0.45. To maintain stock size in 1979 at 1978 level, a total catch in 1978 [commercial & recreational & discards] of between 25-28Kt would be required.
1979	Div 5Z & SA 6	Serchuk et al. 1979	No VPA update; commercial landings in 1978 were 35Kt, the highest since 1969 but underestimate the catch due to high discarding and suspected unreported landings; recreational landings in 1977-1978 not known; the 1978 survey wt/tow indices were among the highest observed due to strong 1975 cohort. Based on survey data, the cod stock is at a relatively high level.

Table 3 (continued). Chronology of assessments conducted on Georges Bank cod.

Year	Area	Source	Results and Conclusions
1980	Div 5Z & SA 6	Serchuk et al. 1980	No VPA update; 1979 commercial landings were 37Kt, highest since 1969 but underestimate the true catch; 1979 survey indices declined from 1978 but still among the highest observed; 1975 cohort dominant in both stock and fishery; 1978 cohort better than average; relative exploitation rates [total catch/survey weight index] stable since 1977, 20% lower than 1971-76 average. Overall, stock biomass remained at relatively high level in 1979.
1981	Div 5Z & SA 6	Serchuk & Wood 1981 Serchuk et al. 1981	No VPA update; 1980 comm landings were 46Kt, highest since 1966; USA CPUE in 1977-80 was highest in 64-80 time series; spring 1980 survey indices higher than in 1979, but fall survey indices lower; 1978 cohort above-average; relative exploitation rates have increased since 1978; 1980 rate was highest since 1970 suggesting that F has increased to levels observed during 1964-70 when stock declines ensued; continuation of 46Kt catch levels will reduce stock size.
1982	Div 5Z & SA 6	Serchuk et al. 1982	No VPA update; 1981 comm landings were 42Kt, with 1978 cohort dominating catches; 1981 survey indices among the highest ever; 1977-1980 cohorts appear above-average or strong; F [from survey catch per tow data] during 1964-1981 ranged from 0.27-0.53; during 1977-81, F=0.39 slightly above F_{max}. Despite near-record high landings, stock biomass remains high due to good R and moderate F; commercial landings of 40Kt appear sustainable during next 2-3 years.
1983	Div 5Z & SA 6	Hurley & O'Boyle 1983 (Canada)	SPA performed using 1960-76 #s-at-age from Serchuk et al. 1977; record-high 1982 commercial catch (58Kt); stock size (3+) in 1982 of 56 million fish, with F82 between 0.25-0.30; Canadian CPUE stable in 1966-72 but has recently doubled; F_{max}=0.25, $F_{0.1}$=0.15; at $F_{0.1}$ and mean R, long-term annual yield would be 45Kt.
1984	Div 5Z & SA 6	Hunt & Waiwood 1984 (Canada)	No SPA update; 1983 comm landings were 49Kt; Canadian CPUE in 1981-83 was 2X historical average; USA fall survey indices declined to low levels in 1982 and 1983; 1983 cohort seems above-average; F83 assumed to be 0.40 from spring survey data; if 1984 catch is 45Kt, $F_{0.1}$ catch in 1985 would be about 20Kt.
1985	Div 5Z & SA 6	Hunt & Waiwood 1985 (Canada)	Revised SPA using comm catch-at-age data from 1978-84; 1984 comm catch (39Kt) lowest since 1980; USA CPUE, stable from 1978-83, declined sharply in 1984 as did Canadian otter-trawl CPUE; 1984 survey indices were unchanged from low 1983 levels; SPA indicated $F_{(3+)}$ increased from 0.4 in 1978 to 0.6 in 1983 and 1984; stock biomass (3+) has fallen 40% since 1980 and in the beginning of 1985 was only 73Kt, the lowest in the series.
1986	Div 5Z & SA 6	Serchuk & Wigley 1986 NEFC 1986	Revised VPA using comm catch-at-age data from 1978-85; 1985 comm catch (37Kt) lowest in 7 years; USA CPUE has declined since 1982, with 1985 CPUE lowest ever; total fishing effort in 1985 was a record-high; fall 1985 survey indices were among lowest observed; strong 1980 & 1983 cohorts in both catch and stock; 1985 cohort may be strong; Between 1978-85, F doubled (0.40 to 0.82), while SSB fell by 50% to a record-low (96Kt to 46Kt); $F_{0.1}$=0.16, F_{max}=0.28; At mean R, equilibrium yield at $F_{0.1}$ = 33Kt, at F_{max} = 35Kt; All data indicate a marked decline in stock size; the stock appears to be growth overfished and perhaps in danger of recruitment overfishing.
	Div 5Z & SA 6	Hunt & Gavaris 1986 (Canada)	SPA updated incorporating 1985 data; 1983 cohort comprised 50% of 1985 comm catch; Canadian CPUE increased in 1985 from reduced 1983-84 values; SPA indicates F85=0.45 and F has declined slightly since 1982 (F82=0.51); stock biomass (3+) declined from 95Kt in 1980 to a record-low 62Kt in 1985; $F_{0.1}$ yield for the stock is less than 15Kt, which is exceeded by the 1985 USA catch [27Kt], and improvement in stock status will require bilateral management by the USA and Canada.

Table 3 (continued). Chronology of assessments conducted on Georges Bank cod.

Year	Area	Source	Results and Conclusions
1987	Div 5Z & SA 6	Hunt 1987 (Canada)	SPA updated incorporating 1986 data; 1986 comm catch (26Kt) lowest since 1976, and 50% of 1982 catch (57 Kt); USA CPUE declined in 1986 to a new record-low; Canadian CPUE in 1986 was slightly less than in 1985; USA fall survey indices have been stable and low since 1982 but increased slightly in 1986; indices from Canadian surveys [begun in 1986] declined in 1987; strong 1985 cohort evident in both USA and CAN surveys; SPA indicates F85=0.82 and F_{86}=0.70 (highest in 78-86 series); stock biomass (3+) in 1985 and 1986 was a record-low 34Kt; stock rebuilding will not be possible without a bilateral USA/CAN management strategy to reduce F.
1988	Div 5Z & SA 6	Serchuk 1988 NEFC 1989	VPA updated using data through 1987; 1987 comm catch (31Kt), higher than 1986, but second-lowest since 1977; 1987 catch dominated by 1985 and 1983 cohorts; USA 1987 CPUE was a record-low; Canadian 1987 CPUE was lowest since 1984 and second-lowest since 1976; total fishing effort in 1987 was a record-high; USA survey indices in 1987 were among the lowest ever but survey indices increased slightly in 1988; 1985 cohort dominates both the stock and catch; strong 1987 cohort evident in 1988 surveys; VPA indicates F87=0.95 [record-high] and about 2.5X greater than in 1978; SSB in 1987-1988 were record-lows (about 30Kt), only 1/3 of SSB in 1980; F is well above $F_{0.1}$=0.15 and F_{max}=0.27 and target %MSP goals will not be attained; since the fishery is highly dependent on young fish (ages 2 & 3), rebuilding of SSB has been precluded despite good R; SSB will decline in 1988 & 1989 unless F is reduced by 30%; SSB may be approaching a level where probability of strong R is low.
	Div 5Z & SA 6	Hunt 1988	SPA updated incorporating 1987 data; stock abundance indices are variable but all show a general decline; USA spring survey indices indicate decreasing abundance and fall indices appear steady at a low level; the 1988 Canadian survey index was higher than in 1987 and similar to that for 1986; CPUE continues to decline, with both USA and CAN relative CPUE indices trending downward since 1982; SPA results [using the ADAPT model] indicate F87=0.80 [record-high], 5X higher than $F_{0.1}$ (0.15) and 2X F78-80 (0.40); stock biomass (3+) in 1987 was only 25Kt, the lowest in the 1978-87 series, and 1/4 of the biomass levels in 1978-1980; although F far exceeds $F_{0.1}$ and F_{max}, the 1987 USA catch [19 Kt] exceeds the estimated $F_{0.1}$ catch (8Kt) and without coordinated USA/CAN management action, it is unlikely that reductions in Canadian catches would result in stock rebuilding.
1989	Areas 5Zj & 5Zm	Hunt 1989 (Canada)	1988 comm catch (20Kt) in 5Zj and 5Zm was the highest since 1983; 1985 and 1983 cohorts accounted for most of catch; standardized CPUE indices for both USA and Canada have declined since 1978, with recent values among the lowest in the time series; 1989 CAN and 1988 USA survey indices in 5Ze were higher than in 1987; strong 1987 and 1985 cohorts are evident in both survey series; preliminary SPA indicated that F has been 2-3X $F_{0.1}$ since 1978. Reduction of total catch by a factor of 2 in 1990 is required to approach $F_{0.1}$=0.20
1990	Div 5Z & SA 6	Serchuk & Wigley 1990 NEFC 1990	VPA updated using data through 1989; 1989 comm catch (33Kt) dominated by strong 1985 cohort; fishing effort peaked in 1988 but declined slightly in 1989; USA survey indices increased in both 1988 & 1989, and indicated strong R from 1987 & 1988 cohorts; VPA results [using Laurec-Shepherd tuning] indicate F peaked at 0.7 in 1985 and has been about 0.5-0.6 since 1986; SSB declined 50% between 1980 and 1986, but has since increased to 66Kt [slightly below the 1978-89 average] due to strong 1983, 1985, and 1988 cohorts; $F_{0.1}$=0.15; F_{max}=0.27; F_{med}=0.47; catch and stock size projections for 1990-92 are critically dependent on strength of 1988 cohort.
	Areas 5Zj & 5Zm	Hunt 1990 (Canada)	1989 comm catch (14Kt) lowest since 1986 and dominated by 1985 & 1987 cohorts; SPA [tuned using ADAPT] indicated $F89_{(3+)}$=0.29, a record-low value mostly because of an early closure of the Canadian trawl fishery; 1990 stock biomass (3+) was 69Kt, well above 1978-90 mean (49 Kt); F90 is expected to be 0.39 and F91 will range between 0.2-0.4, depending on catch options [$F_{0.1}$; 50% rule in 1991; catch 91 = catch 90].

able 4. Stratified mean catch per tow in numbers and weight (kg) for Atlantic cod in NEFC offshore spring and autumn research vessel bottom trawl surveys on Georges Bank (Strata 13-25), 1963 - 1990. [a,b]

	Spring		Autumn	
Year	No/Tow	Wt/Tow	No/Tow	Wt/Tow
1963	-	-	2.80	11.0
1964	-	-	1.91	7.1
1965	-	-	2.72	7.2
1966	-	-	3.08	5.0
1967	-	-	6.66	8.4
1968	3.03	7.8	2.11	5.3
1969	2.98	11.0	1.41	5.0
1970	2.78	9.7	3.25	7.7
1971	2.17	8.8	2.04	6.1
1972	5.75	11.7	8.39	14.2
1973	11.98 [c]	24.5 [c]	7.87	19.0
1974	9.45	22.5	2.24	5.1
1975	4.42	16.1	4.11	8.7
1976	4.52	11.5	6.69	10.9
1977	4.04	9.5	4.42	11.5
1978	7.89	19.3	6.97	21.5
1979	3.31	10.5	4.83	15.2
1980	4.97	15.3	2.36	6.2
1981	8.47	24.0	7.34	17.5
1982	6.65 [d]	14.2 [d]	2.38	4.3
1983	4.94	14.8	2.33	4.0
1984	2.62	9.5	3.04	6.3
1985	6.94	21.5	2.43	3.5
1986	5.04	16.7	3.12	4.7
1987	3.26	10.3	2.33	4.4
1988	5.86	13.4	3.11	5.8
1989	6.07	16.1	6.05	6.9
1990	5.99	17.3	4.58 [e]	10.5 [e]

a] Spring surveys during 1973-1981 were accomplished with a '41 Yankee' trawl; in all other years, spring surveys were accomplished with a '36 Yankee' trawl. No adjustments have been made to the catch per tow data for these gear differences.

b] During 1963-1984, BMV oval doors were used in spring and autumn surveys; since 1985, Portuguese polyvalent doors have been used in both surveys. No adjustments have been made to the catch per tow data for these gear differences.

c] Excludes unusually high catch of 1894 cod (2558 kg) at Station 230 (Strata tow 20-4).

d] Excludes unusually high catch of 1032 cod (4096 kg) at Station 323 (Strata tow 16-7).

e] Excluding unusually high catch of 111 cod (504 kg) at Station 205 (Strata tow 23-4).

Table 5. Stratified mean catch per tow at age (numbers) of Atlantic cod in NEFC offshore spring and autumn bottom trawl surveys on Georges Bank, 1963 - 1990. [a,b,c,d]

Year	Age Group 0	1	2	3	4	5	6	7	8	9	10+	Totals 0+	1+	2+	3+	4+	5+
Spring																	
1968	0.329	0.087	1.035	0.529	0.426	0.247	0.158	0.090	0.053	0.036	0.037	3.027	2.698	2.611	1.576	1.047	0.621
1969	0.000	0.079	0.350	1.141	0.569	0.289	0.209	0.138	0.082	0.046	0.072	2.975	2.975	2.896	2.546	1.405	0.836
1970	0.000	0.244	0.522	0.308	0.830	0.104	0.420	0.176	0.039	0.087	0.053	2.783	2.783	2.539	2.017	1.709	0.879
1971	0.000	0.133	0.525	0.322	0.143	0.375	0.091	0.225	0.195	0.051	0.112	2.172	2.172	2.039	1.514	1.192	1.049
1972	0.036	1.860	1.175	1.693	0.327	0.076	0.208	0.078	0.141	0.074	0.080	5.748	5.712	3.852	2.677	0.984	0.657
1973 [e]	0.036	0.334	7.464	1.403	1.628	0.273	0.201	0.227	0.032	0.130	0.249	11.977	11.941	11.607	4.143	2.740	1.112
1974	0.000	0.286	2.921	3.828	0.488	1.284	0.282	0.065	0.165	0.022	0.112	9.453	9.453	9.167	6.246	2.418	1.930
1975	0.000	0.041	0.242	1.309	1.982	0.167	0.440	0.083	0.060	0.069	0.025	4.418	4.418	4.377	4.135	2.826	0.844
1976	0.071	0.834	1.232	0.605	0.443	1.008	0.105	0.168	0.023	0.000	0.035	4.524	4.453	3.619	2.387	1.782	1.339
1977	0.000	0.018	2.261	0.692	0.335	0.179	0.466	0.033	0.042	0.000	0.013	4.039	4.039	4.021	1.760	1.068	0.733
1978	2.123	0.241	0.120	3.545	0.621	0.499	0.092	0.457	0.033	0.091	0.070	7.892	5.769	5.528	5.408	1.863	1.242
1979	0.070	0.279	0.871	0.191	1.226	0.347	0.150	0.056	0.093	0.008	0.014	3.305	3.235	2.956	2.085	1.894	0.668
1980	0.067	0.025	1.452	1.723	0.134	0.950	0.383	0.123	0.020	0.019	0.071	4.967	4.900	4.875	3.423	1.700	1.566
1981	0.244	1.869	1.555	2.255	1.353	0.081	0.706	0.218	0.117	0.000	0.069	8.467	8.223	6.354	4.799	2.544	1.191
1982 [f]	0.120	0.396	2.755	1.141	1.051	0.843	0.013	0.242	0.052	0.013	0.028	6.654	6.534	6.138	3.383	2.242	1.191
1983	0.052	0.211	1.261	1.954	0.491	0.447	0.276	0.035	0.123	0.000	0.087	4.937	4.885	4.674	3.413	1.459	0.968
1984	0.000	0.258	0.296	0.511	0.744	0.286	0.272	0.143	0.000	0.100	0.005	2.615	2.615	2.357	2.061	1.550	0.806
1985	0.244	0.098	2.633	0.757	1.058	1.328	0.270	0.203	0.172	0.025	0.150	6.938	6.694	6.596	3.963	3.206	2.148
1986	0.092	0.871	0.423	1.824	0.360	0.545	0.633	0.063	0.119	0.095	0.015	5.040	4.948	4.077	3.654	1.830	1.470
1987	0.000	0.034	1.612	0.403	0.752	0.060	0.179	0.147	0.016	0.027	0.025	3.255	3.255	3.221	1.609	1.206	0.454
1988	0.180	0.700	0.684	3.115	0.413	0.645	0.045	0.020	0.052	0.000	0.007	5.861	5.681	4.981	4.297	1.182	0.769
1989	0.000	0.481	1.689	0.940	1.939	0.288	0.436	0.064	0.050	0.102	0.085	6.074	6.074	5.593	3.904	2.964	1.025
1990	0.052	0.246	1.172	2.161	0.826	1.134	0.158	0.176	0.016	0.020	0.034	5.995	5.943	5.697	4.525	2.364	1.538
Autumn																	
1963	0.012	0.461	0.499	0.590	0.575	0.227	0.209	0.112	0.066	0.009	0.044	2.804	2.792	2.331	1.832	1.242	0.667
1964	0.006	0.410	0.448	0.377	0.345	0.093	0.087	0.040	0.032	0.019	0.053	1.910	1.904	1.494	1.046	0.669	0.324
1965	0.111	0.833	0.640	0.453	0.310	0.107	0.115	0.072	0.052	0.015	0.015	2.723	2.612	1.779	1.139	0.686	0.376
1966	0.657	1.085	0.641	0.330	0.169	0.064	0.061	0.040	0.025	0.001	0.011	3.084	2.427	1.342	0.701	0.371	0.202
1967	0.046	4.869	0.855	0.335	0.260	0.085	0.085	0.035	0.033	0.008	0.045	6.656	6.610	1.741	0.886	0.551	0.291
1968	0.045	0.201	1.033	0.502	0.174	0.047	0.043	0.017	0.015	0.005	0.031	2.113	2.068	1.867	0.834	0.332	0.158
1969	0.000	0.220	0.399	0.401	0.212	0.060	0.039	0.012	0.015	0.014	0.038	1.410	1.410	1.190	0.791	0.390	0.178
1970	0.265	1.082	0.867	0.336	0.445	0.098	0.000	0.021	0.035	0.035	0.063	3.247	2.982	1.900	1.033	0.697	0.252
1971	0.256	0.386	0.405	0.250	0.193	0.305	0.117	0.027	0.057	0.000	0.048	2.044	1.788	1.402	0.997	0.747	0.554
1972	0.607	4.771	0.830	1.135	0.256	0.156	0.366	0.070	0.131	0.014	0.053	8.389	7.782	3.011	2.181	1.046	0.790
1973	0.130	1.121	3.891	0.758	1.290	0.135	0.145	0.112	0.040	0.089	0.161	7.872	7.742	6.621	2.730	1.972	0.682
1974	0.296	0.262	0.419	0.975	0.105	0.073	0.066	0.000	0.044	0.000	0.000	2.240	1.944	1.682	1.263	0.288	0.183
1975	1.524	0.637	0.270	0.400	1.080	0.072	0.100	0.000	0.000	0.000	0.024	4.107	2.583	1.946	1.676	1.276	0.196
1976	0.000	3.941	1.328	0.489	0.178	0.474	0.035	0.173	0.025	0.034	0.013	6.690	6.690	2.749	1.421	0.932	0.754
1977	0.123	0.192	2.778	0.570	0.204	0.141	0.321	0.006	0.022	0.000	0.063	4.420	4.297	4.105	1.327	0.757	0.553
1978	0.321	1.505	0.207	3.392	0.782	0.272	0.134	0.279	0.041	0.024	0.011	6.968	6.647	5.142	4.935	1.543	0.761
1979	0.096	1.314	1.393	0.182	1.309	0.240	0.146	0.029	0.093	0.006	0.018	4.826	4.730	3.416	2.023	1.841	0.532
1980	0.227	0.664	0.458	0.628	0.062	0.204	0.043	0.054	0.020	0.000	0.000	2.360	2.133	1.469	1.011	0.383	0.321
1981	0.212	2.860	1.826	1.265	0.478	0.044	0.470	0.046	0.052	0.015	0.067	7.335	7.123	4.263	2.437	1.172	0.694
1982	0.205	0.561	1.342	0.141	0.044	0.062	0.000	0.010	0.000	0.000	0.014	2.379	2.174	1.613	0.271	0.130	0.086
1983	0.661	0.415	0.655	0.510	0.035	0.030	0.002	0.000	0.008	0.000	0.015	2.331	1.670	1.255	0.600	0.090	0.055
1984	0.119	1.600	0.065	0.568	0.558	0.011	0.040	0.025	0.004	0.025	0.028	3.043	2.924	1.324	1.259	0.691	0.133
1985	1.084	0.220	0.803	0.103	0.115	0.101	0.000	0.000	0.004	0.000	0.000	2.430	1.346	1.126	0.323	0.220	0.105
1986	0.096	2.280	0.153	0.382	0.010	0.061	0.090	0.016	0.000	0.008	0.028	3.124	3.028	0.748	0.595	0.213	0.203
1987	0.204	0.414	1.353	0.112	0.195	0.028	0.012	0.000	0.000	0.007	0.000	2.325	2.121	1.707	0.354	0.242	0.047
1988	0.549	0.903	0.433	0.909	0.091	0.178	0.000	0.011	0.039	0.000	0.000	3.113	2.564	1.661	1.228	0.319	0.228
1989	0.332	3.466	1.304	0.232	0.632	0.070	0.010	0.005	0.000	0.000	0.000	6.051	5.719	2.253	0.949	0.717	0.085
1990 [g]	0.198	0.458	1.942	1.473	0.264	0.184	0.015	0.016	0.000	0.000	0.028	4.578	4.380	3.922	1.980	0.507	0.243

[a] Spring and autumn: Strata 13-25. [b] Catch per tow at age values for 1963-69 obtained by applying combined 1970-81 age-length keys to stratified mean catch per tow at length distributions from each survey. [c] Spring surveys during 1973-1981 were accomplished with a '41 Yankee' trawl; in all other years, spring surveys were accomplished with a '36 Yankee' trawl. No adjustments have been made to the catch per tow data for these gear differences. [d] During 1963-1984, BMV oval doors were used in spring and autumn surveys; since 1985, Portuguese polyvalent doors have been used in both surveys. No adjustments have been made to the catch per tow data for these gear differences. [e] Excludes an unusually high catch of 1894 cod (2558 kg) taken at Station 230 (Strata tow 20-4). [f] Excludes an unusually high catch of 1032 cod (4096 kg) taken at Station 323 (Strata tow 16-7). [g] Excludes an unusually high catch of 111 cod (504 kg) taken at Station 205 (Strata tow 23-4).

Table 6. Estimates of instantaneous total mortality (Z) and fishing mortality (F)[1] for the Georges Bank cod stock for seven time-periods, 1964 - 1989, derived from NEFC offshore spring and autumn bottom trawl survey data.[2]

Time Period	Spring		Autumn		Geometric Mean	
	Z	F	Z	F	Z	F
1964-1967	-	-	0.73	0.53	0.73	0.53
1968-1972	0.34	0.14	0.49[3]	0.29	0.41	0.21
1973-1976	0.70	0.50	0.56	0.36	0.63	0.43
1977-1981	0.44	0.24	0.63	0.43	0.53	0.33
1982-1984	0.74	0.54	1.29	1.09	0.98	0.78
1985-1987	0.84	0.64	1.17	0.97	0.99	0.79
1987-1989	0.47	0.27	0.53	0.33	0.50	0.30

[1] Instantaneous natural mortality (M) assumed to be 0.20.

[2] Estimates derived from:

Georges Bank spring: ln (Σ age 4+ for year i to j/ Σ age 5+ for years i+1 to j+1).
Georges Bank autumn: ln (Σ age 3+ for years i-1 to j-1/ Σ age 4+ for years i to j).

[3] Excludes autumn 1971-1972 data (3+/4+) since these gave negative Z value.

Table 7. USA commercial landings (L)[1], days fished (DF)[2], and landings per day fished (L/DF), by vessel tonnage class (Class 2: 5-50 GRT; Class 3: 51-150 GRT; Class 4: 151-500 GRT), of Atlantic cod. for otter trawl trips catching cod from Georges Bank (NAFO Subdivision 5Ze), 1965 - 1990. Data are also provided for otter trawl trips in which cod comprised 50% or more of the total trip catch, by weight ['directed trips'].

	Class 2			Class 3			Class 4			Totals	
Year	L	DF	L/DF	L	DF	L/DF	L	DF	L/DF	L	L/DF[3]
						ALL TRIPS					
1965	487	1661	0.29	5201	9719	0.54	4351	4175	1.04	10039	0.74
1966	386	1555	0.25	4754	10505	0.45	4731	4510	1.05	9871	0.73
1967	437	1069	0.41	5292	8570	0.62	4519	3789	1.19	10248	0.86
1968	321	570	0.56	6861	8534	0.80	4903	3397	1.44	12085	1.05
1969	433	500	0.87	7942	7953	1.00	4819	2783	1.73	13194	1.26
1970	508	535	0.95	6729	8296	0.81	4033	2218	1.82	11270	1.18
1971	563	681	0.83	7652	8808	0.87	4215	2195	1.92	12430	1.22
1972	524	721	0.73	6382	9257	0.69	3274	1766	1.85	10180	1.07
1973	322	550	0.59	7814	8668	0.90	4295	1701	2.52	12431	1.45
1974	585	617	0.95	8222	9438	0.87	5266	2097	2.51	14073	1.49
1975	509	534	0.95	7029	8684	0.81	4527	2085	2.17	12065	1.33
1976	421	474	0.89	7861	7791	1.01	3969	1469	2.70	12251	1.55
1977	850	607	1.40	13250	9492	1.40	4423	1472	3.00	18523	1.78
1978	1165	715	1.63	14853	9411	1.58	4829	1551	3.11	20847	1.94
1979	956	658	1.45	18377	9924	1.85	7116	2507	2.84	26449	2.10
1980	1062	882	1.20	21331	10961	1.95	10053	3726	2.70	32446	2.16
1981	1184	845	1.40	17025	10615	1.60	9404	3797	2.48	27613	1.89
1982	1406	695	2.02	20468	10717	1.91	11450	4296	2.67	33324	2.18
1983	835	429	1.95	17112	10694	1.60	13011	5116	2.54	30958	2.00
1984	375	427	0.88	14883	13605	1.09	10899	5746	1.90	26157	1.42
1985	370	453	0.82	12852	13629	0.94	8215	5501	1.49	21437	1.15
1986	150	233	0.64	8014	10442	0.77	5411	4354	1.24	13575	0.96
1987	108	220	0.49	8505	12067	0.70	5090	4770	1.07	13703	0.84
1988	100	233	0.43	12808	13791	0.93	7345	5799	1.27	20253	1.05
1989	144	320	0.45	10104	13151	0.77	7631	5274	1.45	17879	1.06
1990	141	260	0.54	11586	13567	0.85	9891	5552	1.78	21618	1.27
						50% TRIPS					
1965	18	8	2.25	353	86	4.10	819	159	5.15	1190	4.79
1966	7	<1	-	370	88	4.20	991	199	4.98	1368	4.74
1967	33	17	1.94	874	238	3.67	1464	318	4.60	2371	4.22
1968	16	3	5.33	1665	464	3.59	1442	328	4.40	3123	3.97
1969	73	9	8.11	2612	773	3.38	1475	359	4.11	4160	3.72
1970	164	25	6.56	1695	534	3.17	1739	388	4.48	3598	3.96
1971	117	15	7.80	2232	721	3.10	2163	494	4.38	4512	3.84
1972	152	54	2.81	2137	716	2.98	1879	445	4.22	4168	3.53
1973	52	16	3.25	3242	820	3.95	3010	486	6.19	6304	5.01
1974	259	119	2.18	3707	1115	3.32	3899	703	5.55	7865	4.39
1975	246	85	2.89	2678	842	3.18	3128	585	5.35	6052	4.29
1976	159	66	2.41	3665	1089	3.37	2664	464	5.74	6488	4.32
1977	502	120	4.18	6595	1342	4.91	2899	373	7.77	9996	5.70
1978	846	215	3.93	6554	1644	3.99	2427	330	7.35	9827	4.81
1979	612	168	3.64	9714	2558	3.80	4270	840	5.08	14596	4.17
1980	644	196	3.29	11727	2909	4.03	5616	1067	5.26	17987	4.39
1981	766	153	5.01	9414	2591	3.63	4312	953	4.52	14492	3.97
1982	1046	212	4.93	14724	3631	4.06	7791	1521	5.12	23561	4.45
1983	566	130	4.35	11884	3033	3.92	8795	1872	4.70	21245	4.25
1984	140	55	2.55	9156	3454	2.65	6620	1918	3.45	15916	2.98
1985	184	65	2.83	8725	4346	2.01	6053	2330	2.60	14962	2.26
1986	58	18	3.22	5258	2969	1.77	3755	1406	2.67	9071	2.15
1987	36	18	2.00	5743	3874	1.48	3354	1781	1.88	9133	1.63
1988	37	22	1.68	9974	6457	1.54	5527	2731	2.02	15538	1.71
1989	66	56	1.18	7864	6023	1.31	6200	3083	2.01	14130	1.62
1990	61	16	3.81	8490	4965	1.71	8151	3204	2.54	16702	2.12

[1] Metric tons, live weight.

[2] Days fished with trawl on bottom; derived by dividing hours fished with trawl on bottom by 24.

[3] Total L/DF was derived by weighting individual tonnage class L/DF values by the percentage of total landings accounted for by each vessel class and summing over the three vessel class categories.

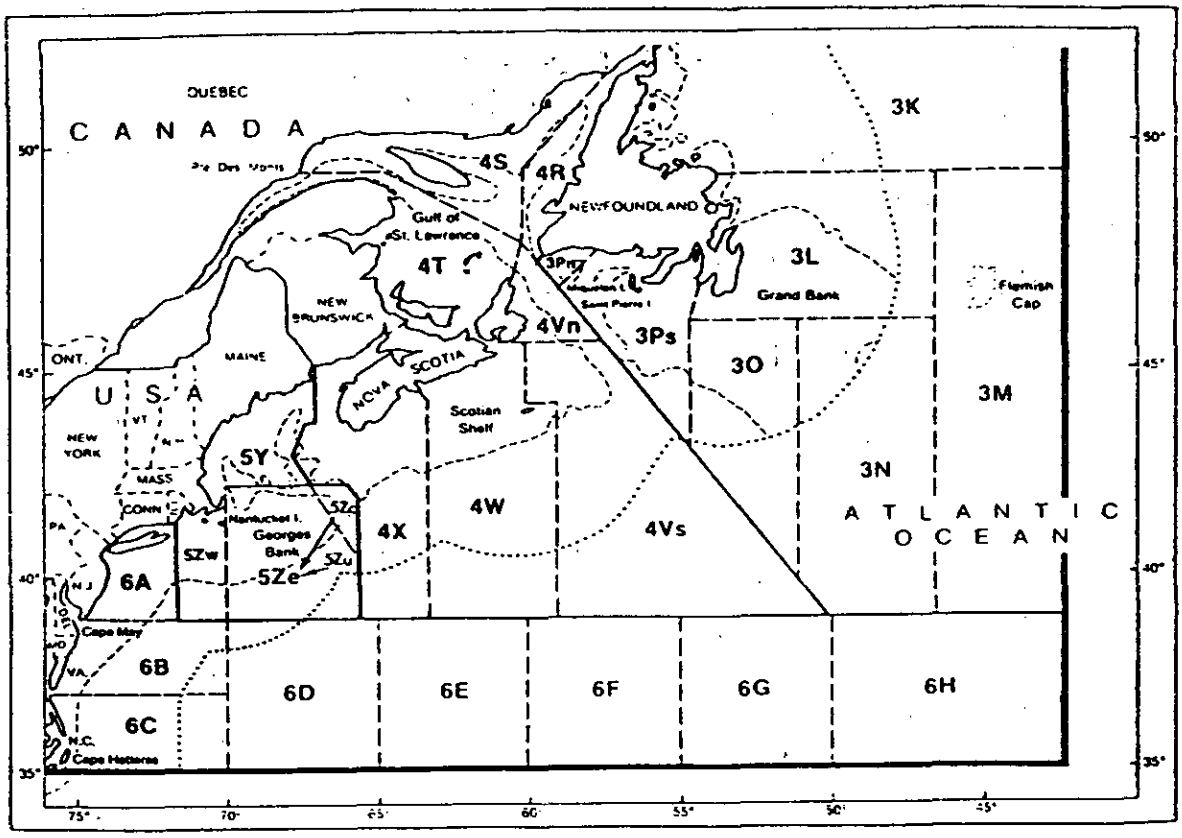
Table 8. Estimates of fishing mortality (F), stock size (thousands of fish) and stock biomass (metric tons) derived from Virtual Population Analysis [VPA] for Georges Bank cod (NAFO Division 5Z and Statistical Area 6), 1978 - 1989.

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
						YEAR						
						FISHING MORTALITY						
1	-	0.002	0.007	0.001	0.029	0.013	0.003	0.022	0.004	0.002	0.001	-
2	0.165	0.099	0.238	0.342	0.447	0.440	0.216	0.390	0.251	0.277	0.169	0.193
3	0.408	0.408	0.469	0.526	0.625	0.587	0.722	0.716	0.488	0.488	0.527	0.572
4	0.375	0.494	0.375	0.382	0.610	0.670	0.584	0.673	0.584	0.431	0.742	0.574
5	0.375	0.320	0.454	0.228	0.550	0.646	0.543	0.714	0.542	0.399	0.623	0.542
6	0.105	0.382	0.667	0.505	0.544	0.634	0.645	0.695	0.610	0.599	0.740	0.462
7	0.349	0.143	0.882	0.543	0.528	0.888	0.814	0.662	0.387	0.553	0.987	0.528
8	0.322	0.481	0.280	0.380	0.448	0.471	0.677	0.968	0.501	0.509	1.075	0.667
9	0.227	-	0.648	0.889	0.610	0.648	0.702	0.805	0.633	0.496	1.192	0.700
10	0.322	0.372	-	0.427	0.551	0.649	0.664	0.738	0.519	0.496	0.782	0.558
11+	-	0.372	-	-	0.551	0.649	0.664	0.738	0.519	0.496	0.782	0.558
F(3-8,U)	0.322	0.372	0.521	0.427	0.551	0.649	0.664	0.738	0.519	0.496	0.782	0.558
F(3-8,W)	0.389	0.437	0.490	0.468	0.591	0.606	0.650	0.709	0.511	0.462	0.569	0.564

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
						STOCK SIZE							
1	27245	22932	17823	42463	18220	9308	28587	8176	42713	13779	18527	[41000]	[18300]
2	3195	22306	18738	14496	34738	14490	7523	23332	6550	34830	11255	15154	[33568]
3	25051	2218	16534	12094	8429	18199	7639	4964	12929	4172	21626	7781	10232
4	7663	13645	1208	8466	5852	3695	8288	3037	1986	6499	2098	10453	3595
5	2926	4312	6815	680	4729	2605	1548	3783	1268	907	3458	818	4819
6	782	1647	2563	3544	443	2234	1118	736	1516	604	498	1518	390
7	1434	577	920	1077	1751	211	970	480	301	675	272	195	783
8	183	828	409	312	512	846	71	352	203	167	318	83	94
9	200	-	419	253	175	268	432	30	109	101	82	89	35
10	40	131	-	180	85	78	115	175	11	48	50	20	36
11+	-	57	-	-	126	87	126	46	70	17	42	18	18
TOTNO	68719	68653	65429	83565	75060	52021	56417	45111	67656	61799	58226	77129	71870
SPWNNO	33359	29756	30974	29057	31080	27543	20471	19565	18870	24249	26915	24608	29222

AGE	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
						STOCK BIOMASS AT AGE							
1	18064	15456	11193	29215	10003	7130	26100	5928	31479	6903	10820	[23944]	[9937]
2	2981	25808	21436	16265	38281	15534	9645	28139	7624	40855	11784	17124	[37495]
3	46920	3952	32110	22676	17440	33687	14736	9367	23789	7953	40355	14364	19165
4	24368	44483	3784	24533	17627	11565	24782	9634	5567	20778	6157	30835	10882
5	11273	18483	34011	3098	20321	11078	6671	16586	6044	4180	16399	3512	21917
6	3503	9416	14804	23107	2570	13195	6336	4403	9346	3972	3089	9012	2432
7	9224	3974	7251	8085	14607	1508	7367	3591	2317	5415	2236	1442	6175
8	1394	7279	3697	2869	4769	8349	627	3431	1835	1582	3005	801	895
9	2037	-	4515	2875	1944	2863	4679	333	1268	1067	830	962	368
10	511	1710	-	2668	1314	987	1381	2111	146	623	611	249	449
11+	-	978	-	-	2188	1503	2179	795	1216	290	729	310	311
TOTBIO	120275	131539	132801	135391	131064	107399	104503	84318	90631	93618	96015	102555	110337
SPWNBIO	84682	89926	92451	83642	83784	74769	61731	51788	46378	54345	62960	58762	66366

Spawning stock numbers and biomass are at spawning time (i.e., March 1).



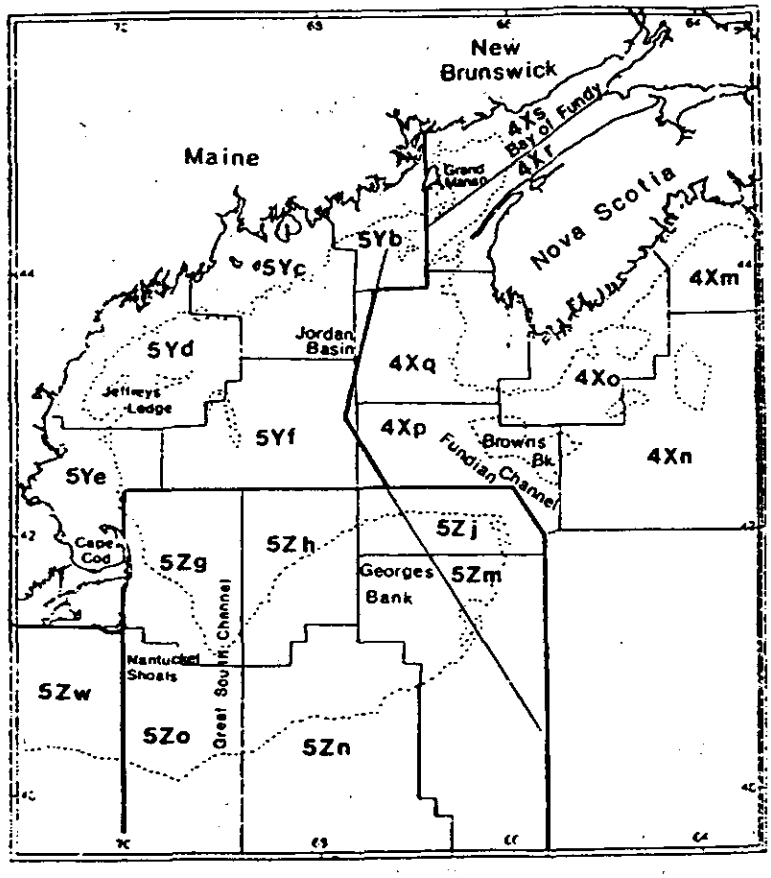


Figure 1. Maps of the Northwest Atlantic showing NAFO areas (upper map) and unit areas on Georges Bank (lower map).

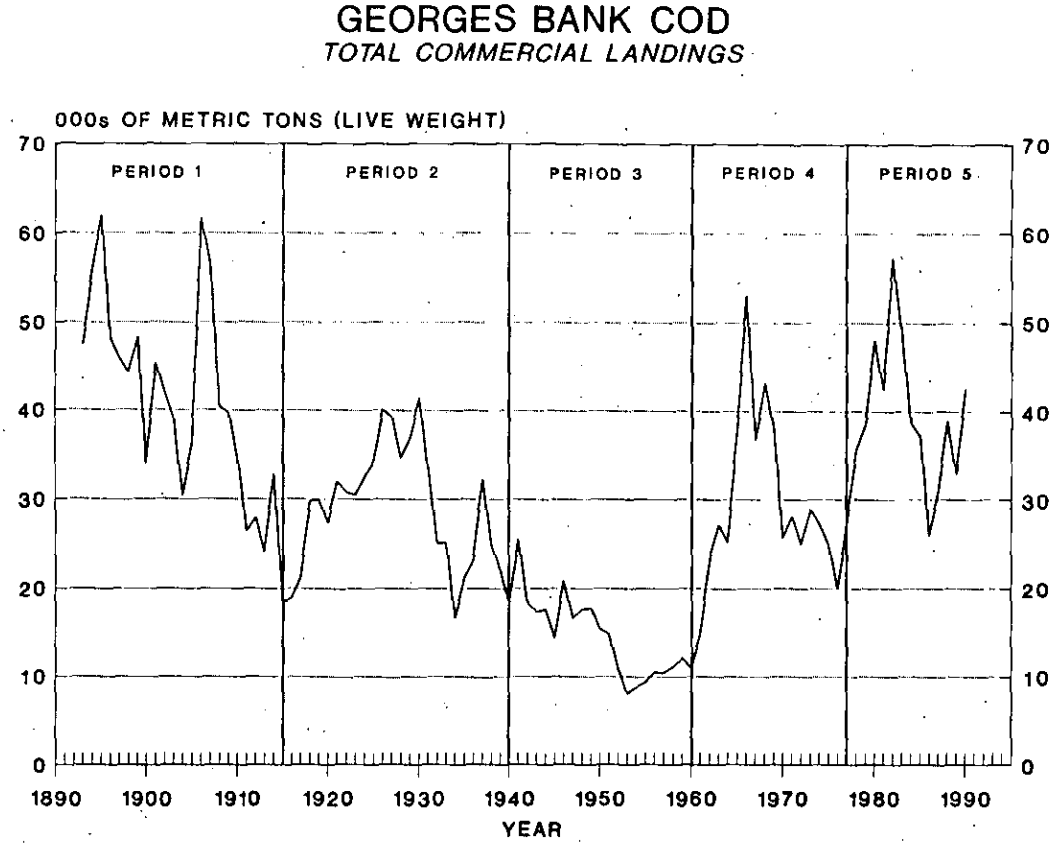


Figure 2. Total commercial landings of cod from Georges Bank, 1893 - 1990.

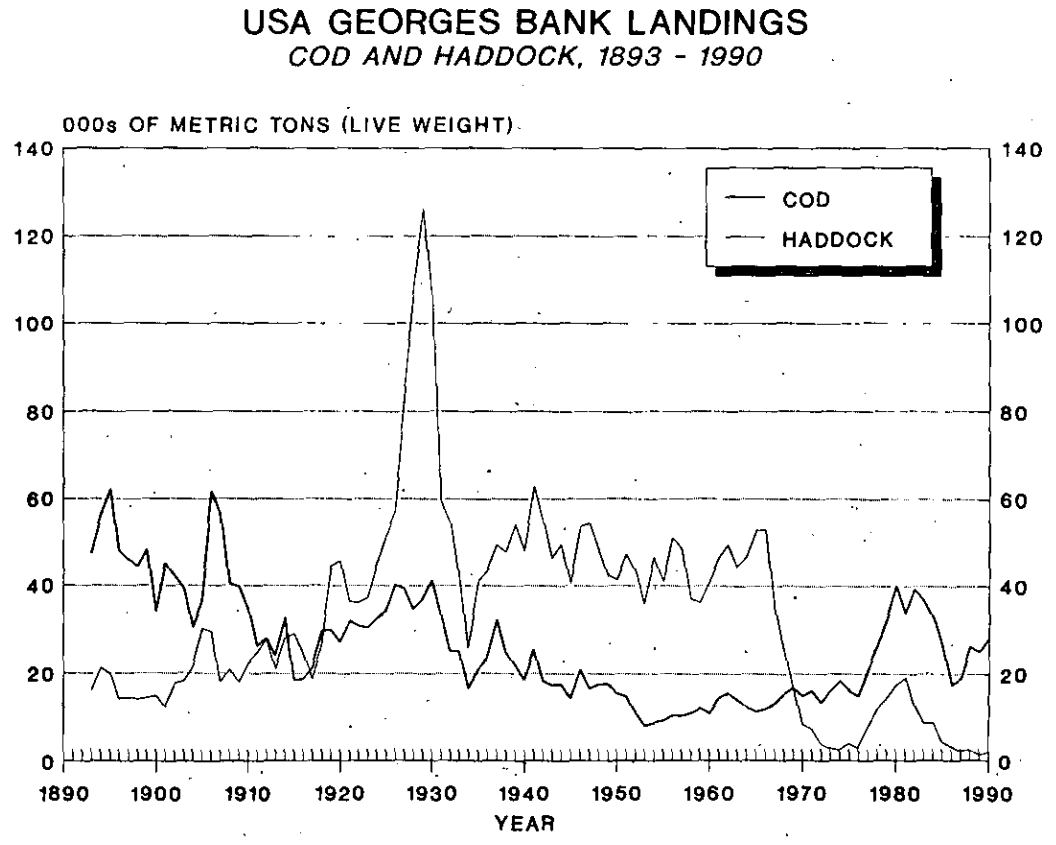


Figure 3. USA commercial landings of cod and haddock from Georges Bank, 1893 - 1990.

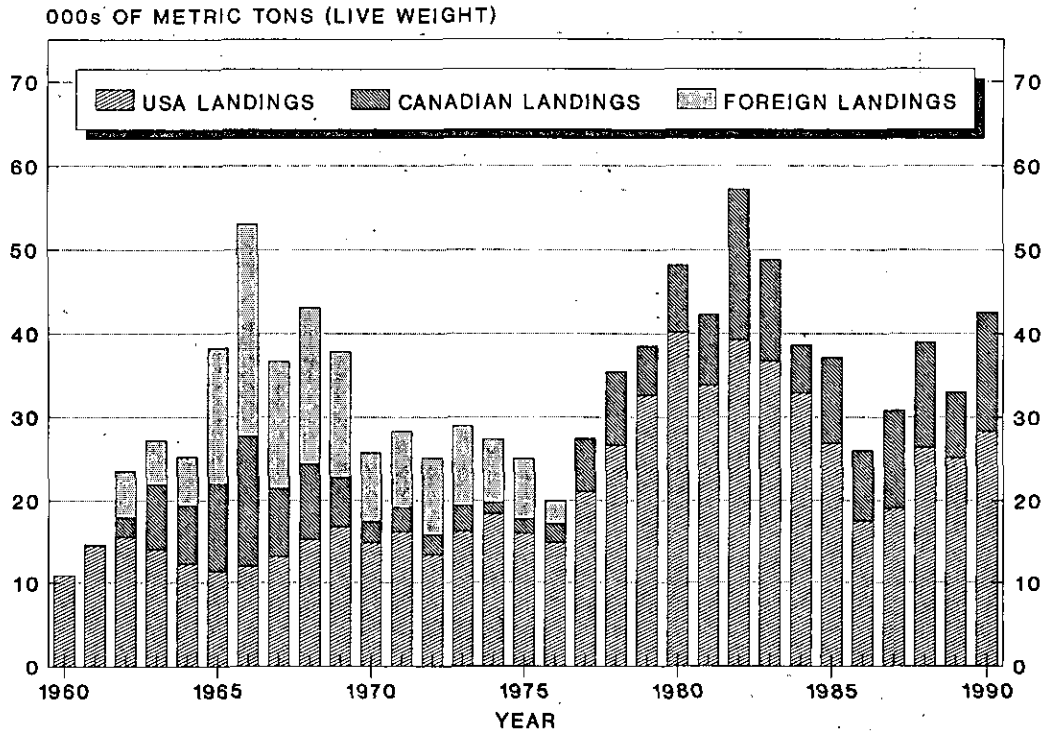


Figure 4. Total commercial landings of cod from Georges Bank (Div 5Z and Subarea 6), 1960 - 1990.

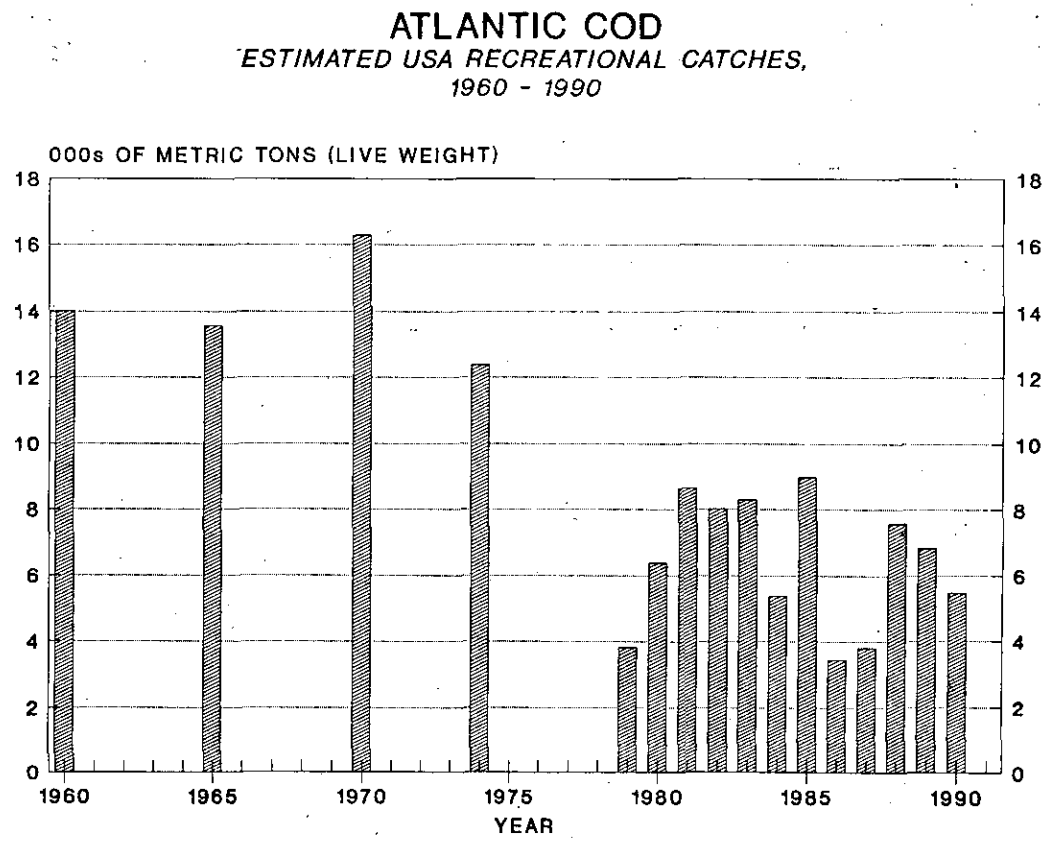


Figure 5. Estimated USA recreational catches of Atlantic cod in 1960, 1965, 1970, 1974 and 1979 - 1990.

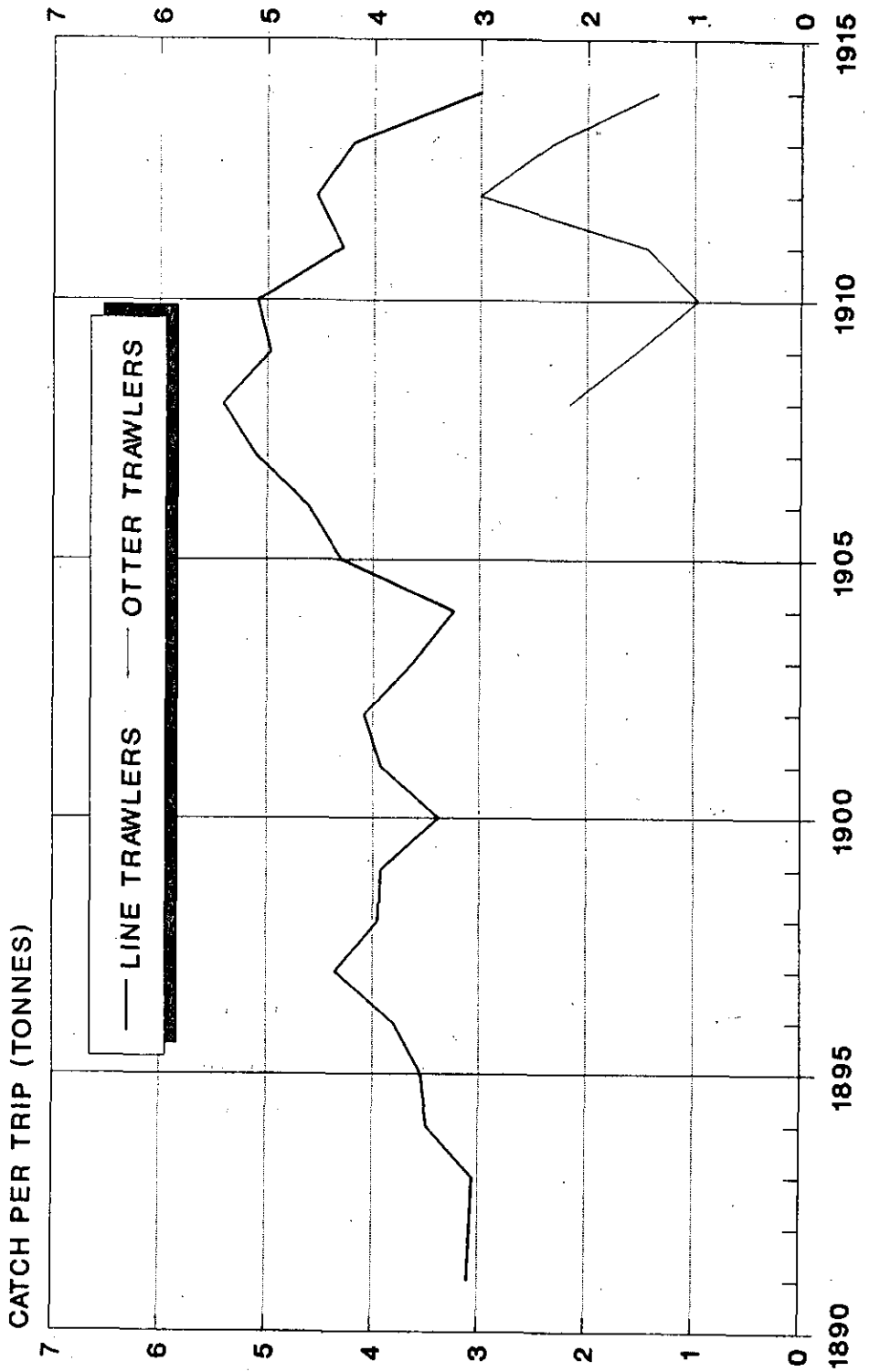
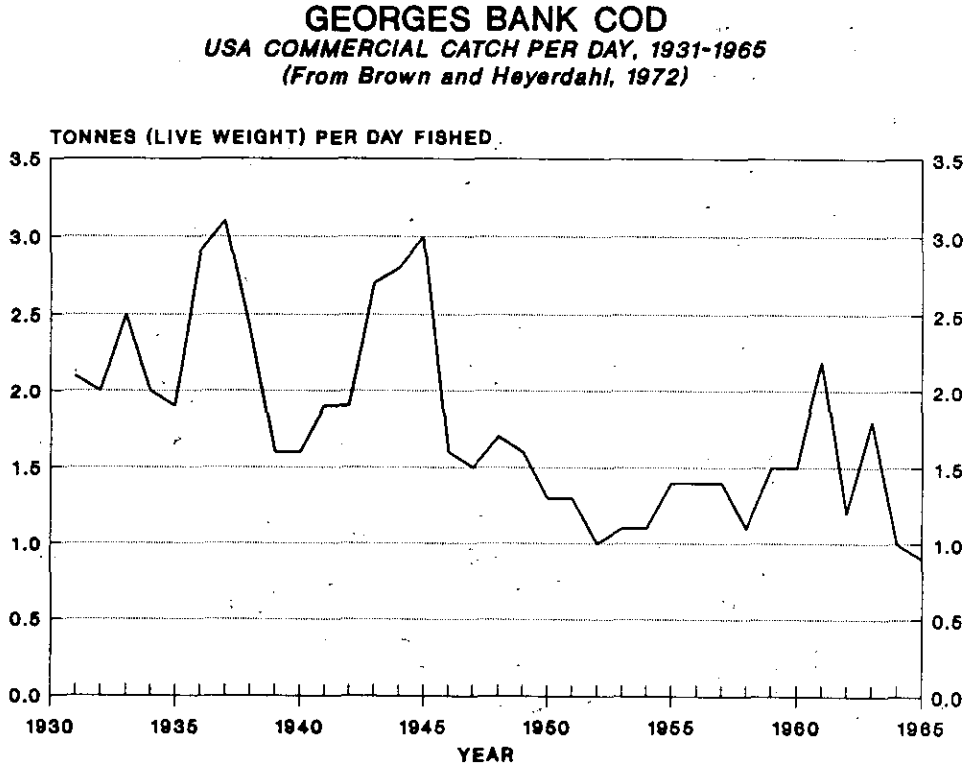


Figure 6. Commercial catch (tonnes) per trip of Georges Bank cod by line trawl and otter trawl vessels, 1891 - 1914.



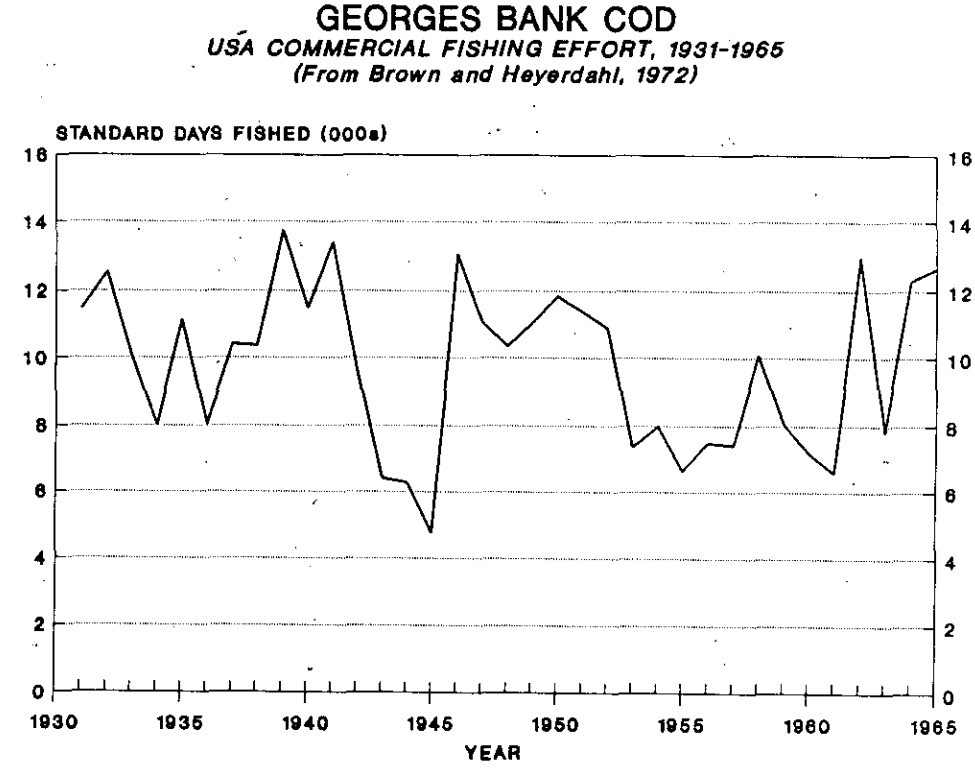


Figure 7. Commercial catch (tonnes) per day fished of Georges Bank cod and annual fishing effort for Georges Bank cod, 1931 - 1965.

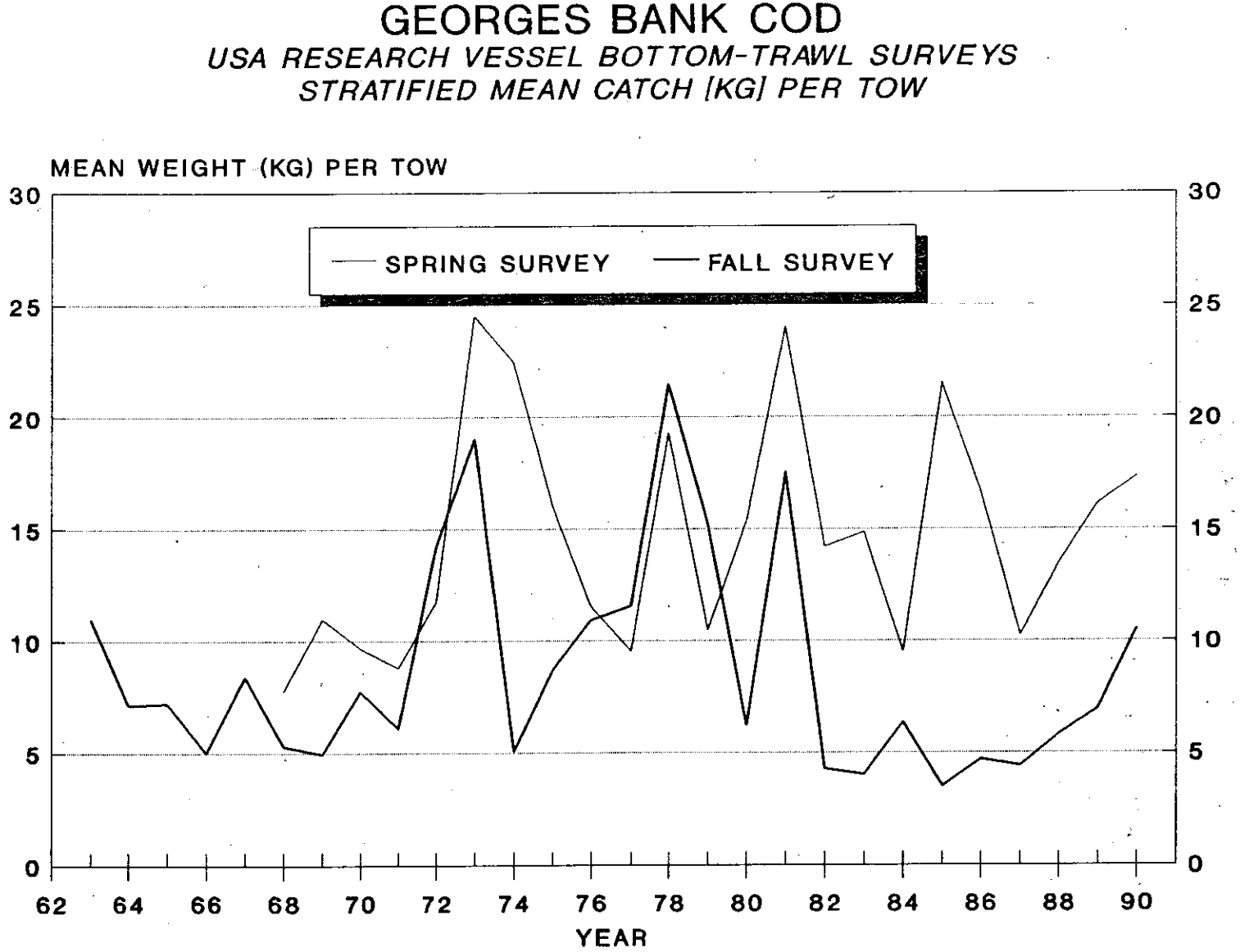


Figure 8. Stratified mean catch (kg) per tow of cod in USA spring and autumn research vessel surveys on Georges Bank, 1963 - 1990.

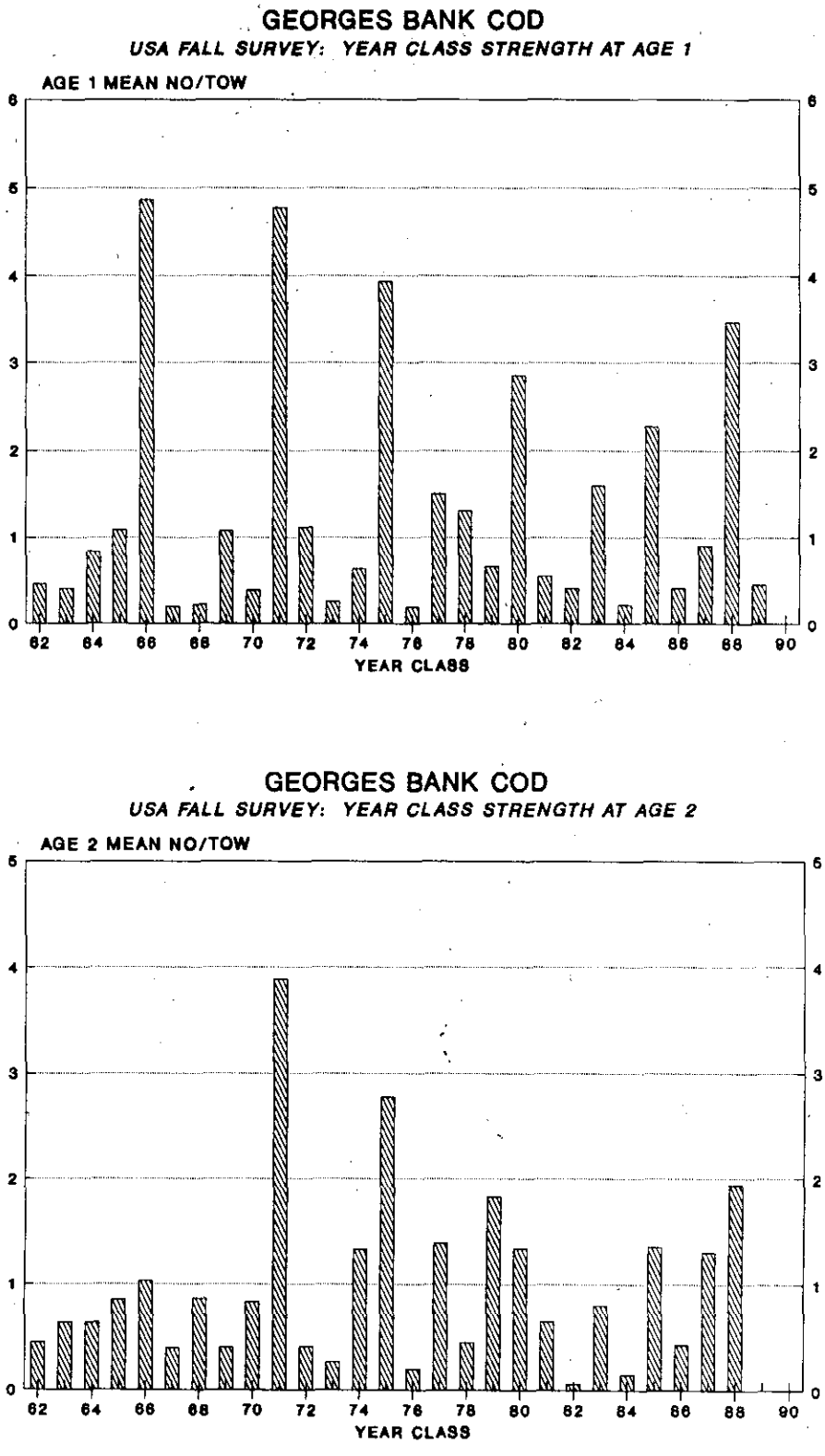


Figure 9. Relative year class strength of Atlantic cod on Georges Bank at age 1 (upper) and age 2 (lower) based on catch per tow indices from USA autumn bottom trawl surveys.

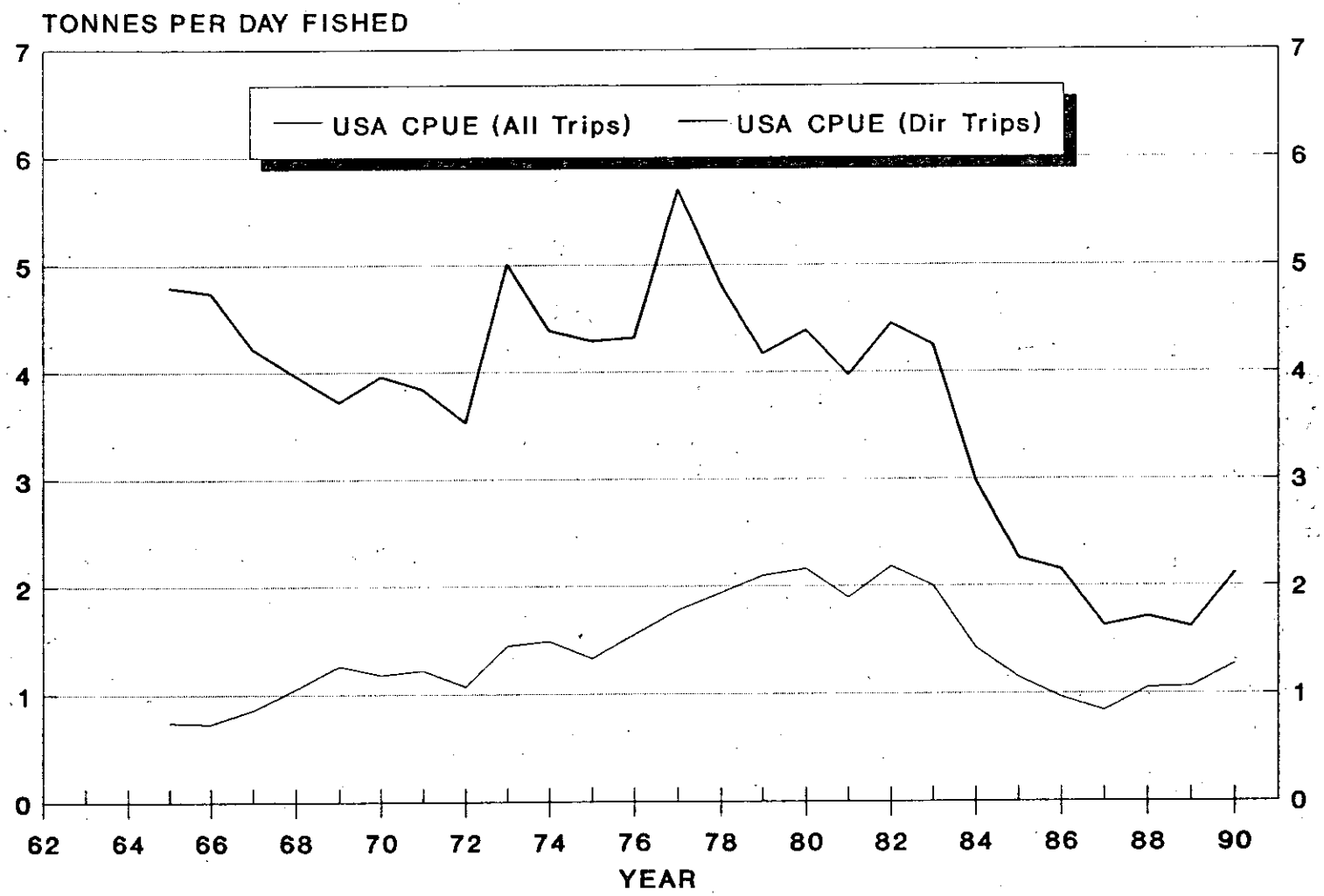


Figure 10. Trends in USA commercial catch (tonnes) per day fished of Georges Bank cod. Data are based on all otter trawl trips in which cod were caught ('All Trips') and for otter trawl trips in which cod comprised 50% or more of the trip catch, by weight ('Directed Trips').

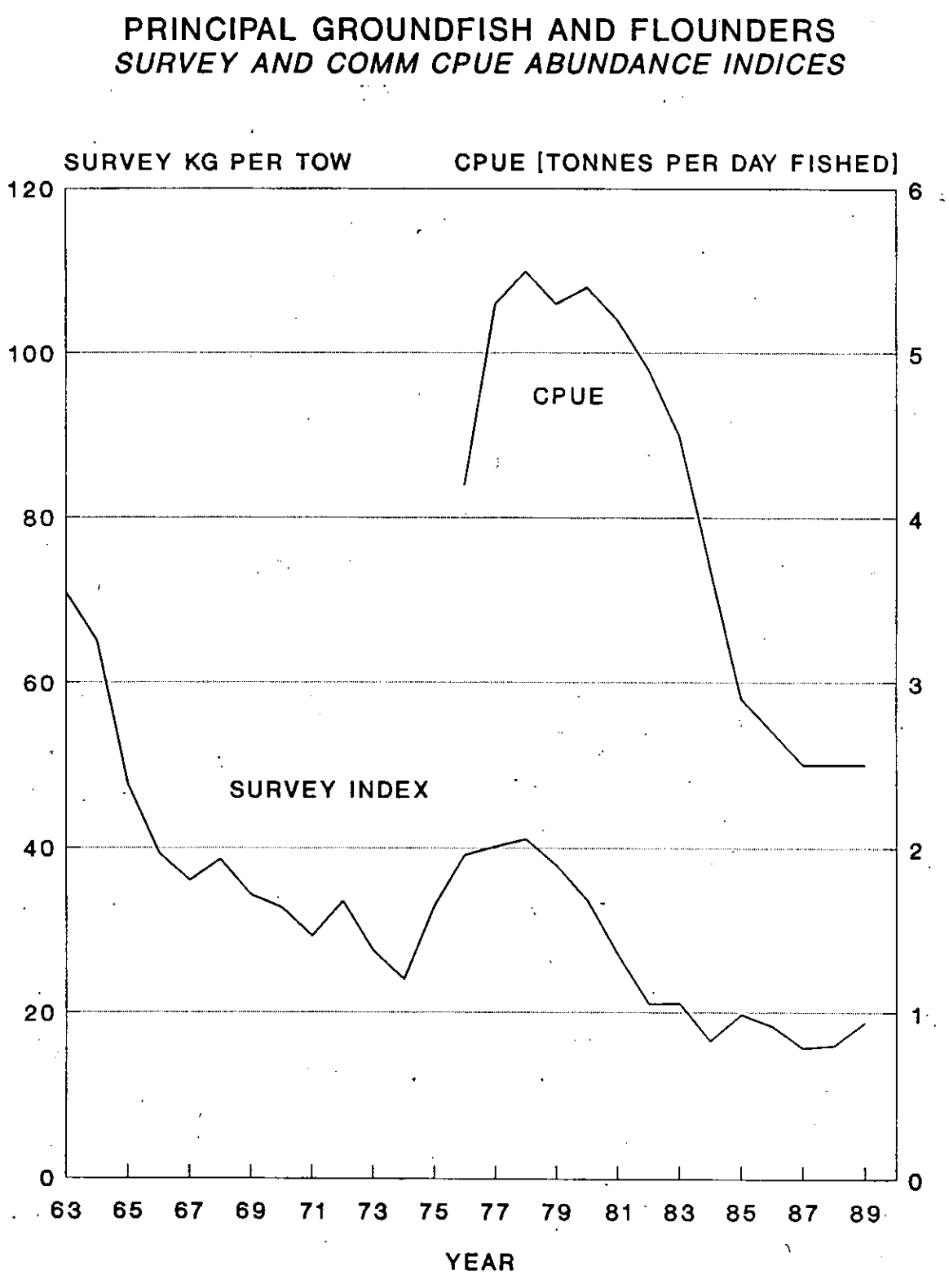
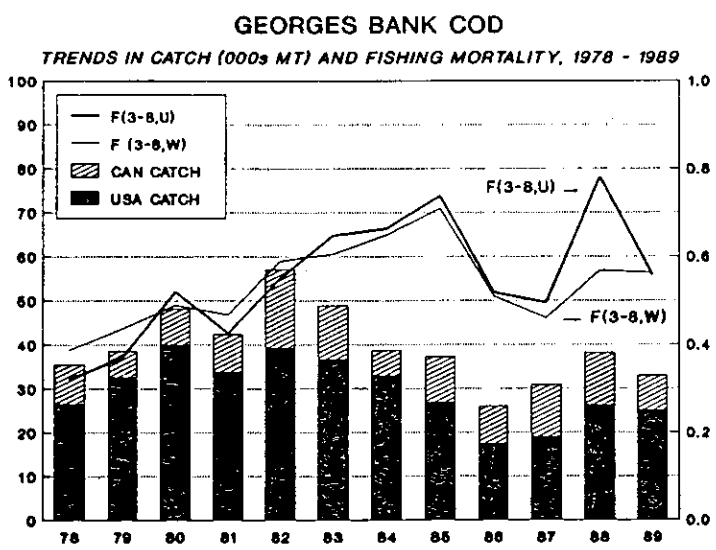
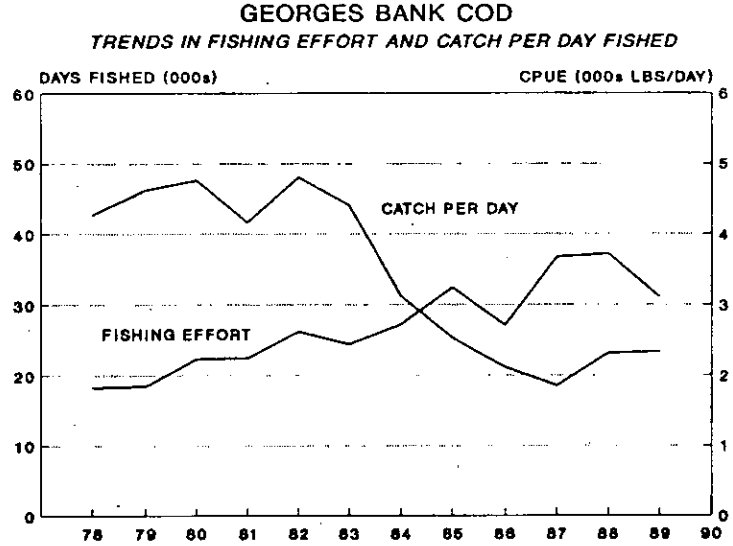
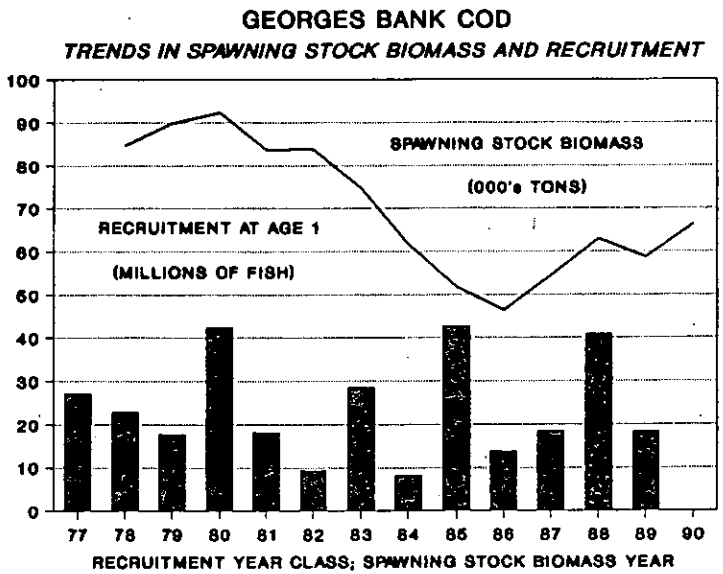


Figure 11. Indices of abundance of principal groundfish and flounders off the New England coast from USA autumn bottom trawl surveys, and from commercial catch per unit of effort, 1963 - 1989.







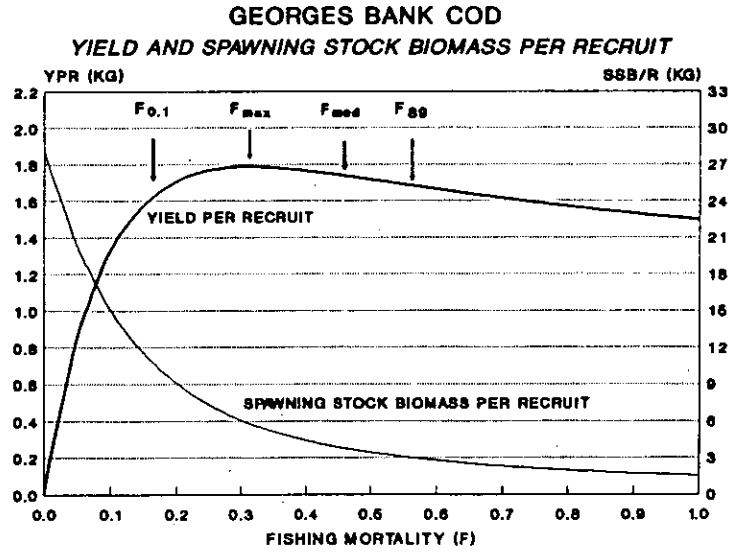


Figure 12. Stock assessment summary diagrams for Georges Bank cod from the 1990 USA assessment (Serchuk and Wigley 1990; NEFC 1990).