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Assessment and Management of the Georges Bank Cod Fishery: An Historical Review and Evaluation

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Abstract

Atlantic cod (*Gadus morhua*) in the Georges Bank region have been commercially exploited since the 17th century and continue as the mainstay of the New England commercial and recreational groundfish fisheries today. Throughout most of its history, the Georges Bank cod fishery was unregulated and growth in the fishery did not appear to exceed resource potential. An historical review of assessment activities and management programs reveals that the Georges Bank cod stock seemed resilient to heavy fishing pressure until the early- and mid-1980s when landings, fishing effort and fishing mortality approached or attained record-high levels. Management plans enacted independently by the USA and Canada under extended fisheries jurisdiction have not been very successful in preventing overfishing of Georges Bank cod. Different management objectives and a lack of compatible management strategies and approaches between the two countries have exacerbated the situation. Both the USA and Canada now recognize that cooperative and coordinated management actions are needed to avert overfishing and rebuild transboundary fishery resources, including Georges Bank cod.

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 with 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 influenced more by cod 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 commercial 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 1988–90, USA Georges Bank cod landings (26 500 tons per year) 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 2 000 tons per year since 1986 (Recreational Fishery Statistics Working Group, MS 1992).

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 1950–76, and (2) USA and Canadian domestic management activities enacted under extended fisheries jurisdiction from 1977 onward.

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, MS 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, MS 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 determined, and hence the existence of a Middle Atlantic subpopulation remains to be confirmed. Serchuk and Wood (MS 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 scarcity of juvenile cod in inshore and offshore research vessel surveys in the Southern New England-Middle Atlantic region, Serchuk and Wood (MS 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 and in Southern New England [ICNAF/NAFO Div. 5Z (eastern Georges Bank to Long Island, New York); Fig. 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 GeorgesBank 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, MS 1987; Hunt, MS 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; Fig. 1); and (2) central and western Georges Bank cod (the remainder of Div. 5Z and Subarea 6) (Hunt, MS 1989). As such, from 1989 onwards, Canada has treated the cod on Georges Bank as being comprised of two separate units (CAFSAC, MS 1989; Halliday and Pinhorn, 1990).

Commerical 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, 1887.

Technological innovations and changes in consumer preferences have strongly influenced commercial landings of cod from Georges Bank (Jensen,

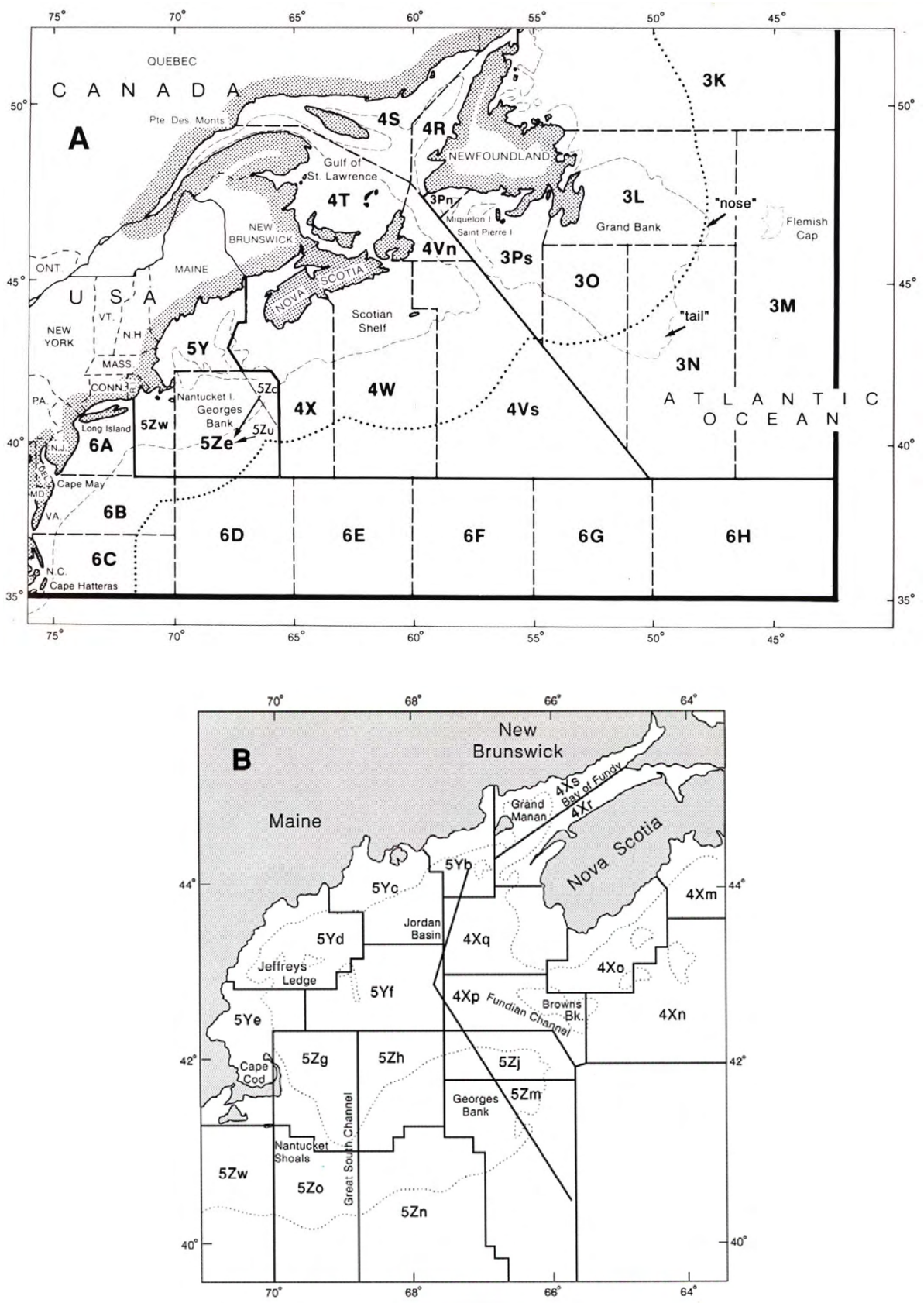

Fig. 1. (**A**) Map showing NAFO Subareas 3–6, and (**B**) statistical unit areas on Georges Bank.

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 lb 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 19th century; in 1880, more than 12 000 tons 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 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 commercial landings statistics of Georges Bank cod is available from 1893 onward (1893–1931, Subarea 5; 1932–59, Div. 5Z; 1960–90, Div. 5Z and Subarea 6). Historically, the fishery can be divided into five time-periods (Fig. 2):

1) an early era from 1893 to 1914 in which record-high landings (>60 000 tons) 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 to 1940 in which annual landings fluctuated between 20 000–40 000 tons and during which cod was generally taken as a by-catch in the Georges Bank haddock fishery. 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 (Fig. 3) and the preeminence of haddock over cod in the marketplace (Sette and Fiedler, 1929; Jensen, 1967).

3) the 1940–60 period when landings declined, 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 (in the early part of the period) and a redirection of fleet effort towards the relatively more abundant haddock resource.

4) the1960–76 period in which Canadian and distant-water fleet fisheries for Georges Bank cod developed (Table 1; Fig. 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 tons). However, landings sharply declined afterward reaching only 20 000 tons 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 tons), declined to only 26 000 tons in 1986, but have since increased to 42 500 tons in 1990.

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, 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 more 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 tons (1986) and 16 300 tons (1970) (Table 2; Fig. 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). Between 1981 and 1985, annual recreational cod landings exhibited little variability; apart from 1984, annual catches ranged between 8 000–9 000 tons, and averaged 8 500 tons per year. Recreational catches declined in 1986 and 1987 to less than 4 000 tons, but have since increased to between 5 000 tons and 7 700 tons.

Preliminary estimates of recreational catches of cod by stock unit have recently been derived using

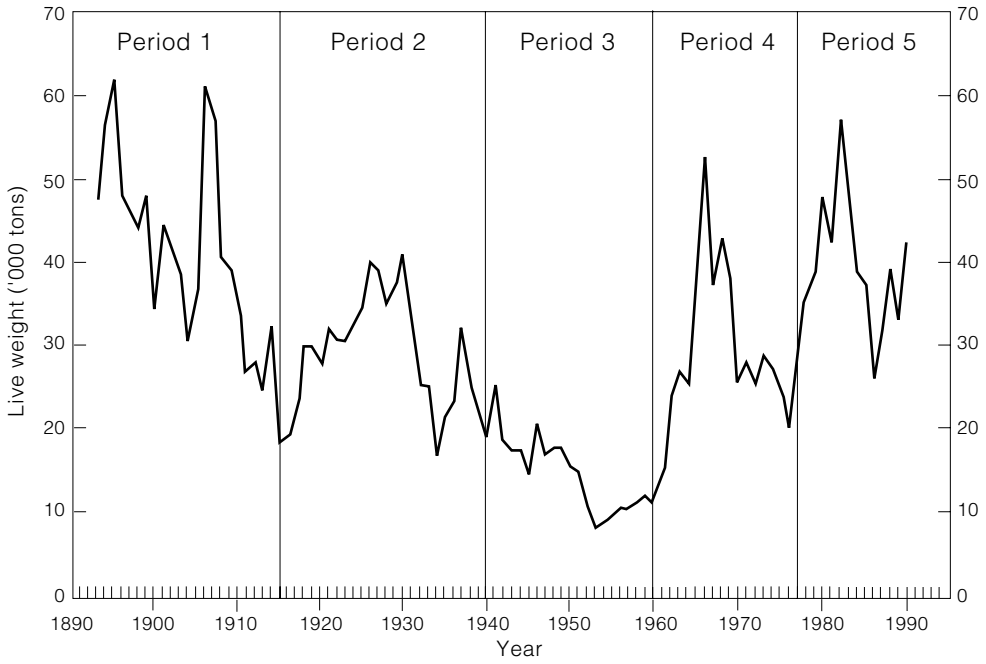

Fig. 2. Total commercial landings of cod from Georges Bank, 1893-1990.

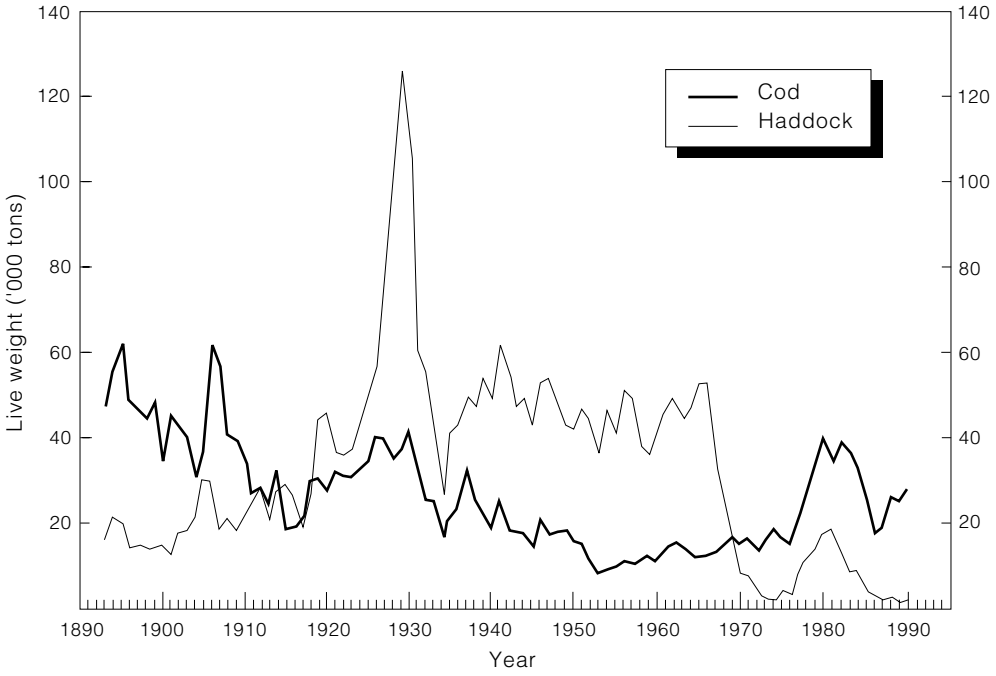

Fig. 3. USA commercial landings of cod and haddock from Georges Bank, 1893-1990.

landing site information (from the field surveys) to allocate catches between the Gulf of Maine and Georges Bank stocks (Recreational Fisheries Statistics Working Group, MS 1992). Between 1981 and 1985, estimated catches from the Georges Bank stock (Div. 5Z and Subarea 6) ranged between 2 400 tons and 5 300 tons and averaged 4 400 tons per year (Table 2). Since 1986, however, recreational catches of Georges Bank cod have averaged just 2 000 tons per year, and accounted (apart from 1988) for only a third of the total USA recreational cod landings (Fig. 5).

TABLE 1. Commercial landings (tons, live) of Atlantic cod from Georges Bank and South (Div. 5Z and Subarea 6), 1960–90.

	Country						
Year	USA	Canada	USSR	Spain	Poland	Other	Total
1960	10 834	19	–	–	–	–	10 853
1961	14 453	223	55	–	–	–	14 731
1962	15 637	2 404	5 302	–	143	–	23 486
1963	14 139	7 832	5 217	–	–	1	27 189
1964	12 325	7 108	5 428	18	48	238	25 165
1965	11 410	10 598	14 415	59	1 851	–	38 333
1966	11 990	15 601	16 830	8 375	269	69	53 134
1967	13 157	8 232	511	14 730	–	122	36 752
1968	15 279	9 127	1 459	14 622	2 611	38	43 136
1969	16 782	5 997	646	13 597	798	119	37 939
1970	14 899	2 583	364	6 874	784	148	25 652
1971	16 178	2 979	1 270	7 460	256	36	28 179
1972	13 406	2 545	1 878	6 704	271	255	25 059
1973	16 202	3 220	2 977	5 980	430	114	28 923
1974	18 377	1 374	476	6 370	566	168	27 331
1975	16 017	1 847	2 403	4 044	481	216	25 008
1976	14 906	2 328	933	1 633	90	36	19 926
1977	21 138	6 173	54	2	–	–	27 367
1978	26 579	8 778	–	–	–	–	35 357
1979	32 645	5 978	–	–	–	–	38 623
1980	40 053	8 063	–	–	–	–	48 116
1981	33 849	8 499	–	–	–	–	42 348
1982	39 333	17 824	–	–	–	–	57 157
1983	36 756	12 130	–	–	–	–	48 886
1984	32 915	5 763	–	–	–	–	38 678
1985	26 828	10 443	–	–	–	–	37 271
1986	17 490	8 411	–	–	–	–	25 901
1987	19 035	11 845	–	–	–	–	30 880
1988	26 310	12 932	–	–	–	–	39 242
1989	25 097	8 001	–	–	–	–	33 098
1990[a]	28 193	14 310	–	–	–	–	42 503

[a] Provisional.

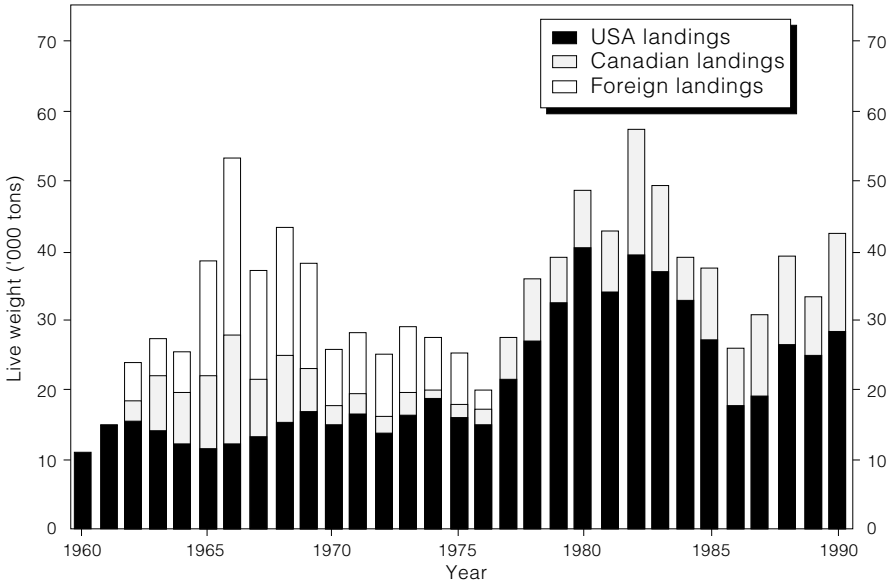

Fig. 4. Total commercial landings of cod from Georges Bank (Div. 5Z and Subarea 6), 1960–90.

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.

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." S. F. Baird, 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, 1987.

TABLE 2. Estimated number ('000) and live weight (tons) of Atlantic cod caught by marine recreational fishermen, in 1960, 1965, 1970, 1974 and 1979–90.

	North Atlantic[a,b]		Mid–Atlantic[b]		All Regions		Georges Bank Stock[c]	
Year	Numbers	Weight	Numbers	Weight	Numbers	Weight	Numbers	Weight
1960	3 998	11 426	793	2 590	4 791	14 016	Not Estimated	
1965	4 970	13 144	62	421	5 032	13 565	Not Estimated	
1970	3 690	16 188	154	104	3 844	16 292	Not Estimated	
1974	2 155	8 566	746	3 802	2 901	12 368	Not Estimated	
1979	3 083	3 762	8	55	3 091	3 817	393	580
1980	2 403	6 376	36	9	2 439	6 385	186	471
1981	4 440	7 281	482	1 367	4 922	8 648	1 605	4 677
1982	2 663	4 378	586	3 633	3 249	8 011	1 453	5 296
1983	3 511	7 432	244	852	3 755	8 284	1 693	4 920
1984	2 463	5 061	102	330	2 565	5 391	832	2 406
1985	3 611	8 644	62	338	3 673	8 982	1 998	4 635
1986	1 493	3 261	56	187	1 549	3 448	331	1 092
1987	1 851	3 217	158	464	2 009	3 681	467	1 168
1988	2 096	4 873	895	2 781	2 991	7 654	1 494	4 284
1989	2 133	3 822	330	1 208	2 463	5 030	538	1 875
1990	2 484	4 753	228	717	2 712	5 470	690	1 696

[a] During 1960, 1965 and 1970 marine recreational fishery statistics surveys in 'North Atlantic' included the States of Maine to New York; in subsequent surveys, 'North Atlantic' included only the States of Maine to Connecticut (i.e. excluding New York).

[b] 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.

[c] From Recreational Fishery Statistics Working Group (MS 1992).

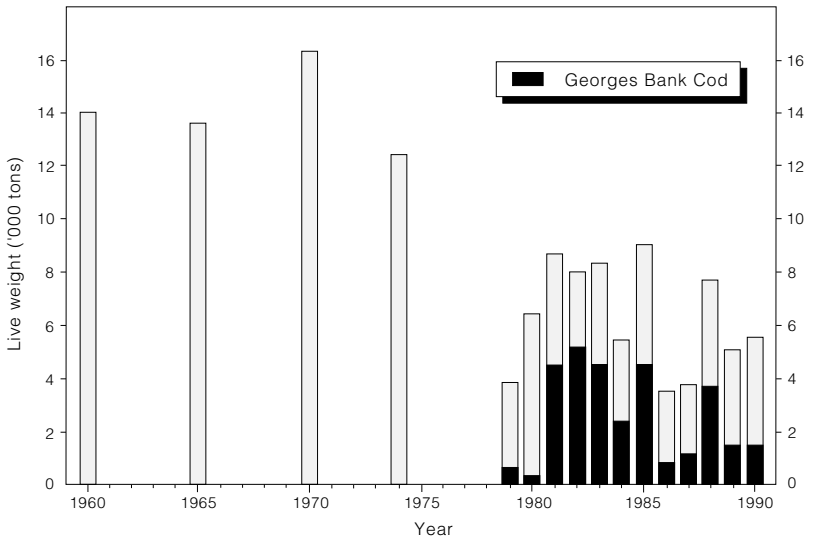

Fig. 5. Estimated USA recreational catches of Atlantic cod in 1960, 1965, 1970, 1974 and 1979–90. Estimated annual recreational catches of cod from the Georges Bank stock are shown for 1979–90.

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 from anecdotal reports 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 of 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-unit-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 (e.g. longline) CPUE had declined by 45% between 1908 and 1914, and that CPUE in 1914 was a record-low value (Fig. 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).

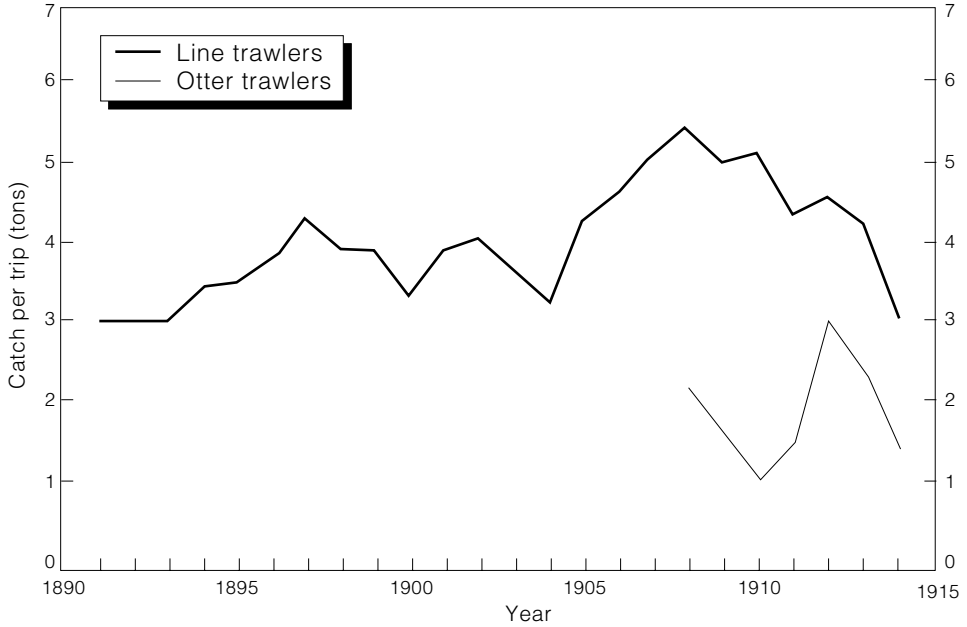

Fig. 6. Commercial catch per trip of Georges Bank cod by line trawl and otter trawl vessels, 1891 – 1914 (from Alexander *et al.*, 1915).

Between World War I and II, Georges Bank cod landings ranged between 20 000 and 40 000 tons, but most scientific attention during the period was focused on Georges Bank haddock. Haddock landings had dropped from over 120 000 tons in 1929 to 28 000 tons in 1934 (Fig. 3) at a time when the USA otter-trawl fleet had grown from 26 to 323 vessels (Sette and Fiedler, 1929; 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 4.75 inches (121 mm) and that a mesh size of 5 to 5.25 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 inches, 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 tons (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 declined. CPUE indices of cod [available from a 'Boston-based haddock study fleet' of large otter-trawlers fishing Georges Bank (Hennemuth, MS 1969; Brown, MS 1971; Brown and Heyerdahl, MS 1972)], peaked in 1937, 1945 and 1961 but declined during 1938–40, 1946–52, and 1962–65 (Fig. 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 (Fig. 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.*, MS 1989). Through these initiatives, it finally became possible to relate changes in cod landings to changes in stock abundance and fishing effort (Sette, 1928; North American Council on Fishery Investigations, 1932).

ICNAF-Era Assessments (1965–76). 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, MS 1977; Burns *et al.*, 1983). These developments, along with the implementation (in1963) of a standardized research vessel bottom-trawl survey program (Grosslein, 1969; Clark, 1979; Azarovitz, 1981) provided a basis for conducting assessments to evaluate 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, MS 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 1965–69 (Table 1; Fig. 4). However, there was 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 Sustainable Yield (MSY) was between 30 000 and 40 000 tons, and noted that annual landings of Subarea 5 cod had exceeded 40 000 tons 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, Fig. 8) and that the elevated catches during 1965–69 were primarily due to increased fishing effort (Brown and Heyerdahl, MS 1972; ICNAF, 1972). Results from a generalized production model suggested that MSY for Georges Bank cod was about 35 000 tons, 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 1964–71 appeared to be lower than in the 1931–63 period (Brown and Heyerdahl, MS 1972).

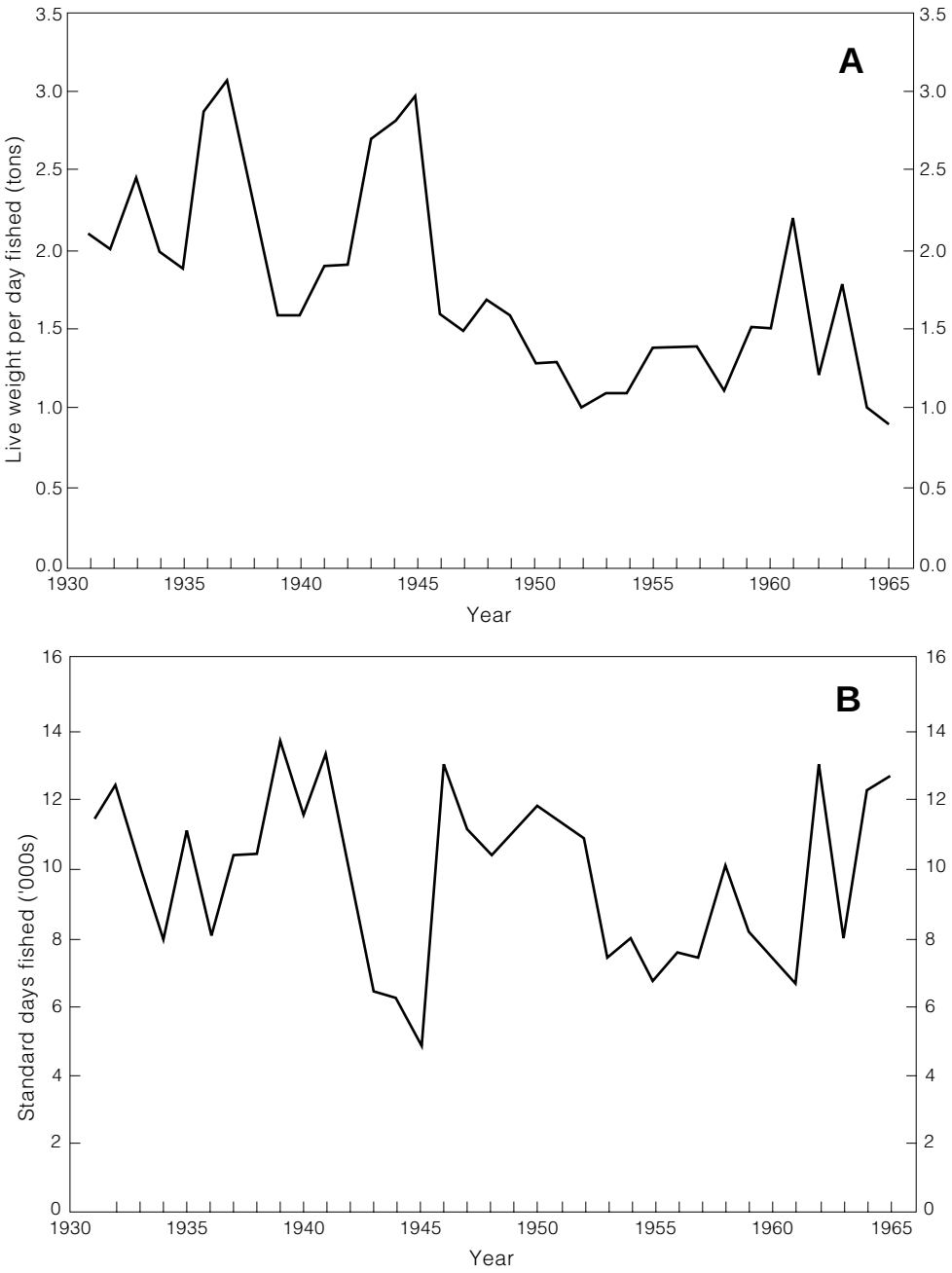

Fig. 7. (**A**) USA commercial catch per day fished of Georges Bank cod and (**B**) annual USA fishing effort for Georges Bank cod, 1931–65 (from Brown and Heyerdahl, MS 1972).

Although no new assessments were conducted from 1973 through 1975, ICNAF established a 35 000 tons Total Allowable Catch (TAC) in 1973 for Div. 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).

TABLE 3. Chronology of Assessment conducted on Georges Bank cod (all assessments are by USA scientists unless indicated otherwise).

Year	Area	Source	Results and Conclusions
1971	SA 5	Brown, MS 1971 ICNAF, 1971	Catch and 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 30 000–40 000 tons; 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 and Heyerdahl, MS 1972 Heyerdahl, MS 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 1931–63 mean; F_{max} = 0.3; MSY is about 35 000 tons; 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 35 000 tons, considered to be the long-term MSY; the 1972 catch was about 24 000 tons; No new evidence to change the TAC for 1974 from 35 000 tons; 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 28 500 tons, <35 000 tons 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 and 1976; catches from increased R will result in F_{MSY}, so maintain 35 000 tons TAC for 1975.
1975	Div. 5Z	ICNAF, 1975	No new assessment available; catches in 1965–75 averaged 34 300 tons and has been <30 000 tons since 1970; survey indices indicate a stable population since 1963; 1971 cohort is strong and subsequent cohorts are present but not as abundant; current F = 0.35 >F_{max}; updated CPUE data give MSY of 32 500 tons but no firm basis to change 35 000 tons TAC for 1986.
1976	Div. 5Z	Penttila and Gifford, 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 24 000 tons; at $F_{0.1}$, catch would be 15 000 tons; it is recommended that the TAC for 1977 be set at 15 000 tons.
1977	Div. 5Z & SA 6	Serchuk *et al.*, MS 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 to 1976; SSB(3+) declined by 50% between 1965 and 1977 (110 000 to 65 000 tons). 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.*, MS 1978	Stock sizes at age and Fs in 1977 and 1978 were projected from 1960 to 1976 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 and recreational and discards) of between 25 000 to 28 000 tons would be required.
1979	Div. 5Z & SA 6	Serchuk *et al.*, MS 1979	No VPA update; commercial landings in 1978 were 35 000 tons, the highest since 1969 but underestimate the catch due to high discarding and suspected unreported landings; recreational landings in 1977–78 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.
1980	Div. 5Z & SA 6	Serchuk *et al.*, MS 1980	No VPA update; 1979 commercial landings were 37 000 tons, 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 and Wood, MS 1981 Serchuk *et al.*, MS 1981	No VPA update; 1980 comm landings were 46 000 tons, highest since 1966; USA CPUE in 1977–80 was highest in 64–80 time series; spring 1980 survey indices higher than in 1979, but autumn 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 46 000 tons catch levels will reduce stock size.

TABLE 3. (Continued).

Year	Area	Source	Results and Conclusions
1982	Div. 5Z & SA 6	Serchuk *et al.*, MS 1982	No VPA update; 1981 comm landings were 42 000 tons, with 1978 cohort dominating catches; 1981 survey indices among the highest ever; 1977–80 cohorts appear above-average or strong; F (from survey catch per tow data) during 1964–81 ranged from 0.27 to 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 40 000 tons appear sustainable during next 2–3 years
1983	Div. 5Z & SA 6	Hurley and O'Boyle, MS 1983 (Canada)	SPA performed using 1960–76 #s-at-age from Serchuk *et al.* 1977; record-high 1982 commercial catch (58 000 tons); stock size (3+) in 1982 of 56 million fish, with F_{82} 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 45 000 tons.
1984	Div. 5Z & SA 6	Hunt and Waiwood, MS 1984 (Canada)	No SPA update, 1983 comm landings were 49 000 tons; Canadian CPUE in 1981–83 was 2x historical average; USA autumn survey indices declined to low levels in 1982 and 1983; 1983 cohort seems above-average; F_{83} assumed to be 0.40 from spring survey data, if 1984 catch is 45 000 tons, $F_{0.1}$ catch in 1985 would be about 20 000 tons.
1985	Div. 5Z & SA 6	Hunt and Waiwood, MS 1985 (Canada)	Revised SPA using comm catch-at-age data from 1978 to 1984; 1984 comm catch (39 000 tons) lowest since 1980; USA CPUE, stable from 1978 to 1983, 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 73 000 tons, the lowest in the series.
1986	Div. 5Z & SA 6	Serchuk and Wigley, MS 1986 NEFC, MS 1986	Revised VPA using comm catch-at-age data from 1978 to 1985; 1985 comm catch (37 000 tons) lowest in 7 years; USA CPUE has declined since 1982, with 1985 CPUE lowest ever; total fishing effort in 1985 was a record-high; autumn 1985 survey indices were among lowest observed; strong 1980 and 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 (96 000 to 46 000 tons); $F_{0.1}$ = 0.16, F_{max} = 0.28; At mean R, equilibrium yield at $F_{0.1}$ = 33 000 tons, at F_{max} = 35 000 tons, 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 and Gavaris, MS 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 F_{85} = 0.45 and F has declined slightly since 1982 (F_{82} = 0.51); stock biomass (3+) declined from 95 000 tons in 1980 to a record-low 62 000 tons in 1985; $F_{0.1}$ yield for the stock is less than 15 000 tons, which is exceeded by the 1985 USA catch (27 000 tons), and improvement in stock status will require bilateral management by the USA and Canada.
1987	Div. 5Z & SA 6	Hunt, MS 1987 (Canada)	SPA updated incorporating 1986 data; 1986 comm catch (26 000 tons) lowest since 1976, and 50% of 1982 catch (57 000 tons); USA CPUE declined in 1986 to a new record-low; Canadian CPUE in 1986 was slightly less than in 1985; USA autumn 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 Canadian surveys; SPA indicates F_{85} = 0 82 and F_{86} = 0.70 (highest in 78–86 series); stock biomass (3+) in 1985 and 1986 was a record-low 34 000 tons; stock rebuilding will not be possible without a bilateral USA/Canada management strategy to reduce F.
1988	Div. 5Z & SA 6	Serchuk, MS 1988 NEFC, MS 1989	VPA updated using data through 1987; 1987 comm catch (31 000 tons) 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 F_{87} = 0.95 (record-high) and about 2.5x greater than in 1978, SSB in 1987–88 were record-lows (about 30 000 tons), only one third 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 and 3), rebuilding of SSB has been precluded despite good R; SSB will decline in 1988 and 1989 unless F is reduced by 30%, SSB may be approaching a level where probability of strong R is low

TABLE 3. (Continued).

Year	Area	Source	Results and Conclusions
1988	Div. 5Z & SA 6	Hunt, MS 1988 (Canada)	SPA updated incorporating 1987 data; stock abundance indices are variable but all show a general decline; USA spring survey indices indicate decreasing abundance and autumn 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 Canadian relative CPUE indices trending downward since 1982; SPA results (using the ADAPT model) indicate F_{87} = 0.80 (record-high), 5x higher than $F_{0.1}$ (0.15) and 2x F_{78-80} (0.40); stock biomass (3+) in 1987 was only 25 000 tons, the lowest in the 1978–87 series, and one fourth of the biomass levels in 1978–80; although F far exceeds $F_{0.1}$ and F_{max}, the 1987 USA catch (19 000 tons) exceeds the estimated $F_{0.1}$ catch (8 000 tons) and without coordinated USA/Canada management action, it is unlikely that reductions in Canadian catches would result in stock rebuilding.
1989	Areas 5Zj & 5Zm	Hunt, MS 1989 (Canada)	1988 comm catch (20 000 tons) 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 Canadian 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 and Wigley, MS 1990 NEFC, 1990	VPA updated using data through 1989; 1989 comm catch (33 000 tons) dominated by strong 1985 cohort; fishing effort peaked in 1988 but declined slightly in 1989; USA survey indices increased in both 1988 and 1989, and indicated strong R from 1987 and 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 66 000 tons (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, MS 1990 (Canada)	1989 comm catch (14 000 tons) lowest since 1986 and dominated by 1985 and 1987 cohorts; SPA (tuned using ADAPT) indicated the 3+ F_{89} =0.29, a record-low value mostly because of an early closure of the Canadian trawl fishery; 1990 stock biomass (3+) was 69 000 tons, well above 1978–90 mean (49 000 tons); F_{90} is expected to be 0.39 and F_{91} will range between 0.2–0.4, depending on catch options ($F_{0.1}$, 50% rule in 1991; catch 91 = catch 90).
1991	Div. 5Z & SA 6	Serchuk *et al.*, MS 1991 NEFC, MS 1992	VPA updated using data through 1990, using revised Canadian catch-at-age data from 1978–90 and standardized USA bottom-trawl survey indices; 1990 comm catch (43 000 tons) highest since 1983 and dominated by 1985, 1987 and 1988 cohorts; USA CPUE in 1990 increased to its highest level since 1983; USA survey indices increased in 1990, and spring 1991 survey indicated strong R from 1988 and 1990 cohorts; VPA results (using ADAPT tuning) indicate F_{4-8} peaked at 0.80 in 1988, and F_{90} = 0.71. SSB (using revised maturity ogives for 1978–90) declined 40% between 1980 and 1985/86, but has since increased to 75 000 tons in 1990 (the highest level since 1983) due to the recent strong recruitment; $F_{0.1}$ = 0.16; F_{max} = 0.30; $F_{20\%}$ = 0.36; F_{med} = 0.57.
	Areas 5Zj & 5Zm	Hunt *et al.*, MS 1991 (Canada)	1990 total comm catch (21 000 tons) highest since 1983 and dominated by 1985 and 1987 cohorts; SPA (tuned using ADAPT) indicated the 3+ F_{90} = 0.40 (about the same level as during 1986–88) and a stock biomass (3+) at the beginning of 1991 of 71 000 tons, well above 1978–90 mean (49 000 tons); F_{91} is expected to be 0.42 and F_{92} will be either 0.30 or 0.46, depending on catch options (50% rule in 1992; catch 92 = catch 91); Partitioning of total advised catch between Canada and the USA is required if management objectives are to be achieved.

The 35 000 tons TAC for Div. 5Z cod was maintained during 1974–76, but annual catches never exceeded 27 000 tons 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 inches), 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, MS 1979).

The 1976 Georges Bank (Div. 5Z) 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

TABLE 4. Standardized 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), 1963-90[a,b,c].

	Spring		Autumn	
Year	No./Tow	Wt./Tow	No./Tow	Wt./Tow
1963	–	–	4.37	17.8
1964	–	–	2.98	11.6
1965	–	–	4.25	11.7
1966	–	–	4.81	8.1
1967	–	–	10.38	13.6
1968	4.72	12.6	3.30	8.6
1969	4.64	17.8	2.20	8.0
1970	4.34	15.6	5.07	12.5
1971	3.39	14.2	3.19	9.9
1972	8.97	19.0	13.09	23.0
1973	18.68[d]	39.7[d]	12.28	30.8
1974	14.75	36.4	3.49	8.2
1975	6.89	26.0	6.41	14.1
1976	7.06	18.6	10.44	17.7
1977	6.30	15.4	5.45	12.5
1978	12.31	31.2	8.59	23.3
1979	5.16	16.9	5.95	16.5
1980	7.75	24.9	2.91	6.7
1981	10.44	26.1	9.04	19.0
1982	8.20[e]	15.4[e]	3.71	6.9
1983	7.70	24.0	3.64	6.5
1984	4.08	15.4	4.75	10.3
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	13.5	3.11	5.8
1989	4.80	10.8	4.78	4.6
1990	4.74	11.6	3.62[f]	7.1[f]
1991	4.39	9.0		

[a] During 1963–84 spring and autumn surveys, BMV oval doors were used; since 1985, Portuguese polyvalent doors have been used. Adjustments have been made to the 1963-84 catch-per-tow data to standardize to polyvalent door equivalents. Conversion coefficients of 1.56 (numbers) and 1.62 (weight) were used in the standardization (NEFC, MS 1991).

[b] R/V Delaware II was used in spring surveys during 1981–82 and 1989-91 and autumn surveys during 1977–81 and 1989–91 and, the R/V Albatross IV in all other years. Adjustments have been made to the R/V Delaware II catch-per-tow data to standardize these to R/V Albatross IV equivalents. Conversion coefficients of 0.79 (numbers) and 0.67 (weight) were used in the standardization (NEFC, MS 1991).

[c] Spring surveys during 1973–81 were accomplished with a '41 Yankee' trawl, in all other years with a '36 Yankee' trawl. No adjustments have been made to the catch-per-tow data for these gear differences.

[d] Excludes unusually high catch of 1 894 cod (2 558 kg) at Station 230 (Strata tow 20-4).

[e] Excludes unusually high catch of 1 032 cod (4 096 kg) at Station 323 (Strata tow 16-7).

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

1970–74 (when commercial catches had averaged 26 500 tons) 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 tons) 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 tons while fishing at $F_{0.1}$ would result in a catch of 15 000 tons. Although two very strong year-classes (1971 and 1975 cohorts) were evident in the stock (Table 5, Fig. 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 tons, corresponding to the $F_{0.1}$ catch. A 20 000 tons 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 tons 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. These would soon blossom, under USA extended jurisdiction, into a countless array of troublesome problems.

Management and Assessment Under Extended Jurisdiction (1977–90). In 1977, extended fisheries jurisdiction took effect in both the USA 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 'seriously depleted' stocks of these species (NEFMC, 1977). Regulations were enacted on an emergency basis in March

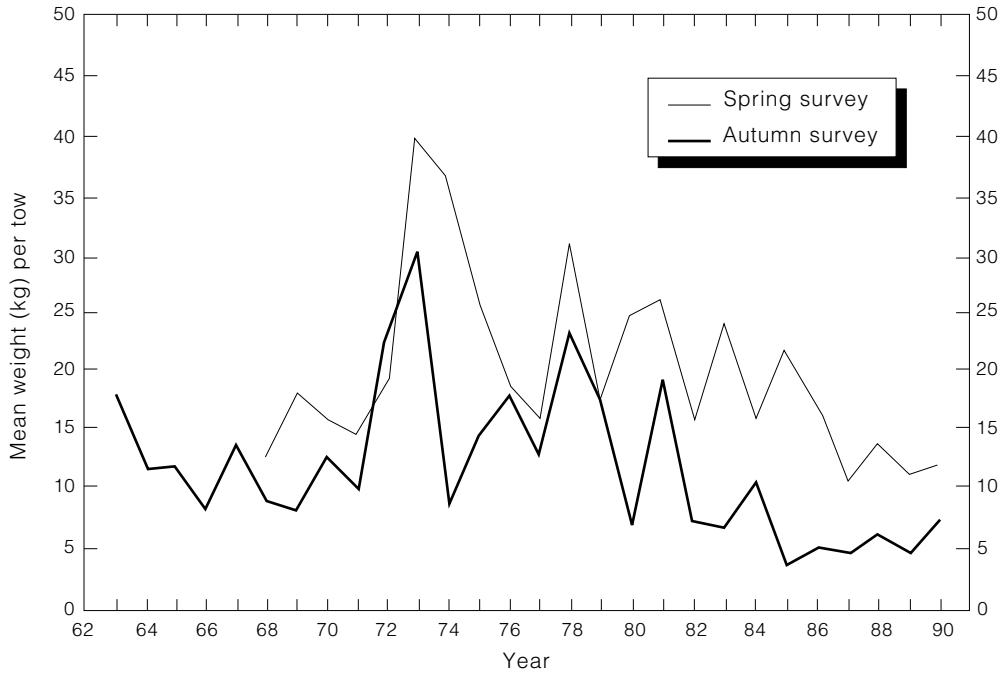

Fig. 8. Standardized stratified mean catch (kg) per tow of cod in USA spring and autumn research vessel surveys on Georges Bank, 1963–90.

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 (now encompassing Div. 5Z + Subarea 6): 20 000 tons commercial; 10 000 tons 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, Fig. 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.*, MS 1977). The estimated recreational catches were incorporated into a surplus production analysis which indicated an overall MSY of 50 000 tons for the Georges Bank cod stock (NEFMC, 1977) and also used in an initial VPA conducted in late-1977 (Serchuk *et al.*, MS 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.*, MS 1977). In retrospect, the inclusion of the existing recreational data in the assessment analyses conducted during Plan development and during 1977–78 (Serchuk *et al.*, MS 1978) was 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 tons 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 tons 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 tons (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 tons. This allowed further incidental (and rather large) catches of cod but when the amendment

TABLE 5. Standardized stratified mean catch-per-tow at age (numbers) of Atlantic cod in NEFC offshore spring and autumn bottom trawl surveys on Georges Bank, 1963–91[a,b,c].

	Age group											Totals					
Year	0	1	2	3	4	5	6	7	8	9	10+	0+	1+	2+	3+	4+	5+
Spring																	
1968	0.513	0.136	1.615	0.825	0.665	0.385	0.246	0 140	0.083	0.056	0.058	4.722	4 209	4.073	2.459	1.633	0.969
1969	0.000	0.123	0.546	1.760	0.888	0.451	0 326	0.215	0.128	0.072	0.112	4.641	4.641	4.518	3 972	2.192	1.304
1970	0.000	0.381	0.814	0.480	1.295	0.162	0.655	0.275	0 061	0 136	0.083	4.341	4.341	3.961	3.147	2.666	1.371
1971	0.000	0.207	0.819	0.502	0 223	0.585	0.142	0.351	0 304	0 080	0.175	3.388	3.388	3.181	2.362	1.660	1.636
1972	0.056	2.902	1.833	2.641	0 510	0.119	0.324	0 122	0.220	0.115	0 125	8 967	8.911	6.009	4.176	1.535	1.025
1973[d]	0.056	0.521	11.644	2.189	2 540	0.426	0.314	0.354	0.050	0.203	0.388	18.684	18.628	18.107	6.463	4 274	1.735
1974	0 000	0.446	4.557	5.972	0.761	2.003	0.440	0.101	0 257	0 034	0.175	14.747	14.747	14.301	9.744	3.772	3 011
1975	0 000	0.064	0 378	2.042	3.092	0.261	0.686	0 129	0.094	0.108	0 039	6.892	6.892	6.828	6 451	4.409	1.317
1976	0.111	1.301	1.922	0.944	0 691	1.572	0.164	0.262	0.036	0.000	0.055	7.057	6 947	5 646	3.724	2 780	2.089
1977	0 000	0.028	3.527	1.080	0 523	0.279	0.727	0.051	0.066	0 000	0.020	6.301	6 301	6.273	2.746	1.666	1.143
1978	3.312	0.376	0.187	5.530	0.969	0.778	0 144	0.713	0.051	0.142	0 109	12.312	9.000	8 624	8.436	2.906	1.938
1979	0.109	0.435	1.359	0 298	1.913	0.541	0.234	0.087	0.145	0.012	0 022	5.156	5.047	4 611	3.253	2.955	1.042
1980	0 105	0 039	2.265	2 688	0 209	1.482	0.597	0 192	0.031	0.030	0.111	7.749	7.644	7.605	5.340	2.652	2 443
1981	0.301	2.303	1.916	2.779	1.667	0.100	0 870	0.269	0.144	0.000	0.085	10 435	10.134	7.831	5.914	3.135	1.468
1982[e]	0.148	0.488	3.395	1.406	1.295	1 039	0.016	0.298	0.064	0.016	0.035	8.200	8.053	7.564	4 169	2.763	1 468
1983	0 081	0.329	1.967	3 048	0.766	0.697	0.431	0.055	0.192	0 000	0.136	7 702	7.621	7.291	5 324	2 276	1.510
1984	0 000	0.402	0.462	0.797	1.161	0.446	0.424	0.223	0.000	0.156	0.008	4.079	4.079	3 677	3 215	2.418	1 257
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	0.380	1.334	0.743	1 532	0.228	0 344	0.051	0 040	0.081	0 067	4.798	4 798	4.418	3 084	2 342	0.810
1990	0.041	0.194	0.926	1.707	0 653	0.896	0.125	0.139	0.013	0.016	0 027	4.736	4.695	4.501	3.575	1 868	1 215
1991	0.195	1.068	0.511	0.807	0 883	0.464	0 336	0.039	0 041	0 000	0.045	4.389	4.194	3.126	2 615	1.808	0.925
Autumn																	
1963	0 019	0.719	0.778	0 920	0.897	0.354	0.326	0.175	0.103	0 014	0.069	4 374	4 356	3.636	2 858	1.938	1 041
1964	0 009	0.640	0 699	0.588	0.538	0.145	0.136	0 062	0.050	0.030	0 083	2.980	2.970	2.331	1.632	1.044	0 505
1965	0 173	1.299	0.998	0.707	0.484	0.167	0.179	0 112	0.081	0.023	0.023	4.248	4.075	2.775	1.777	1 070	0 587
1966	1 025	1 693	1 000	0.515	0.264	0 100	0.095	0 062	0 039	0.002	0 017	4.811	3.786	2.094	1 094	0.579	0 315
1967	0.072	7 596	1 334	0.523	0.406	0 133	0.133	0.055	0.051	0.012	0 070	10.383	10.312	2 716	1 382	0.860	0.454
1968	0.070	0.314	1.611	0 783	0.271	0 073	0.067	0.027	0.023	0 008	0.048	3.296	3.226	2.913	1.301	0 518	0.246
1969	0.000	0.343	0 622	0 626	0.331	0.094	0.061	0.019	0.023	0 022	0.059	2.200	2.200	1 856	1.234	0 608	0.278
1970	0.413	1.688	1.353	0 524	0.694	0.153	0.000	0 033	0.055	0 055	0.098	5.065	4 652	2.964	1.611	1.087	0 393
1971	0 399	0.602	0.632	0.390	0.301	0.476	0 183	0 042	0.089	0.000	0.075	3.189	2.789	2 187	1 555	1.165	0.864
1972	0 947	7.443	1 295	1.771	0.399	0.243	0.571	0.109	0.204	0 022	0.083	13.087	12.140	4.697	3.402	1.632	1 232
1973	0 203	1 749	6.070	1.182	2.012	0.211	0 226	0.175	0 062	0.139	0.251	12.280	12.078	10.329	4.259	3.076	1.064
1974	0.462	0 409	0.654	1.521	0.164	0.114	0.103	0.000	0 069	0.000	0.000	3.494	3.033	2 624	1.970	0.449	0 285
1975	2.377	0.994	0.421	0.624	1.685	0 112	0 156	0.000	0.000	0.000	0.037	6.407	4.029	3.036	2.615	1 991	0.306
1976	0.000	6.148	2.072	0.763	0.278	0 739	0.055	0.270	0 039	0.053	0.020	10.436	10.436	4.288	2.217	1 454	1.176
1977	0.152	0.237	3.424	0.702	0 251	0.174	0.396	0.007	0 027	0.000	0.078	5.447	5.296	5.059	1.635	0 933	0.682
1978	0.396	1.855	0.255	4.180	0.964	0.335	0 165	0 344	0.051	0 030	0.014	8.587	8.192	6.337	6.082	1 902	0 938
1979	0.118	1.619	1.717	0.224	1.613	0.296	0.180	0 036	0.115	0.007	0.022	5.948	5.829	4.210	2.493	2 269	0.656
1980	0.280	0.818	0.564	0 774	0.076	0.251	0.053	0 067	0.025	0.000	0 000	2.908	2.629	1.810	1 246	0 472	0 396
1981	0.261	3.525	2 250	1 559	0 589	0.054	0.579	0 057	0.064	0.018	0.083	9.040	8.778	5.254	3.003	1 444	0.855
1982	0.320	0.875	2.094	0 220	0.069	0 097	0.000	0 016	0.000	0.000	0.022	3.711	3.391	2.516	0.423	0 203	0 134
1983	1.031	0 647	1 022	0 796	0.055	0.047	0.003	0 000	0 012	0.000	0.023	3.636	2.605	1 958	0 936	0 140	0.086
1984	0.186	2.496	0.101	0 886	0.870	0.017	0.062	0 039	0.006	0.039	0 044	4.747	4.561	2.065	1 964	1 078	0.207
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	0.262	2.738	1 030	0 183	0 499	0.055	0.008	0.004	0.000	0.000	0 000	4.780	4 518	1.780	0.750	0 566	0.067
1990[f]	0.156	0 362	1 534	1 164	0.209	0.145	0.012	0.013	0.000	0.000	0.022	3.617	3 460	3 098	1.564	0.401	0.192

[a] During 1963–84 spring and autumn surveys, BMV oval doors were used, since 1985, Portuguese polyvalent doors have been used Adjustments have been made to the 1963–84 catch-per-tow data to standardize to polyvalent door equivalents Conversion coefficients of 1 56 (numbers) and 1 62 (weight) were used in the standardization (NEFC, MS 1991)

[b] *R/V Delaware II* was used in spring surveys during 1981–82 and 1989–91 and the autumn surveys during 1977–81 and 1989–91 and, the *R/V Albatross IV* in all other years Adjustments have been made to the *R/V Delaware II* catch-per-tow data to standardize these to *R/V Albatross IV* equivalents Conversion coefficients of 0 79 (numbers) and 0 67 (weight) were used in the standardization (NEFC, MS 1991)

[c] Spring surveys during 1973–81 were accomplished with a '41 Yankee' trawl, in all other years with a '36 Yankee' trawl No adjustments have been made to the catch-per-tow data for these gear differences

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

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

[f] Excludes unusually high catch of 111 cod (504 kg) at Station 205 (Strata tow 23-4)

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

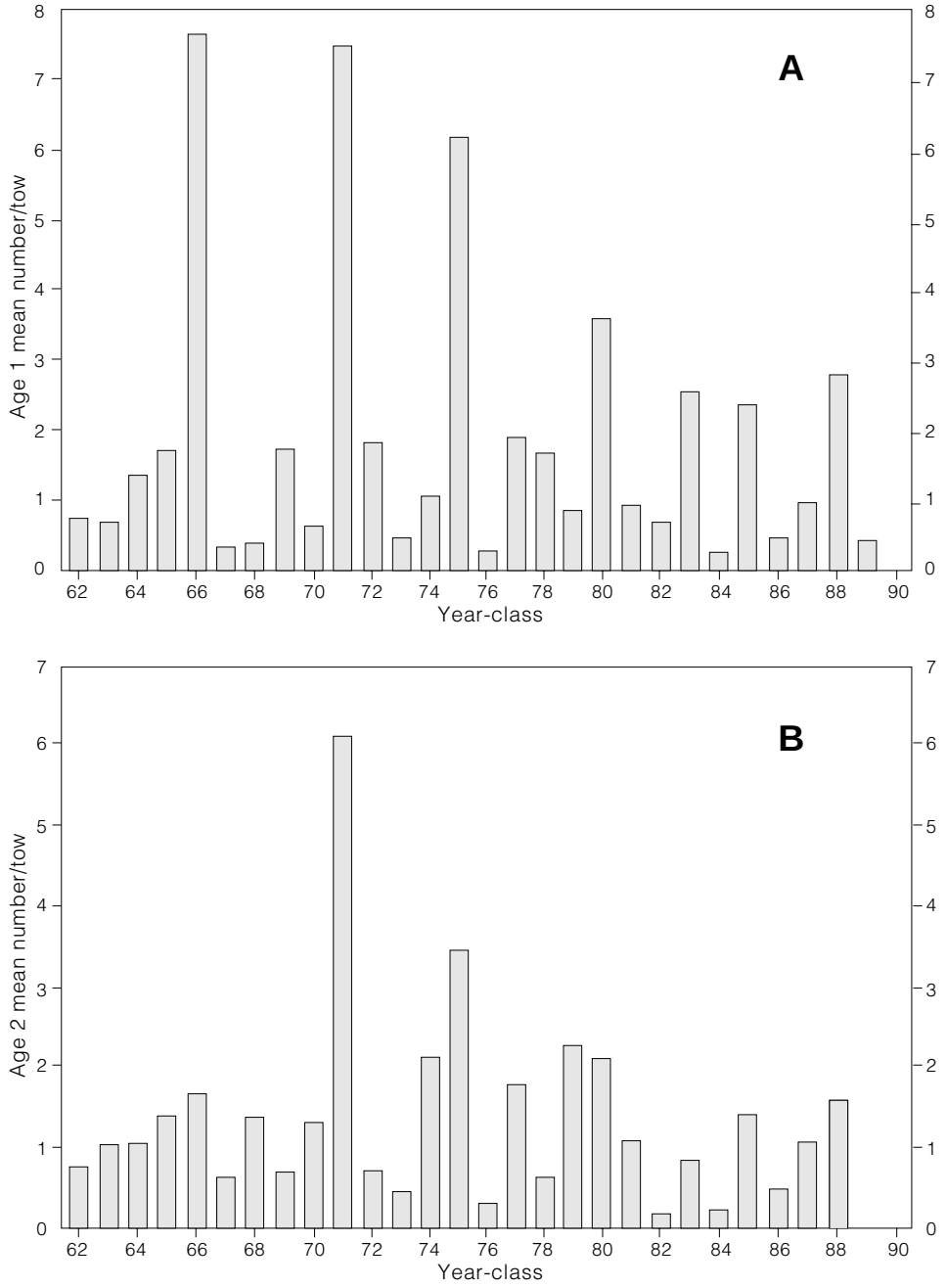

Fig. 9. (**A**) Relative year-class strength of Atlantic cod on Georges Bank at age 1 and (**B**) at age 2 based on standardized catch per tow indices from USA autumn bottom trawl surveys.

changes were made to the FMP management regulations during the 1977–82 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 tons for the USA commercial fishery, was increased to 26 000 tons in July 1978 to allow 4 000 tons for Canada. Management on a 'fishing year basis' (October-September) was insti-

tuted in October 1978 to allow (among other things) more timely use of the USA bottom-trawl survey data in setting annual OYs (Clark *et al.*, 1982). The 1978/79 OY for Georges Bank cod was initially set at 26 000 tons but was revised upwards in July 1979 to 34 960 tons (30 960 tons USA; 4 000 tons for Canada) (Pierce, 1982). In both 1979/80 and 1980/81, the OY was set at 35 000 tons (29 620 tons USA; 5 380 tons Canada). All of the OYs, however, were exceeded as total commercial landings in the 1978–81 period ranged between 35 000 and 48 000 tons. Actual catches were probably much higher (especially during 1978 and 1979) since discarding and misreporting/underreporting of landings occurred as a consequence of many of the management restrictions (closures, trip limits, by-catch restrictions, etc).

The increased OYs during 1978–81 were predicated, in part, on assessment results which indicated that the Georges Bank stock had increased in size since 1975. The 1979–82 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.*, MS 1979, MS 1980, MS 1981, MS 1982; Serchuk and Wood, MS 1981). Stock size had been maintained through a succession of above-average year-classes (1975, 1977, 1978 and 1980 cohorts) (Fig. 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 tons could well lead to stock size reductions (Serchuk and Wood, MS 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 e*t al.*, MS 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 1977–84, 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

TABLE 6. Estimates of instantaneous total mortality (Z) and fishing mortality (F) with instantaneous natural mortality (M) assumed to be 0.20, for the Georges Bank cod stock for seven time-periods between 1964 and 1990, derived from NEFC offshore spring[a] and autumn[b] bottom trawl survey data.

Time period	Spring		Autumn		Geometric mean	
	Z	F	Z	F	Z	F
1964–67	–	–	0.73	0.53	0.73	0.53
1968–72	0.34	0.14	0.35	0.15	0.34	0.14
1973–76	0.70	0.50	0.56	0.36	0.63	0.43
1977–81	0.47	0.27	0.67	0.47	0.56	0.36
1982–84	0.42	0.22	1.12	0.92	0.68	0.48
1985–87	0.84	0.64	1.45	1.25	1.10	0.90
1988–90	0.60	0.40	0.60	0.40	0.60	0.40

[a] Estimates derived from: ln (Σ age 4+ for year i to j/ Σ age 5+ for years i+1 to j+1).

[b] Estimates derived from: ln (Σ age 3+ for years i–1 to j–1/ Σ age 4+ for years i to j).

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 (e.g. 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, MS 1983) and annual assessments have been performed ever since (Table 3). The 1985 assessment (Hunt and Waiwood, MS 1985) was the first to indicate that stock abundance had declined sharply after 1982. USA autumn survey indices in 1982–84 were among the lowest ever (Table 4, Fig. 8) and USA CPUE indices, stable during 1978–83, had fallen sharply in 1984 (Table 7, Fig. 10). Sequential population analysis (SPA) of combined USA/Canadian commercial catch-at-age data from 1978 to 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, MS 1986; Hunt and Gavaris, MS 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 tons. The autumn 1985 USA survey

weight-per-tow index was a record-low (Fig. 8), as was the 1985 USA commercial CPUE (Fig. 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, MS 1986). The 1986 Canadian assessment noted that since *"the $F_{0.1}$ yield for this stock is less than 15 000 tons, 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, MS 1986).

The assessments conducted in 1985–86 indicated that management of cod under the NEFMC 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 had got worse, not better. This was true, not only for the Georges Bank cod stock, but for the entire demersal species complex (NEFC, MS 1987; Fig. 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 (Fig. 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 (NMFS) 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, MS 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 which 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 NMFS 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.

TABLE 7. USA commercial landings (L)[a], days fished (DF)[b], 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), 1965–90. 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[c]
					All Trips						
1965	487	1 661	0.29	5 201	9 719	0.54	4 351	4 175	1.04	10 039	0.74
1966	386	1 555	0.25	4 754	10 505	0.45	4 731	4 510	1.05	9 871	0.73
1967	437	1 069	0.41	5 292	8 570	0.62	4 519	3 789	1.19	10 248	0.86
1968	321	570	0.56	6 861	8 534	0.80	4 903	3 397	1.44	12 085	1.05
1969	433	500	0.87	7 942	7 953	1.00	4 819	2 783	1.73	13 194	1.26
1970	508	535	0.95	6 729	8 296	0.81	4 033	2 218	1.82	11 270	1.18
1971	563	681	0.83	7 652	8 808	0.87	4 215	2 195	1.92	12 430	1.22
1972	524	721	0.73	6 382	9 257	0.69	3 274	1 766	1.85	10 180	1.07
1973	322	550	0.59	7 814	8 668	0.90	4 295	1 701	2.52	12 431	1.45
1974	585	617	0.95	8 222	9 438	0.87	5 266	2 097	2.51	14 073	1.49
1975	509	534	0.95	7 029	8 684	0.81	4 527	2 085	2.17	12 065	1.33
1976	421	474	0.89	7 861	7 791	1.01	3 969	1 469	2.70	12 251	1.55
1977	850	607	1.40	13 250	9 492	1.40	4 423	1 472	3.00	18 523	1.78
1978	1 165	715	1.63	14 853	9 411	1.58	4 829	1 551	3.11	20 847	1.94
1979	956	658	1.45	18 377	9 924	1.85	7 116	2 507	2.84	26 449	2.10
1980	1 062	882	1.20	21 331	10 961	1.95	10 053	3 726	2.70	32 446	2.16
1981	1 184	845	1.40	17 025	10 615	1.60	9 404	3 797	2.48	27 613	1.89
1982	1 406	695	2.02	20 468	10 717	1.91	11 450	4 296	2.67	33 324	2.18
1983	835	429	1.95	17 112	10 694	1.60	13 011	5 116	2.54	30 958	2.00
1984	375	427	0.88	14 883	13 605	1.09	10 899	5 746	1.90	26 157	1.42
1985	370	453	0.82	12 852	13 629	0.94	8 215	5 501	1.49	21 437	1.15
1986	150	233	0.64	8 014	10 442	0.77	5 411	4 354	1.24	13 575	0.96
1987	108	220	0.49	8 505	12 067	0.70	5 090	4 770	1.07	13 703	0.84
1988	100	233	0.43	12 808	13 791	0.93	7 345	5 799	1.27	20 253	1.05
1989	144	320	0.45	10 104	13 151	0.77	7 631	5 274	1.45	17 879	1.06
1990	141	260	0.54	11 586	13 567	0.85	9 891	5 552	1.78	21 618	1.27
					50% Trips						
1965	18	8	2.25	353	86	4.10	819	159	5.15	1 190	4.79
1966	7	<1	–	370	88	4.20	991	199	4.98	1 368	4.74
1967	33	17	1.94	874	238	3.67	1 464	318	4.60	2 371	4.22
1968	16	3	5.33	1 665	464	3.59	1 442	328	4.40	3 123	3.97
1969	73	9	8.11	2 612	773	3.38	1 475	359	4.11	4 160	3.72
1970	164	25	6.56	1 695	534	3.17	1 739	388	4.48	3 598	3.96
1971	117	15	7.80	2 232	721	3.10	2 163	494	4.38	4 512	3.84
1972	152	54	2.81	2 137	716	2.98	1 879	445	4.22	4 168	3.53
1973	52	16	3.25	3 242	820	3.95	3 010	486	6.19	6 304	5.01
1974	259	119	2.18	3 707	1 115	3.32	3 899	703	5.55	7 865	4.39
1975	246	85	2.89	2 678	842	3.18	3 128	585	5.35	6 052	4.29
1976	159	66	2.41	3 665	1 089	3.37	2 664	464	5.74	6 488	4.32
1977	502	120	4.18	6 595	1 342	4.91	2 899	373	7.77	9 996	5.70
1978	846	215	3.93	6 554	1 644	3.99	2 427	330	7.35	9 827	4.81
1979	612	168	3.64	9 714	2 558	3.80	4 270	840	5.08	14 596	4.17
1980	644	196	3.29	11 727	2 909	4.03	5 616	1 067	5.26	17 987	4.39
1981	766	153	5.01	9 414	2 591	3.63	4 312	953	4.52	14 492	3.97
1982	1 046	212	4.93	14 724	3 631	4.06	7 791	1 521	5.12	23 561	4.45
1983	566	130	4.35	11 884	3 033	3.92	8 795	1 872	4.70	21 245	4.25
1984	140	55	2.55	9 156	3 454	2.65	6 620	1 918	3.45	15 916	2.98
1985	184	65	2.83	8 725	4 346	2.01	6 053	2 330	2.60	14 962	2.26
1986	58	18	3.22	5 258	2 969	1.77	3 755	1 406	2.67	9 071	2.15
1987	36	18	2.00	5 743	3 874	1.48	3 354	1 781	1.88	9 133	1.63
1988	37	22	1.68	9 974	6 457	1.54	5 527	2 731	2.02	15 538	1.71
1989	66	56	1.18	7 864	6 023	1.31	6 200	3 083	2.01	14 130	1.62
1990	61	16	3.81	8 490	4 965	1.71	8 151	3 204	2.54	16 702	2.12

[a] In tons, live weight.

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

[c] 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.

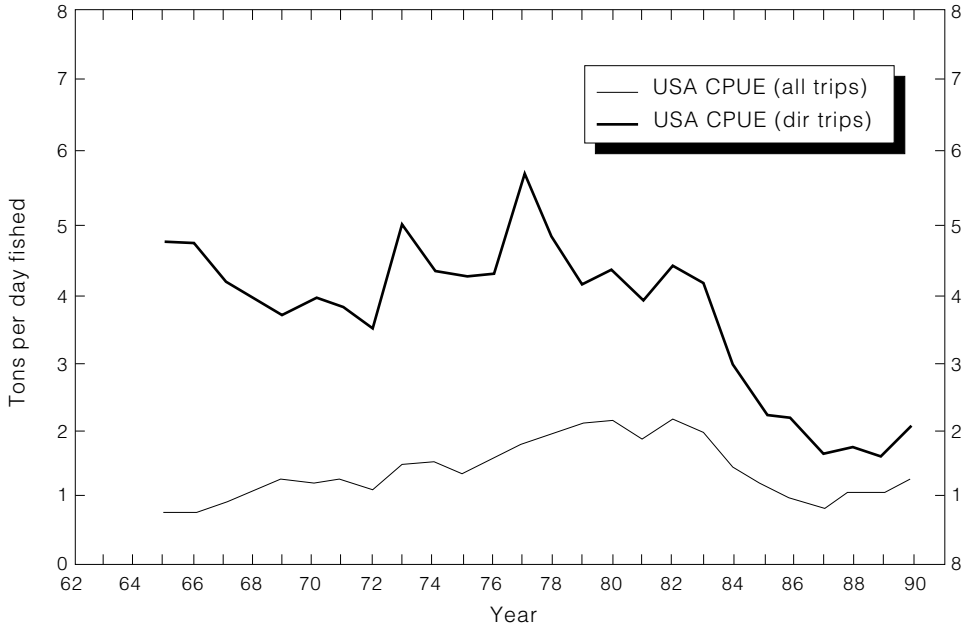

Fig. 10. Trends in USA commercial catch (tons) per day fished of Georges Bank cod. Data are based on all otter trawl trips in which cod were caught ('All Trips') and for otter trawl trips in which cod comprised 50% or more of the trip catch by weight ('Directed Trips').

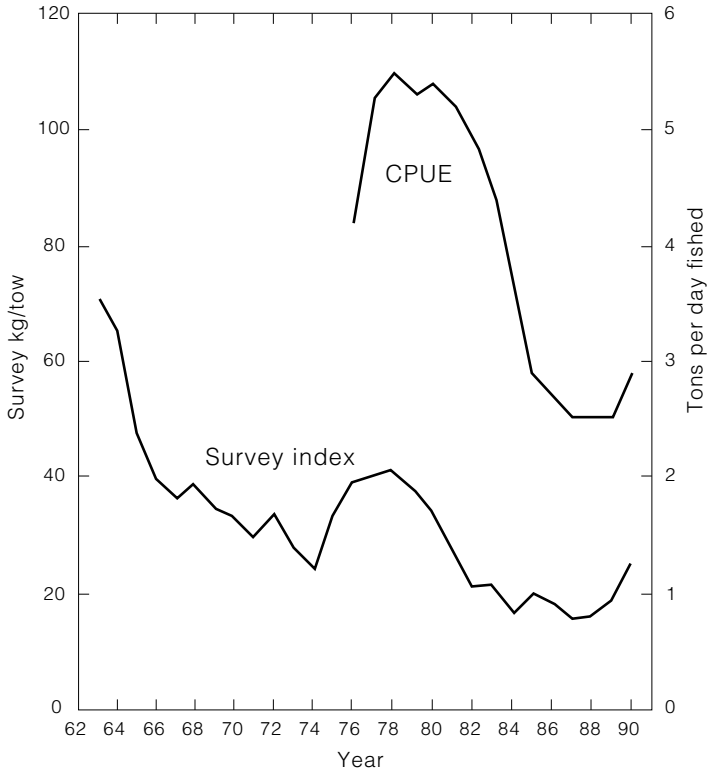

Fig. 11. Indices of abundance of principal groundfish and flounders off the New England coast from USA autumn bottom trawl surveys, and from USA commercial catch per unit of effort, 1963–90.

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, MS 1987; MS 1988; Serchuk, MS 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_{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, MS 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, (5) catch allocations be forthrightly addressed, (6) state regulations must support federal regulations, and (7) management council members be required to have a 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, MS 1987; MS 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, MS 1989; MS 1990; Hunt *et al.*, MS 1991).

In the USA, the Multispecies Plan is still operative and has been amended three additional times

since October1987. 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 were not being met), the current Plan still lacks explicit rebuilding strategies for any of the stocks. This seems unfortunate since the 1990 and 1991 USA cod assessments (Serchuk and Wigley, MS 1990; Serchuk *et al.*, MS 1991; NEFC, MS 1992) suggest that, due to good recruitment from the 1985, 1987, 1988 and 1990 year-classes, the Georges Bank cod stock has started to recover (Table 8, Fig. 12).

However, the tides of management are changing. In July 1991, a legislative bill was introduced to 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 NMFS 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 required implementation (by 1 November 1992) of a new management plan designed to rebuild stocks of cod and yellowtail flounder within 5 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.

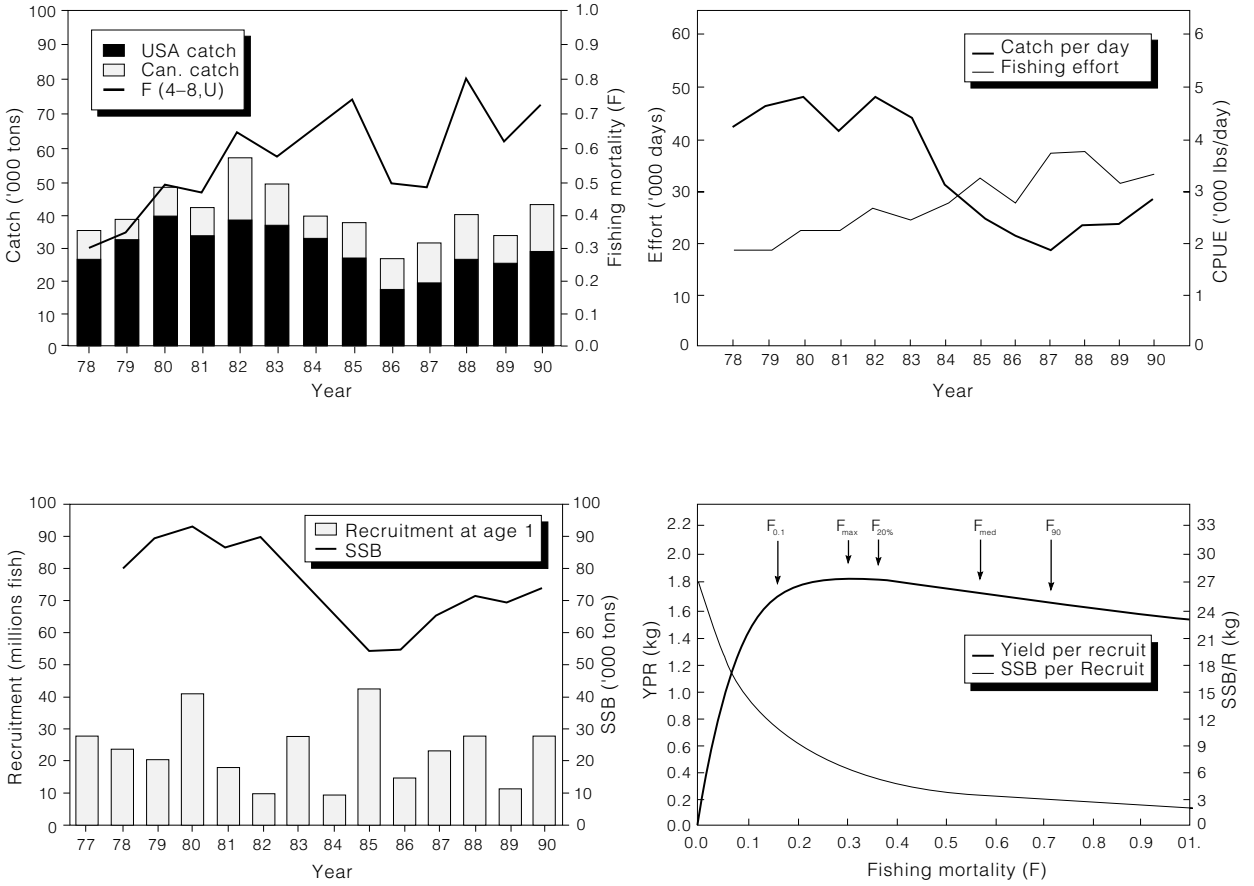

Fig.12. Stock assessment summary diagrams for Georges Bank cod from the 1991 USA assessment (from Serchuk *et al.*, MS 1991; NEFC, MS 1992).

TABLE 8. Estimates of fishing mortality (F), stock size (thousands of fish) and mean stock biomass (tons) derived from Virtual Population Analysis for the Georges Bank cod stock (NAFO Div. 5Z and Area 6, 1978–90.

	Year													
Age	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
							Fishing Mortality							
1	0.0001	0.0016	0 0049	0 0007	0.0212	0 0126	0.0032	0.0177	0 0040	0 0020	0 0005	0.0000	0.0007	
2	0.1073	0 1019	0 2448	0 2437	0 3540	0.4134	0.2070	0.3780	0.2425	0.2665	0.1638	0.1290	0.2761	
3	0.4086	0.3811	0.4845	0 4757	0.5144	0.6120	0.6918	0.7448	0.5096	0.4392	0 5114	0.5155	0.5210	
4	0 3861	0.4902	0.3780	0.3885	0.6758	0.7500	0.5562	0 6671	0 5810	0.4724	0 6633	0.5488	0.7564	
5	0.3838	0.3608	0 4561	0.3061	0.6361	0 5913	0.6286	0.7205	0.5218	0 4108	0.7352	0.4716	0.6668	
6	0 1379	0 3789	0.6370	0.5621	0.7405	0.5471	0.6572	0.7427	0.5600	0.5786	0.7823	0.6526	0.7116	
7	0.3091	0.1122	0 7911	0.5476	0.5816	0 6032	0.7443	0.6532	0.3342	0.5022	0.9452	0.6676	0.7116	
8	1 4849	0.3921	0.1789	0 5227	0 6067	0.4102	0.6319	0.9119	0.4649	0 4324	0.8707	0.7200	0.7116	
9	0 3605	0 4384	0.4895	0.4425	0 6617	0.6510	0.5990	0 7209	0.5466	0.4805	0 7430	0.5630	0.7116	
10+	0 3605	0.4384	0.4895	0.4425	0 6617	0.6510	0.5990	0.7209	0 5466	0 4805	0.7430	0.5630	0.7116	
F(4-8,u)	0 5404	0 3468	0.4882	0.4654	0.6481	0.5804	0.6437	0.7391	0.4924	0.4793	0.7993	0 6121	0.7116	
F(4-8,w)	0.3621	0 4375	0.4921	0.4413	0 6509	0 6459	0.5913	0.7083	0.5409	0 4753	0 7306	0.5557	0.7062	
							Stock Size							
1	27 709	23 520	20 102	41 406	17 454	9 553	27 647	8 459	43 295	14 117	23 300	27 652	10 915	27 721
2	4 268	22 685	19 226	16 378	33 876	13 990	7 724	22 563	6 805	35 306	11 535	19 068	22 640	8 930
3	25 527	3 139	16 773	12 323	10 509	19 467	7 576	5 141	12 658	4 371	22 144	8 017	13 722	14 064
4	7 947	13 889	1 755	8 459	6 270	5 144	8 642	3 106	1 999	6 226	2 307	10 872	3 920	6 672
5	2 878	4 422	6 965	985	4 696	2 612	1 989	4 057	1 305	915	3 178	973	5 141	1 506
6	1 124	1 605	2 524	3 614	594	2 035	1 184	869	1 616	634	497	1 247	497	2 161
7	1 434	802	900	1 093	1 687	232	964	502	338	756	291	186	532	200
8	67	862	587	334	518	772	104	375	214	198	375	93	78	214
9	146	12	477	402	162	231	419	45	123	110	105	128	37	31
10+	54	148	28	190	187	148	293	206	75	69	98	46	81	48
1+	71 155	71 085	69 338	85 184	75 952	54 185	56 544	45 323	68 429	62 703	63 830	68 282	57 563	61 547
2+	43 245	47 404	48 730	43 186	58 149	44 252	28 184	36 612	24 935	48 407	40 326	40 455	46 530	33 747
3+	38 977	24 719	29 504	26 808	24 273	30 262	20 460	14 050	18 130	13 101	28 792	21 388	23 890	24 817
							Mean Stock Biomass at Age							
1	17 756	18 788	15 232	32 901	11 963	8 322	26 245	6 849	36 345	9 472	16 595	20 276	8 218	
2	4 817	29 253	22 659	19 762	36 465	15 582	10 374	24 299	8 110	41 787	14 707	26 257	28 100	
3	47 076	5 120	29 975	21 124	20 006	31 685	12 282	6 938	22 181	8 059	37 379	12 998	24 071	
4	20 861	42 233	4 889	21 843	16 012	10 985	21 944	8 074	5 079	18 982	5 425	28 864	8 888	
5	9 447	16 542	28 847	4 022	17 036	8 366	6 876	13 491	5 212	3 978	11 148	3 820	16 817	
6	5 525	8 740	11 415	18 267	2 505	9 170	5 236	3 606	8 138	3 399	2 100	5 622	2 064	
7	8 293	6 348	4 787	6 596	10 955	1 274	5 555	2 736	2 344	4 864	1 520	1 017	2 946	
8	273	6 715	4 439	2 345	3 524	5 951	717	2 315	1 556	1 481	2 291	643	551	
9	1 311	108	2 897	4 213	1 362	1 744	3 265	341	1 103	907	765	1 058	311	
10+	521	1 383	321	2 517	2 009	1 460	3 095	1 816	732	715	937	491	763	
TOTBIO	115 880	135 230	125 460	133 590	121 838	94 539	95 589	70 465	90 800	93 644	92 866	101 046	92 729	
SPWNBIO[a]	80 612	89 501	92 748	86 483	89 656	78 409	67 257	55 479	55 783	66 941	72 147	70 775	74 914	

[a] Spawning stock biomass is at spawning time (i.e. March 1).

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, 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' to the USA Congress, 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 (Brown and Halliday, 1983), the Georges Bank cod stock remained relatively stable. The stock seemed resilient to heavy exploitation until the early- and mid-1980s when (under extended fisheries jurisdiction), landings, fishing effort and fishing mortality approached or attained record-high levels. Spawning stock biomass declined by 40% between 1980 and 1985/86 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 USA 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.

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