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## **Atlantic Cod**

by

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### **Distribution, Biology and Management**

The Atlantic cod, *Gadus morhua*, is a demersal gadoid species found on both sides of the North Atlantic. In the Northwest Atlantic cod occur from Greenland to North Carolina. In U.S. waters, cod are assessed and managed as two stocks: Gulf of Maine, and Georges Bank and Southward (Figure 1.1). Both stocks support important commercial and recreational fisheries. Commercial fisheries are conducted year round, primarily with otter trawls and gill nets. Recreational fishing also occurs year round; peak activity occurs during the late summer in the lower Gulf of Maine and during late autumn to early spring from Massachusetts southward.

Cod may attain lengths of up to 130 cm (51 in.) and weights of 25 to 35 kg (55 to 77 lb). Maximum age is in excess of 20 years, although young fish (ages 2 to 5) generally constitute the bulk of the catch. Sexual maturity is attained between ages 2 to 4 (O'Brien et al. 1993, O'Brien 1998); spawning occurs during winter and early spring. Cod are omnivorous, feeding on a variety of invertebrates and fish species (Lough 2004, O'Brien et al. 2005). Growth rates differ between the stocks although each is exploited by the same gear types with similar selection characteristics. Growth of cod in the Gulf of Maine has historically been slower than on Georges Bank (Pentilla and Gifford 1976, O'Brien 1998), but appears to have increased in recent years. Differences in growth rate by sex have also become less pronounced in both stocks.

United States commercial and recreational fisheries for cod are managed under the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan (FMP). Under this FMP cod are included in a complex of 15 groundfish species that has been managed by time/area closures, gear restrictions, and minimum size limits. As well, since 1994, this complex has been managed using direct effort controls including a moratorium on permits and days-at-sea restrictions under Amendments 5, 7, and 13 to the FMP. Trip limits are also in effect for both Gulf of Maine and Georges Bank cod. Amendment 9 established initial biomass rebuilding targets (NEFMC 1998) and defined control rules which specify target fishing mortality rates and corresponding rebuilding time horizons. Amendment 13 implemented formal rebuilding plans

within specified time frames based on revised biomass and fishing mortality targets derived by the Working Group on Re-evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002a). The goal of the management program is to reduce fishing mortality to levels which will allow stocks within the complex to initially rebuild above minimum biomass thresholds, and, ultimately, to remain at or near target biomass levels. In addition, a formal quota sharing agreement was implemented in 2004 between Canada and the U.S. to share the harvest of cod in the transboundary eastern Georges Bank cod management unit. The agreement includes total allowable catch quotas for each country as well as in-season monitoring of the U.S. catch of cod on eastern Georges Bank. The Canadian fishery on Georges Bank is managed under an individual quota system.

Total commercial cod landings from the Georges Bank and Gulf of Maine stocks in 2005 were 6,957 mt, a 17% decrease from 8,381 mt in 2004. United States commercial landings in 2005 equaled 6,327 mt, 13% less than in 2004 (7,269 mt). Recreational cod landings totaled 1,585 mt in 2004, a 45% decrease from 2003. Landings from both stocks remain well below the maxima taken during the 1970s and 1980s. The information provided herein reflects the results of the most recent peer-reviewed assessments for the Gulf of Maine and Georges Bank cod stocks (Mayo and Col 2006, O'Brien et al. 2006, NEFSC 2005).

## **GULF OF MAINE COD**

### **The Fishery**

Total commercial landings in 2005 were 3,909 mt, slightly below those from 2001-2003 but approximately 139% greater than in 1999 (Table 1.1, Figure 1.2). Since 1977, the USA fishery has accounted for all of the commercial catch. Although otter trawl catches account for the largest percentage of the landings (averaging between 50 and 59% between 1993 and 2003), the otter trawl fraction has declined considerably compared to the period prior to 1993. Most of this change can be attributed to an increase in the percentage of cod taken by sink gillnets since 1993, although the percentage from combined handline and line trawls also increased substantially during the 1990s. The percentage landed by otter trawls declined further in 2004 to 44%. Discards have also become a significant part of the commercial catch of Gulf of Maine cod, ranging from 15 to 160 percent of the landings since 1999.

Gulf of Maine cod landings have generally been dominated by age 3 and 4 fish in numbers (Figure 1.3). Representation of age 2 cod was relatively high in the early 1980s but, in response to a series of minimum mesh size increases during the 1990s, age 2 fish have gradually all but disappeared from the landings. Cod from the strong 1987 year class predominated from 1990 through 1992 but, by 1993, fish from the 1990 year class accounted for the greatest proportion of the total number landed. From 1994 through 1996, landings were dominated by age 4 cod and in 1997 age 5 fish were dominant, reflecting the higher abundance of the 1992 year class. Although traditionally low in terms of their contribution to the total landings, age 10 and 11+ fish were absent for several years during the 1990s, and numbers of age 8 and 9 fish have also been unusually low. More recently, the 1998 year class has dominated the landings at ages 3 through

6 in 2001 through 2004, respectively. As well, the proportion of cod older than age 7 has begun to increase.

### **Research Vessel Survey Indices**

NEFSC spring and autumn biomass indices for Gulf of Maine cod have generally exhibited similar trends throughout the survey time series (Figure 1.4). Total biomass declined during the mid- and late 1960s, but between 1972 and 1985 both have fluctuated as a result of a series of recruitment pulses. Sharp increases in indices reflect above-average recruitment of the 1971, 1973, 1977-1980, and 1985-1987 year classes at ages 1 and 2. The sequential dominance of these cohorts at older ages is evident from number-per-tow-at-age values in the autumn NEFSC surveys (Figure 1.5). Increases in the autumn 1994-1995 and spring 1996-1997 biomass indices may be attributed to somatic growth of fish from the 1992 year class which was the largest in a series of poor year classes. The survey age composition data reveal a persistent truncation in the population age structure from about 1985 to 1995 followed by a period of expanding age structure. More recently, autumn biomass indices have shown a modest increase, but the large value in 2002 (Figure 1.4) is the result of a single very large tow that unduly influenced the calculation of the mean. The 1998 year class is equivalent to the 1992 year class, and the 2003 and 2004 year classes also appear to be relatively strong. Biomass indices in 2003-2005 suggest the population biomass remains slightly above the low level of the early 1990s.

### **Assessment Results**

Average fishing mortality (ages 4-5, unweighted) fluctuated around 1.0 during the 1980s and early 1990s, but steadily declined thereafter to less than 0.4 in 2002 (Figure 1.6). Fishing mortality in 2004 was estimated to be 0.58, an increase from 2002 and 2003. The spawning stock biomass of age 1 and older cod declined from 23,987 mt in 1982 to 15,302 mt in 1987 (Figure 1.7). Following the recruitment and maturation of the strong 1987 year class, SSB increased to 24,261 mt in 1990 but declined to 10,797 mt in 1993, a 3-year reduction of 55%. SSB increased to 14,996 mt in 1995 due to the growth and maturation of the 1992 year class, but declined again in 1996 and fell to 11,128 mt in 1997. SSB increased again beginning in 1998, reaching 25,369 mt in 2002, based primarily on growth and maturation of the 1998 year class. Spawning stock biomass has since declined to 20,549 mt in 2004.

Since 1982, recruitment at age 1 has ranged from less than 4 million fish (1993, 1994, 1995, 2000 and 2002 year classes) to 25.2 million fish (1987 year class) (Figure 1.7). Over the 1982-2004 period, geometric mean recruitment for the 1981-2003 year classes was 6.3 million fish. The 1987 year class is the highest in the 1982-2004 series and about twice the size of the next strongest year class. The 1992, 1998 and 2001 year classes were of moderate strength, while the 1993-1995, 1999-2000 and 2002 year classes were weak. The initial estimate of the strength of the 2003 year class (22 million) is very close to that of the 1987 year class.

### **Biological Reference Points**

Yield and spawning stock biomass biological reference points (Figure 1.8) were last calculated in the 2001 assessment (Mayo et al. 2002) and are the same as those applied by the Working Group

on Re-evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002a) and reported in the 2002 and 2005 GARM assessments (NEFSC 2002b, 2005; Mayo and Col 2002, 2005). These are given in Table 1.2.

The relationship between spawning stock biomass and recruitment for Gulf of Maine cod over the period covering the 1982-2003 year classes is illustrated in Figure 1.9. The stock-recruitment trajectory indicates the position of the most recent levels of SSB and recruitment in the upper right corner of the plot illustrating the emergence of the 2003 year class from a relatively high spawning stock. The solid horizontal line indicates the geometric mean recruitment over the same period. Survival ratios, recruits per unit of spawning biomass (Figure 1.10) also illustrate the relatively high survival of the dominant 1987, 1992 and 1998 year classes in addition to the 2003 year class.

MSY-based reference points were last calculated by the Working Group on Re-evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002a) using data and results from the 2001 assessment (Mayo et al. 2002). A complete description of the approach is given in Mayo et al. (2002) and NEFSC (2002a). The MSY-based reference points calculated using this method are given in Table 1.2.

### Summary

Gulf of Maine cod spawning stock biomass has increased since the late 1990s from 11,100 mt in 1997 to 20,500 mt in 2004, but the stock remains low relative to  $SSB_{MSY}$  (82,830 mt). Fully recruited fishing mortality declined to about 0.35 in 2000 and 2001, but has since increased to 0.58 in 2004, indicating that  $F$  continues to remain very high relative to fully recruited  $F$  reference points ( $F_{0.1} = 0.15$ ;  $F_{msy} = 0.23$ ;  $F_{max} = 0.27$ ). Thus, the stock remains in an overfished condition and overfishing continues to occur.

**Table 1.1** Recreational and commercial landings of Gulf of Maine cod (thousand metric tons).

Category	1986-95 Average	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
<b>U. S. Recreational</b>	1.6	1.0	0.4	1.1	0.9	1.6	2.8	1.4	2.6	1.2	N/A
<b>Commercial</b>											
<b>United States</b>											
<b>Landings</b>	10.2	7.2	5.4	4.2	1.6	3.7	4.4	4.1	4.0	3.8	3.9
<b>Discards</b>	-	-	-	-	2.5	1.0	1.5	1.5	1.5	0.5	N/A
<b>Canada</b>	-	-	-	-	-	-	-	-	-	-	-
<b>Other</b>	-	-	-	-	-	-	-	-	-	-	-
<b>Total Nominal Catch</b>	11.8	8.2	5.8	5.3	5.0	6.3	8.7	7.0	8.1	5.5	3.9

**Table 1.2** Yield and SSB per Recruit and MSY Based Reference Points for Gulf of Maine Cod.

#### Yield and SSB per Recruit-based Reference Points

$$F_{0.1} = 0.15$$

$$F_{\max} = 0.27$$

$$F_{20\%} = 0.36$$

**MSY-based Reference Points**

$$MSY = 16,600 \text{ mt}$$

$$SSB_{MSY} = 82,830 \text{ mt}$$

$$F_{MSY} = 0.23$$

**GEORGES BANK COD****The Fishery**

Total commercial landings of Georges Bank cod in 2005 were estimated to be a record-low 3,048 mt, 33% lower than in 2004 (Table 1.3, Figure 1.11). Since 1978 the USA fleet landed has landed an average 75% of the total landings and the Canadian fleet has landed the remaining 25%. USA cod landings are generally highest in the second calendar quarter (April-June) and are taken predominantly from the western part (SA 521-522, 525-526, 537-539, and Subarea 6) of Georges Bank throughout the year (Figure 1.1). The majority of the landings from the eastern part (SA 561-562) of Georges Bank are taken in the first and second calendar quarters (January to June). The Canadian fishery for Georges Bank cod is open in January, and then June to December, with the majority of the landings taken in the third calendar quarter (July-September).

Prior to 1994, USA landings were taken primarily by otter trawl gear, accounting for 85% of the landings. Since 1994, otter trawl gear account for 65% of the landings; the recent decline in otter trawl landings is attributed to the increase in gillnet (17%) and line trawl (17%) landings. The majority of Canadian landings have been taken by longline gear since 1996 (Gavaris et al. 2006).

Cod landings from Georges Bank, categorized by size as 'scrod' (small), 'market' (medium), and 'large', continue to be dominated by 'market' cod in both weight and number in recent years. Historically, 'market' cod have accounted for 37-67% of the landings by weight. Market cod are generally dominated by fish aged 3 or 4 years old, and will vary with the strength of incoming year classes. The most recent strong year classes that have supported the fishery occurred in 1996 and 1998 (Figure 1.12).

**Research Vessel Survey Indices**

NEFSC spring and autumn catch per tow biomass indices show similar trends throughout the time series (Figure 1.13). Total biomass indices were relatively stable between 1963 and 1971, increasing to a record high in 1973, and then generally declining over the next two decades, reaching record low levels between 1991 and 1994. The indices have improved slightly since 1994 and have fluctuated with no trend. Both the spring and autumn indices remained below average in 2005. Autumn survey abundance indices for both ages 1 and 2 indicate above-average recruitment of the 1965, 1966, 1971, 1975, 1977, 1980, 1985, and 1988 year classes (Figure 1.14). The magnitude of an above-average year class has been declining over time, particularly noticeable in the recruits at age 2.

## **Assessment Results**

Average (ages 4-8, unweighted) fishing mortality gradually increased during 1978-1994 to a maximum of 1.5 (67% exploitation) and has since declined to 0.24 (19% exploitation) in 2004 (Figure 1.15). Spawning stock biomass declined from about 93,000 mt in 1980 to a record low of 17,340 mt in 1995 and then slowly increased to 30,000 mt by 2001, primarily due to the growth of the 1996 and 1998 year classes (Figure 1.16). The 2004 estimate of SSB was 22,564 mt, a decrease of 25% from 2001, the last year the 1996 year class dominated the SSB. The 2004 estimate is, however, an increase of 30% from the record low 1995 estimate.

Since 1978, recruitment at age 1 has ranged from 2 million (2002 year class) to 43 million (1985 year class) (Figure 1.16). The 2004 year class is estimated to be about 10.4 million fish at age 1, below the long term (1978-2004) arithmetic average of 14.7 million age 1 fish. The 2003 year class, however, is estimated to be 21.2 million age 1 fish, well above the long term average. The previous above average year class occurred in 1990 (17.8 million age 1 fish). The 1998 year class (12.8 million age 1 fish), although below average, was the strongest since 1990. The 1994, 2001, and 2002 year classes are the poorest of the 28-year time series.

## **Biological Reference Points**

Yield and spawning stock biomass biological reference points (Figure 1.17) were last calculated by the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002a) using data from the 2001 assessment (O'Brien and Munroe 2001) and are the same as those applied and reported in the 2002 and 2005 GARM assessments (NEFSC 2002b, 2005; O'Brien et al. 2002, 2005). These are provided in Table 1.4.

The relationship between spawning stock biomass and recruitment for Georges Bank cod over the period covering the 1978-2004 year classes is illustrated in Figure 1.18. In the last decade, low recruitment at age 1 has generally been associated with low SSB in contrast to the earlier time period (1978-1990) when higher recruitment was realized from higher SSB. The most recent levels of SSB and recruitment occur in the lower left portion of the plot illustrating the emergence of the above average 2003 and the average 2004 year classes from the same relatively low spawning stock. The solid horizontal line indicates the geometric mean recruitment over the same period. Survival ratios, recruits per unit of spawning biomass (Figure 1.19) also illustrate the relatively high survival of the 1985, 1992, and 1998 year classes in addition to the 2003 year class.

MSY-based reference points were last calculated by the Working Group on Re-evaluation of Biological Reference Points for New England Groundfish (NEFSC 2002a) using data and results from the 2001 assessment (O'Brien and Munroe 2001). A complete description of the approach is given in O'Brien et al. (2006) and NEFSC (2002a). The MSY-based reference points calculated using this method are given in Table 1.4. The MSY estimate includes commercial landings only and does not include recreational landings or discards.

## **Summary**

Georges Bank cod biomass indices derived from research surveys indicate that the stock remains below the long term average of the 43 year time series. Fishing mortality has been steadily declining since 1997, except for a slight increase in 2001, and is currently at the lowest level in the time series. Spawning stock biomass reached a record low in 1995 and slowly increased, due to the growth of the 1996 and 1998 year classes; however, since 2001 SSB has been declining. SSB in 2004 was 22,600 mt ton, 10 % of  $SSB_{MSY}$ . Thus, Georges Bank Atlantic cod are considered overfished and overfishing is occurring.

**Table 1.3** Recreational and commercial landings of Georges Bank cod (thousand metric tons)

Category	1986-95 Average	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005
U. S. Recreational	1.3	0.5	0.8	0.3	0.3	0.6	0.4	0.7	0.3	0.3	N/A
Commercial											
United States	18.8	7.0	7.5	7.0	8.1	7.6	10.6	9.0	6.6	3.5	2.4
Canada	9.5	1.9	2.9	1.9	1.8	1.6	2.1	1.3	1.3	1.1	0.6
Other	-	-	-	-	-	-	-	-	-	-	-
Total Nominal Catch	29.6	9.4	11.2	9.2	10.2	9.8	13.1	11.0	8.2	4.9	3.0

**Table 1.4** Yield and SSB per Recruit and MSY Based Reference Points for Georges Bank cod.

**Yield and SSB per Recruit-based Reference Points**

$F_{0.1} = 0.17$

$F_{max} = 0.33$

$F_{40\%} = 0.17$

**MSY-based Reference Points**

$MSY = 35,200$  mt

$SSB_{MSY} = 217,000$  mt

$F_{MSY} = 0.18$

**For further information**

Collette, B.B. and G. Klein-MacPhee (editors). 2002. *Bigelow and Schroeder's Fishes of the Gulf of Maine*. Smithsonian Institution Press, Washington, D.C.

Gavaris, S., L.O'Brien, B.Hatt, and K.Clark 2006. Assessment of Eastern Georges Bank Cod. TRAC Reference Document - 2006/05; 49 p.

Lough, R. G. 2004. Essential Fish Habitat Source Document: Atlantic Cod, *Gadus morhua*, Life History and Habitat Characteristics. 2<sup>nd</sup> ed. November 2004. NOAA Technical Memorandum NMFS-NE-190, vi + 94 p.

Mayo, R. K., E. M. Thunberg, S. E. Wigley, and S. X. Cadrin. 2002. The 2001 Assessment of the Gulf of Maine Atlantic Cod Stock. Northeast Fisheries Science Center Reference

Document 02-02, 154 p.

Mayo, R. K and L. Col. 2002. Gulf of Maine Cod, p123-145. In: Assessment of 20 Groundfish Stocks through 2001. A Report of the Groundfish Assessment Review Meeting (GARM), Northeast Fisheries Science Center Reference Document 02-16.

Mayo, R. K and L. Col. 2005. Gulf of Maine Cod, p153-184. In: Assessment of 19 Northeast Groundfish Stocks Through 2004. 2005 Groundfish Assessment Review Meeting (2005 GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, 15-19 August, 2005. by R. K. Mayo and M. Terceiro, editors. Northeast Fisheries Science Center Reference Document 05-13.

Mayo, R.K. and L. Col. 2006. The 2005 Assessment of the Gulf of Maine Atlantic Cod Stock. Northeast Fisheries Science Center Reference Document 06-02, 109 p.

NEFMC 1998. Evaluation of Existing Overfishing Definitions And Recommendations for New Overfishing Definitions To Comply with the Sustainable Fisheries Act. Report of the Overfishing Definition Review Panel.

NEFSC 2002a. Final Report of the Working Group on Re-Evaluation of Biological Reference Points for New England Groundfish. Northeast Fisheries Science Center Reference Document 02-04, 254 p.

NEFSC 2002b. Assessment of 20 Northeast Groundfish Stocks Through 2001. Groundfish Assessment Review Meeting (GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, October 8-11, 2002 . Northeast Fisheries Science Center Reference Document 02-16.

NEFSC 2005. Assessment of 19 Northeast Groundfish Stocks Through 2004. 2005 Groundfish Assessment Review Meeting (2005 GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, 15-19 August, 2005, by R. K. Mayo and M. Terceiro, editors. Northeast Fisheries Science Center Reference Document 05-13.

O'Brien, L., J. Burnett, and R. K. Mayo. 1993. Maturation of Nineteen Species of Finfish off the Northeast Coast of the United States, 1985-1990. NOAA Tech. Report. NMFS 113, 66 p.

O'Brien, L. 1998. Factors influencing rates of maturation in the Georges Bank and Gulf of Maine Atlantic cod stocks. Northwest Atl. Fish. Organ. (NAFO) Sci. Council. Res. Doc. No. 98/104. 34 p.

O'Brien, L. and N. J. Munroe 2001. Assessment of the Georges Bank Atlantic cod stock for 2001. Northeast Fisheries Science Center Reference Document 01-10:126.

O'Brien, L., N.J. Munroe, and L. Col. 2002. A. Georges Bank Atlantic Cod in: Assessment of 20 Northeast groundfish stocks through 2001. A Report of the Groundfish Assessment



Review Meeting (GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, October 8-11, 2002. Northeast Fisheries Science Center Ref. Doc. 02-16: 522.

O'Brien, L., R. G. Lough, R. K. Mayo, and J. J. Hunt. 2005a. Gulf of Maine and Georges Bank (NAFO Subareas 5 and 6). In: K. Brander, ed. Spawning and life history information for North Atlantic cod stocks. ICES Cooperative Research Report No. 274, 152 p.

O'Brien, L., N.J. Munroe, and L. Col. 2005b. A. Georges Bank Atlantic Cod in: Assessment of 19 Northeast groundfish stocks through 2004. 2005 Groundfish Assessment Review Meeting (2005 GARM), Northeast Fisheries Science Center, Woods Hole, Massachusetts, August 15-19, 2005. Northeast Fisheries Science Center Reference Document 05-13: 508.

O'Brien, L., N. Shepherd, and L. Col. 2006. Assessment of the Georges Bank Atlantic cod stock for 2005. Northeast Fisheries Science Center Reference Document. 06-10:148.

Pentilla, J. and V. M. Gifford. 1976. Growth and Mortality Rates for Cod from the Georges Bank and Gulf of Maine Areas. Int. Comm. Northw. Atl. Fish. Res. Bull. No. 12: 29-36.

Serchuk, F. M., M. D. Grosslein, R. G. Lough, D. G. Mountain, and L. O'Brien. 1994. Fishery and environmental factors affecting trends and fluctuations in the Georges Bank and Gulf of Maine Atlantic cod stocks – an overview. ICES Mar. Sci. Symp. 198: 77-109.

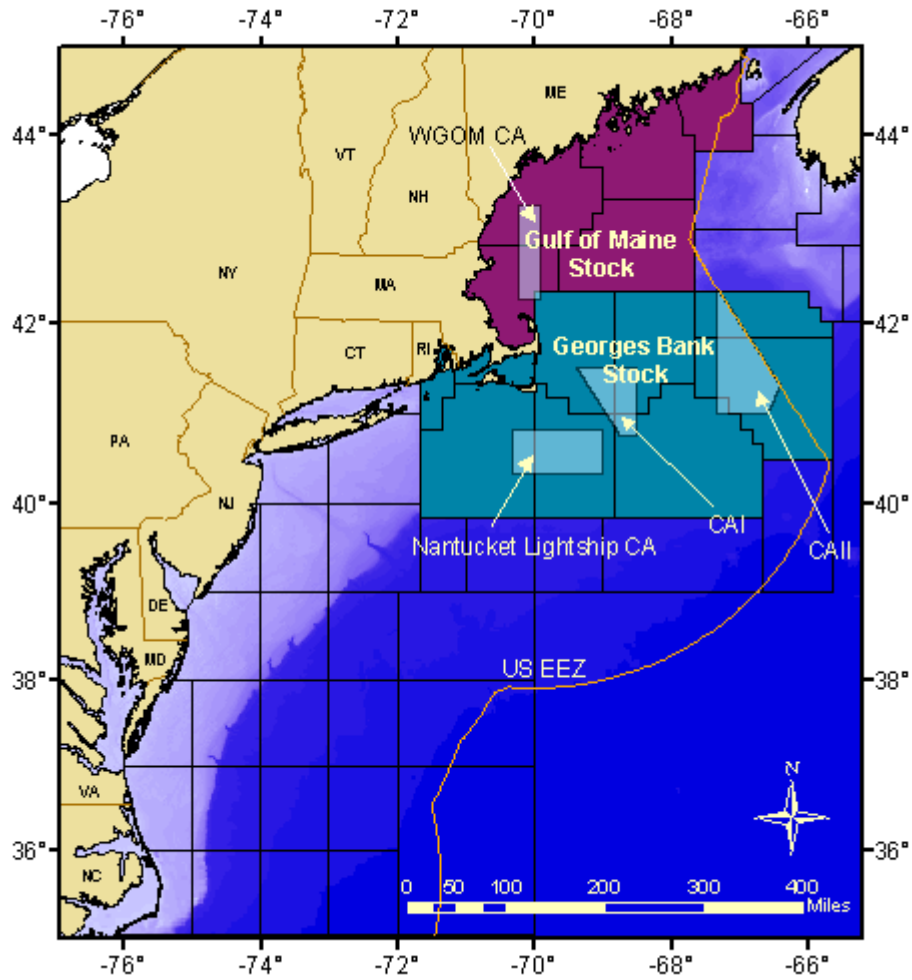


Figure 1.1. Statistical areas used to define the Gulf of Maine and Georges Bank cod stocks.

### Gulf of Maine Cod Total Commercial Landings

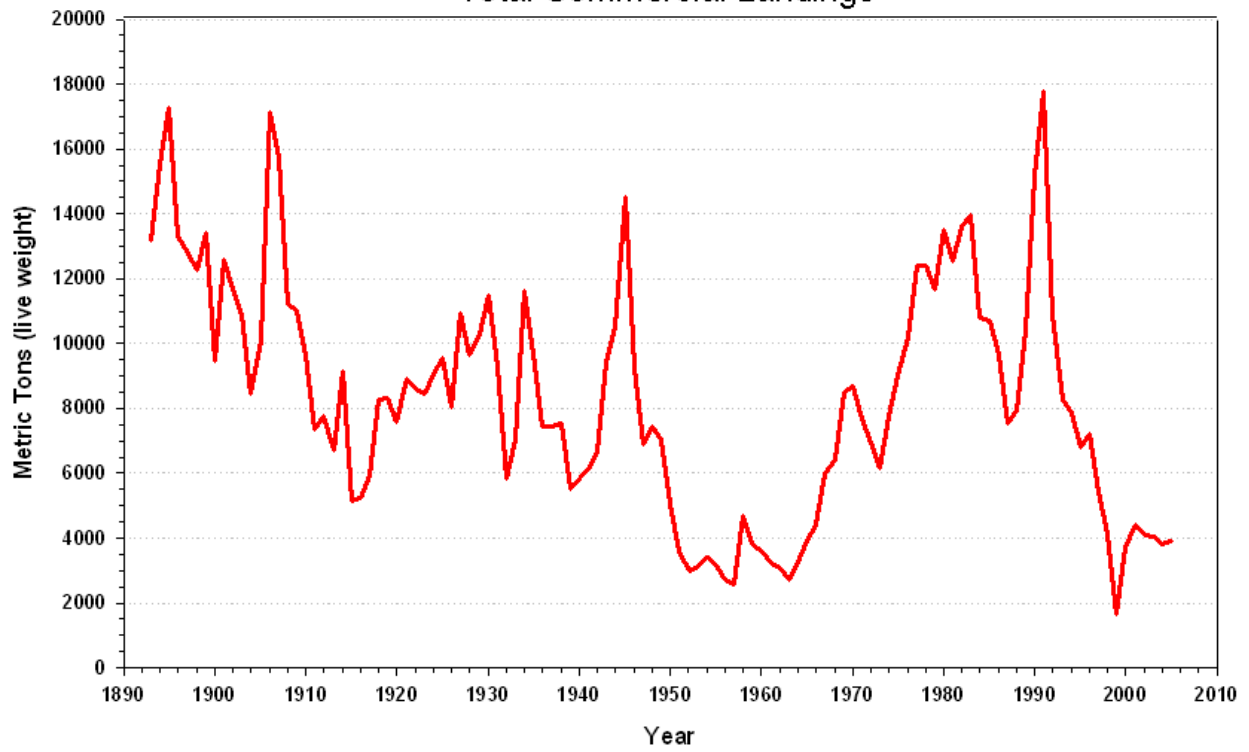
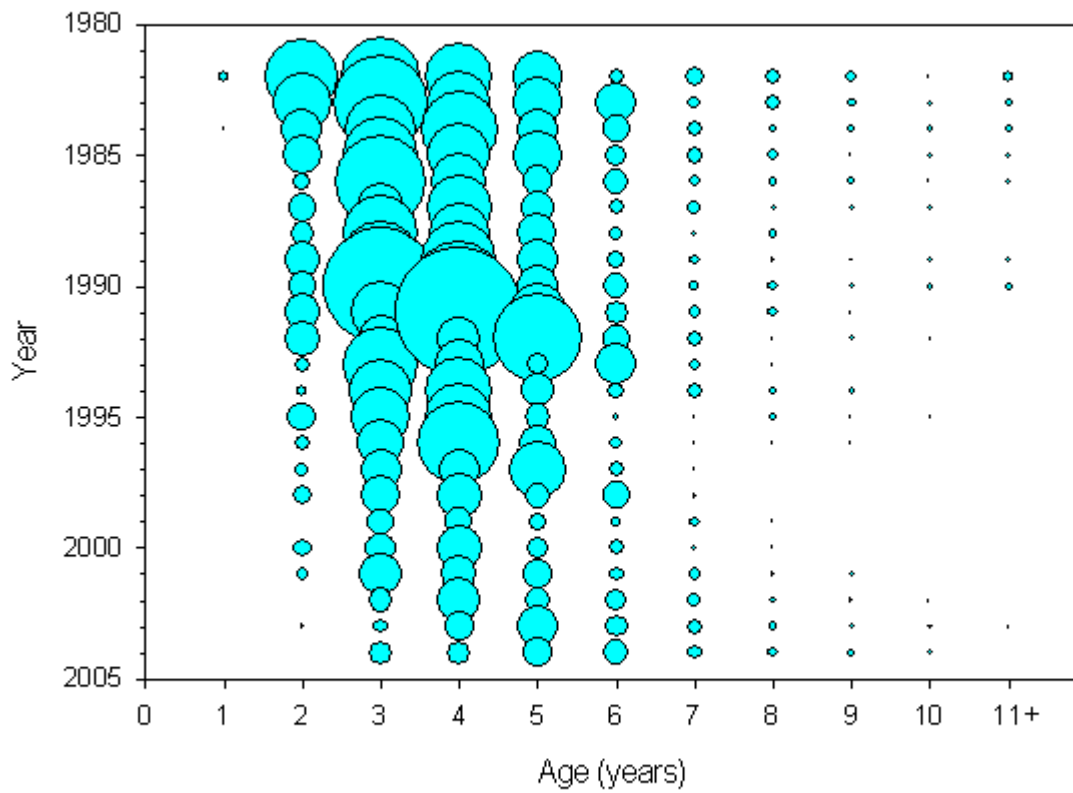


Figure 1.2. Total commercial landings of Gulf of Maine cod (NAFO Div. 5Y), 1893-2005.

## Gulf of Maine Cod Commercial Landings by Age



**Figure 1.3. Age structure of the Gulf of Maine commercial cod landings, 1982-2004.**

### Gulf of Maine Cod NEFSC Spring and Autumn Biomass Indices

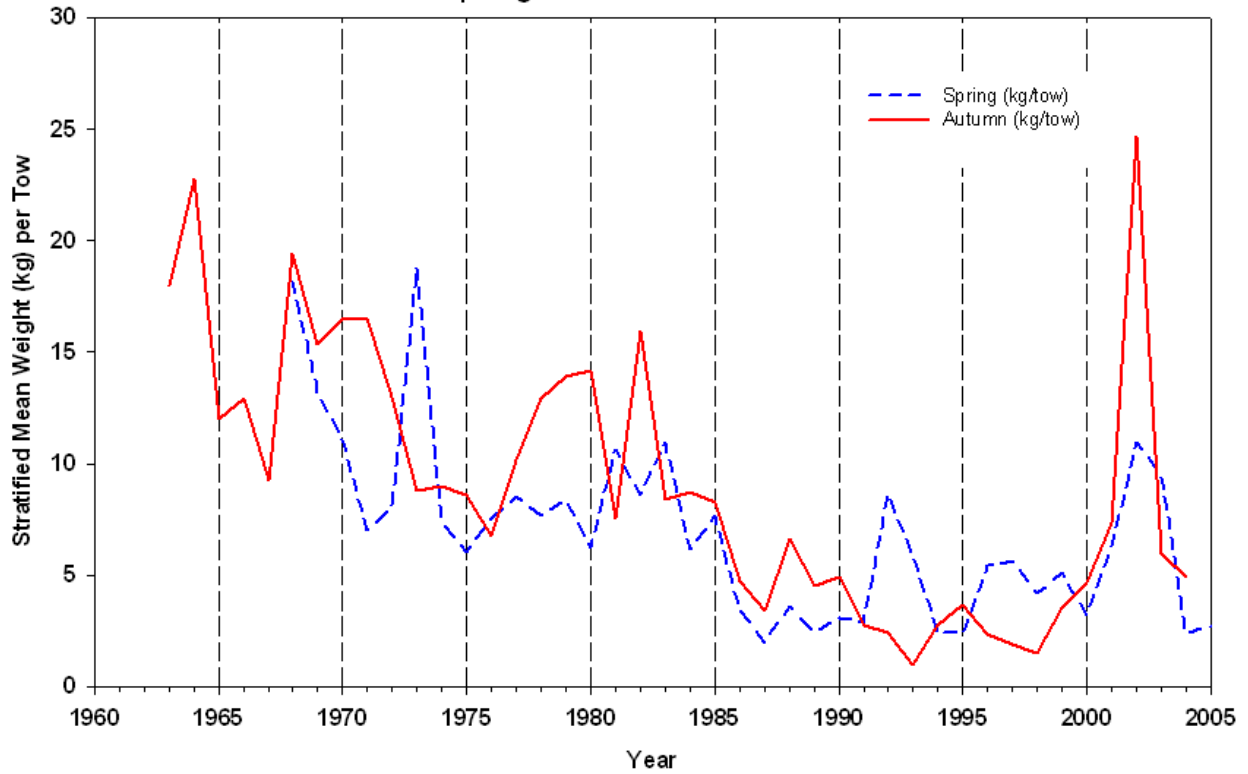
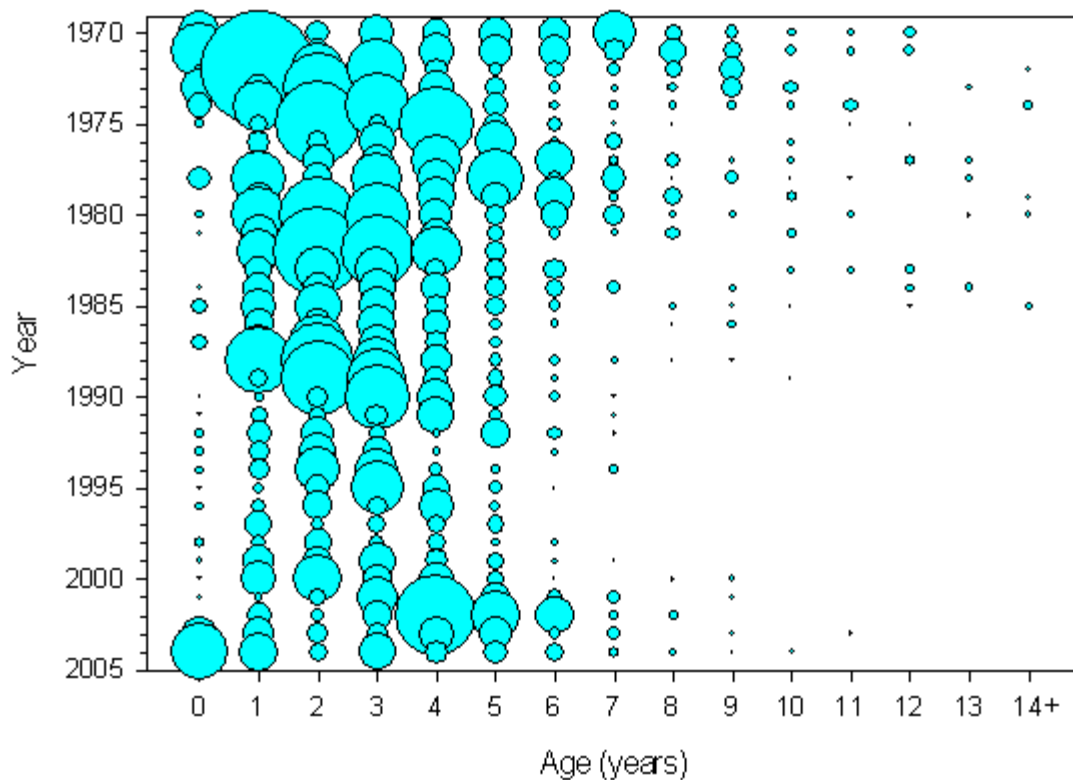


Figure 1.4. Biomass indices (stratified mean weight per tow) for Gulf of Maine cod from NEFSC spring and autumn research vessel surveys.

### Gulf of Maine Cod Autumn Survey Indices by Age



**Figure 1.5.** Age structure of the Gulf of Maine cod population as indicated by autumn research vessel survey indices of abundance, 1970-2004.

## Gulf of Maine Cod Trends in Catch and Fishing Mortality

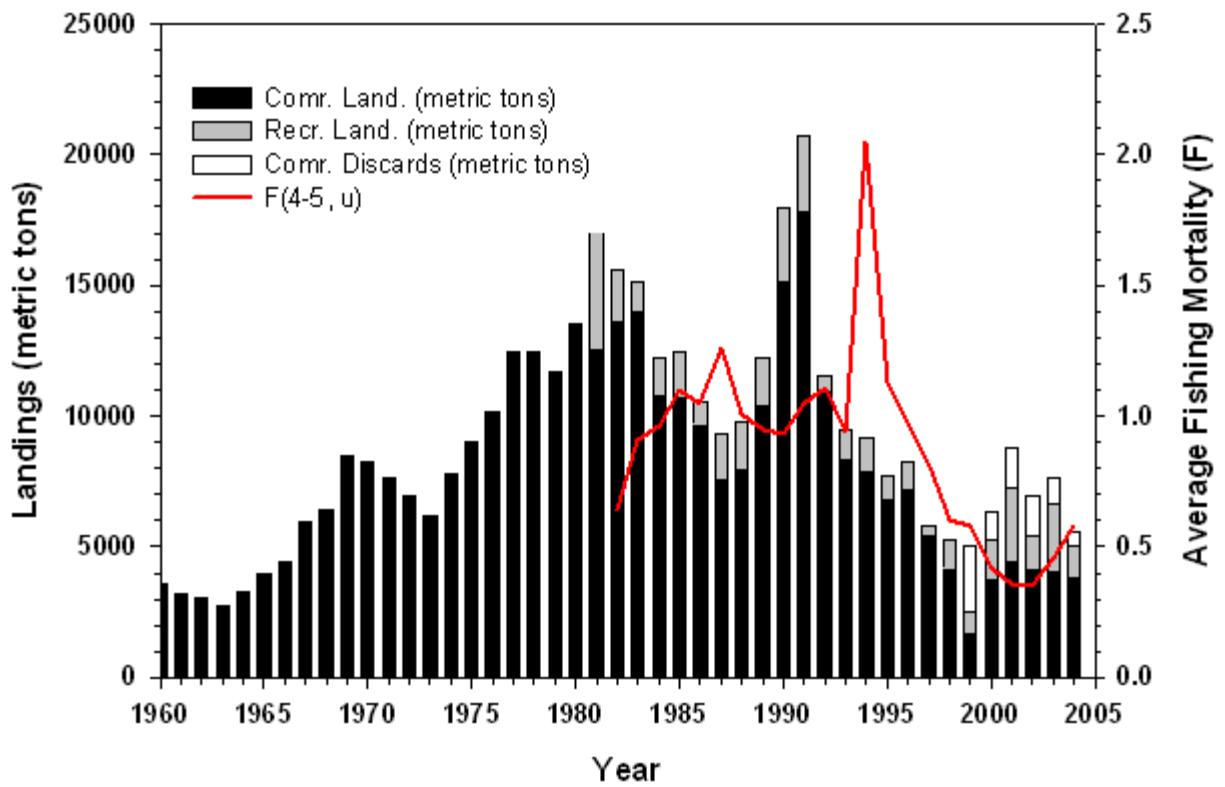


Figure 1.6. Trends in catch and fishing mortality for Gulf of Maine cod.

## Gulf of Maine Cod Trends in Recruitment and Biomass

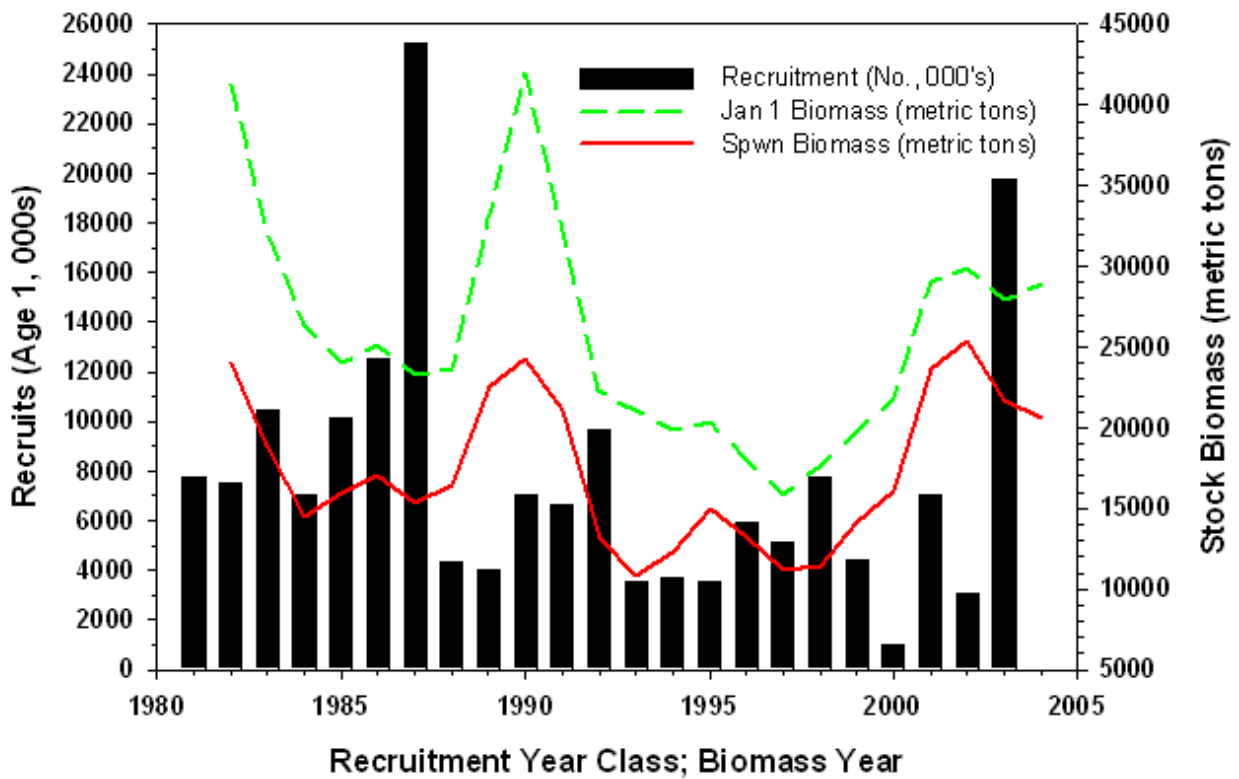


Figure 1.7. Trends in recruitment (age 1) and biomass for Gulf of Maine cod.



# Gulf of Maine Cod Yield and SSB per Recruit

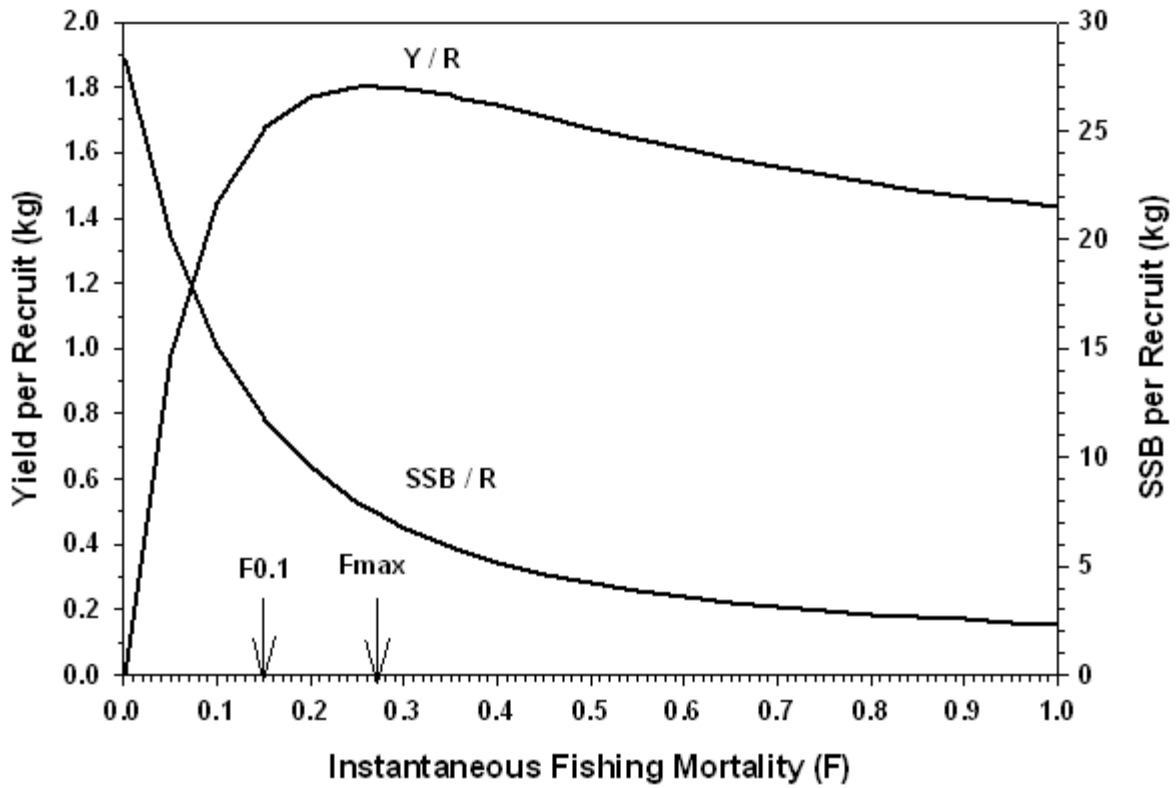


Figure 1.8. Yield and SSB per recruit reference points for Gulf of Maine cod.

## Gulf of Maine Cod Stock-Recruitment Plot

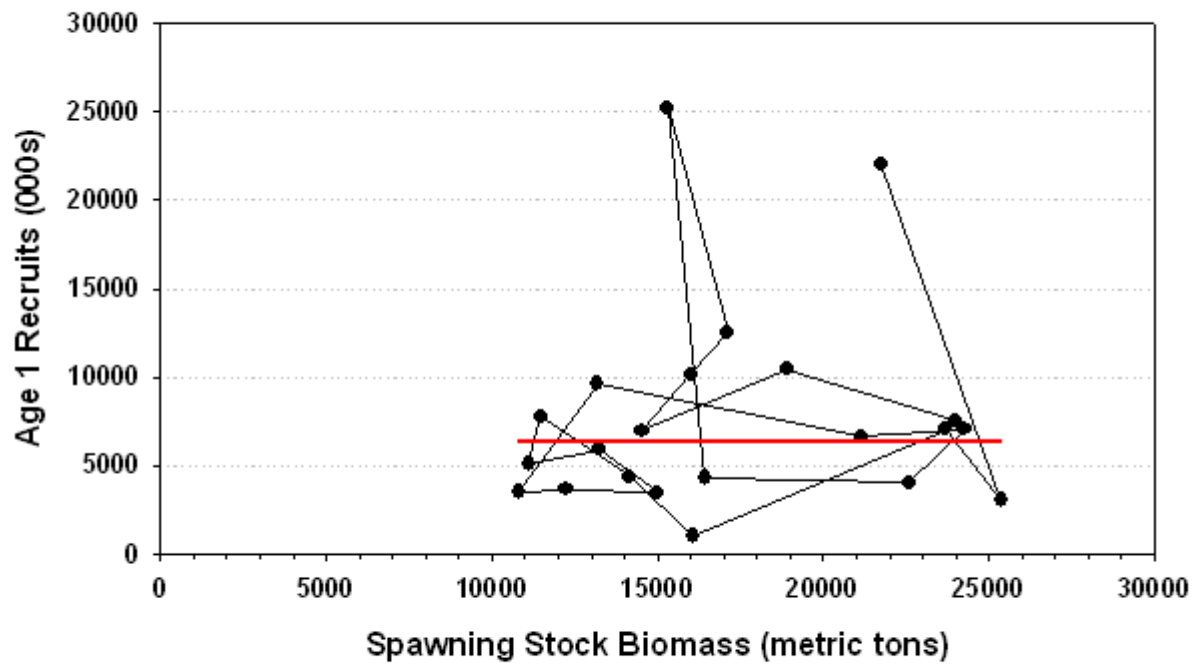


Figure 1.9. Spawning stock-recruitment scatterplot for Gulf of Maine cod. The solid horizontal line represents the geometric mean recruitment.

### Gulf of Maine Cod R/SSB Survival Ratios

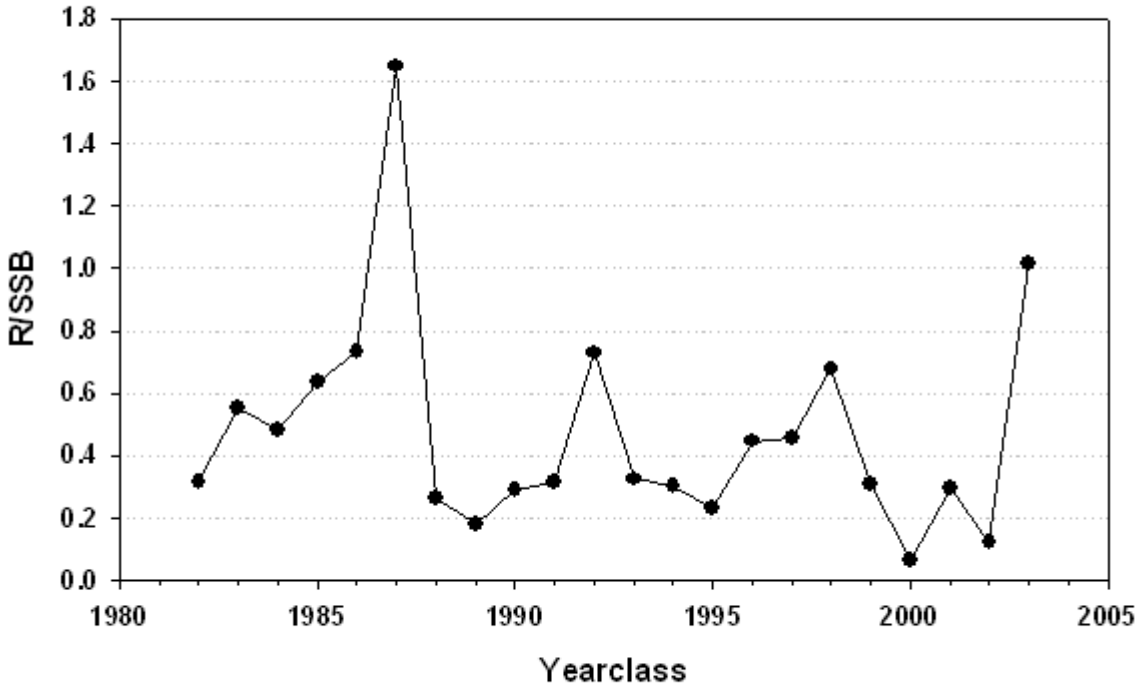
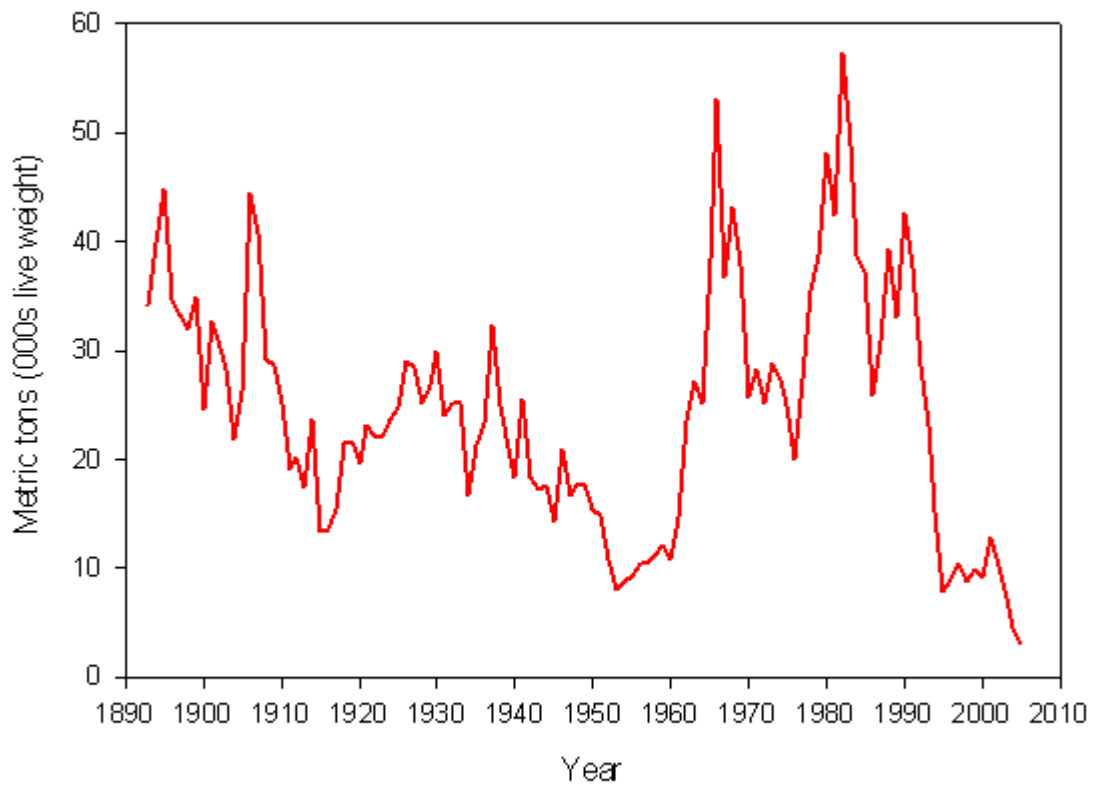


Figure 1.10. Trends in survival ratios (R/SSB) for Gulf of Maine cod.

## Georges Bank Cod Total Commercial Landings



**Figure 1.11** Total commercial landings of Georges Bank cod (NAFO Div. 5Z and Subarea 6), 1893-2005.

### Georges Bank Cod Commercial Landings by Age

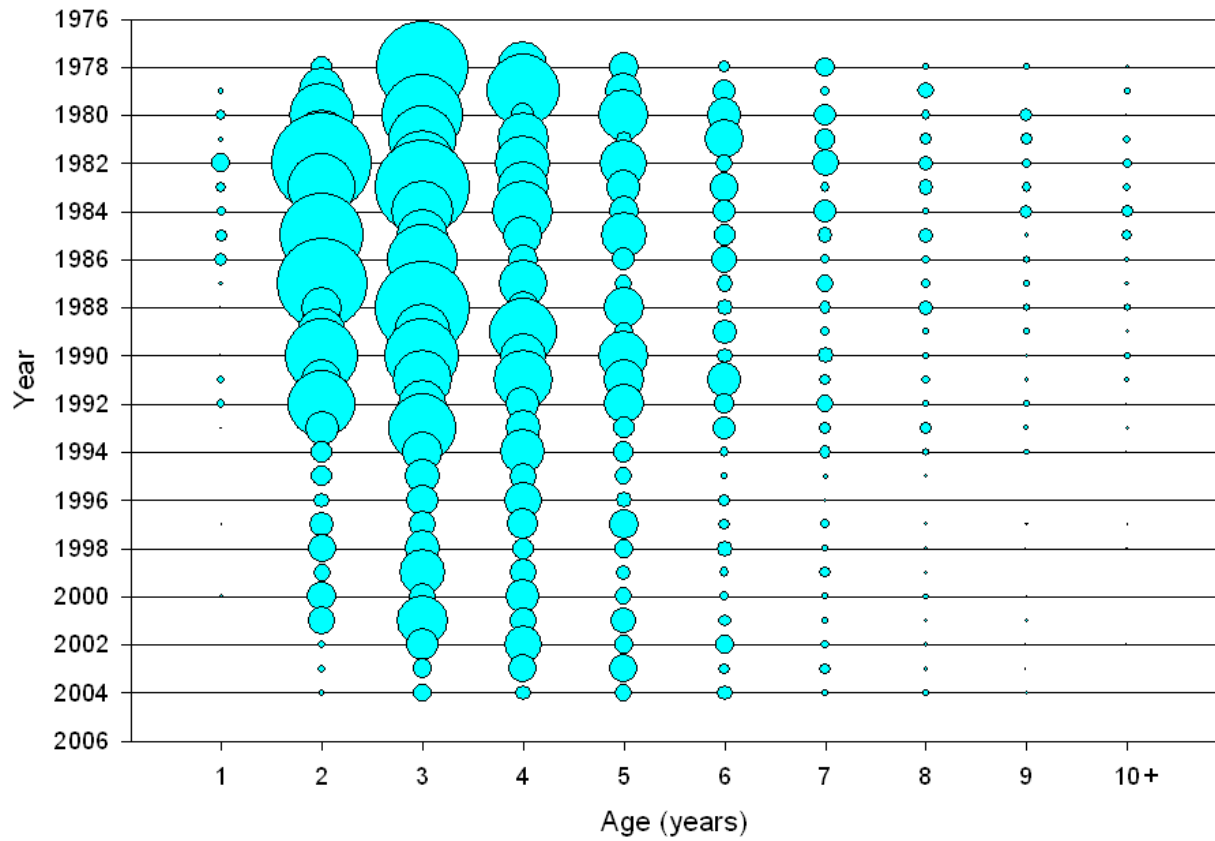
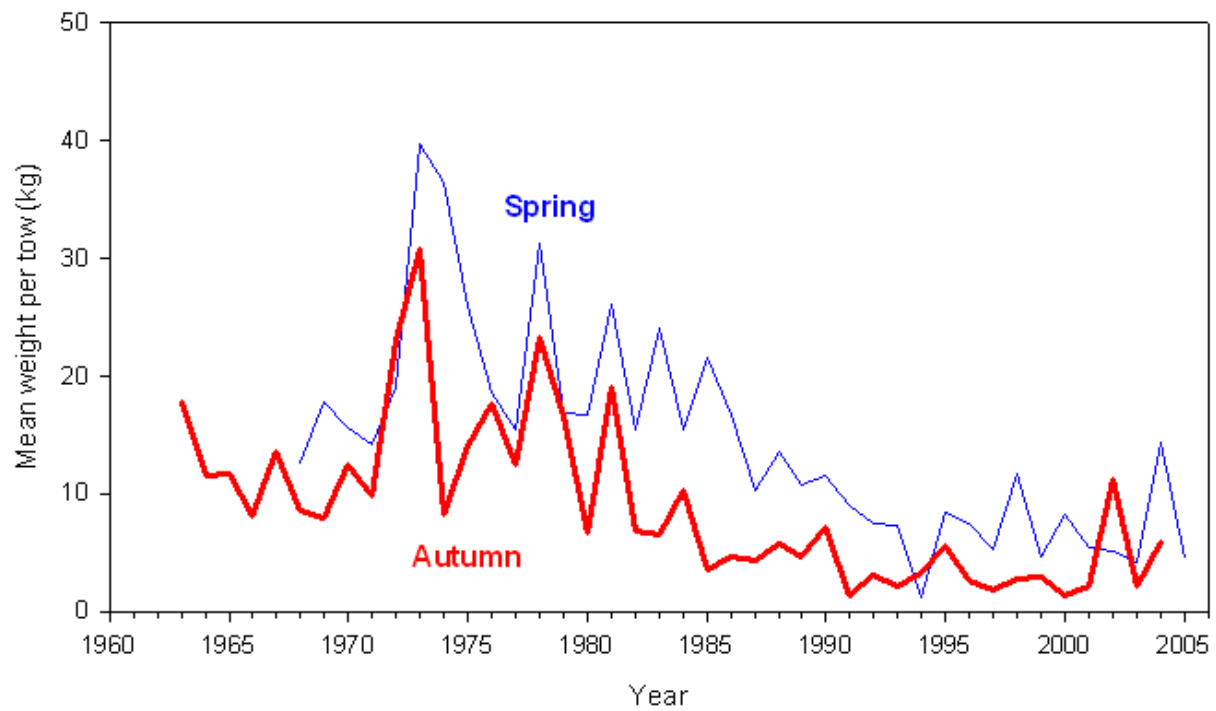


Figure 1.12. Age composition of Georges Bank Atlantic cod commercial landings, 1978-2004.

## Georges Bank Cod NEFSC Spring and Autumn Biomass Indices



**Fig 1.13. Biomass indices (stratified mean weight per tow) of Georges Bank Atlantic cod from NEFSC spring and autumn research vessel bottom trawl surveys, 1963-2005.**

### Georges Bank Atlantic Cod Autumn Survey Indices

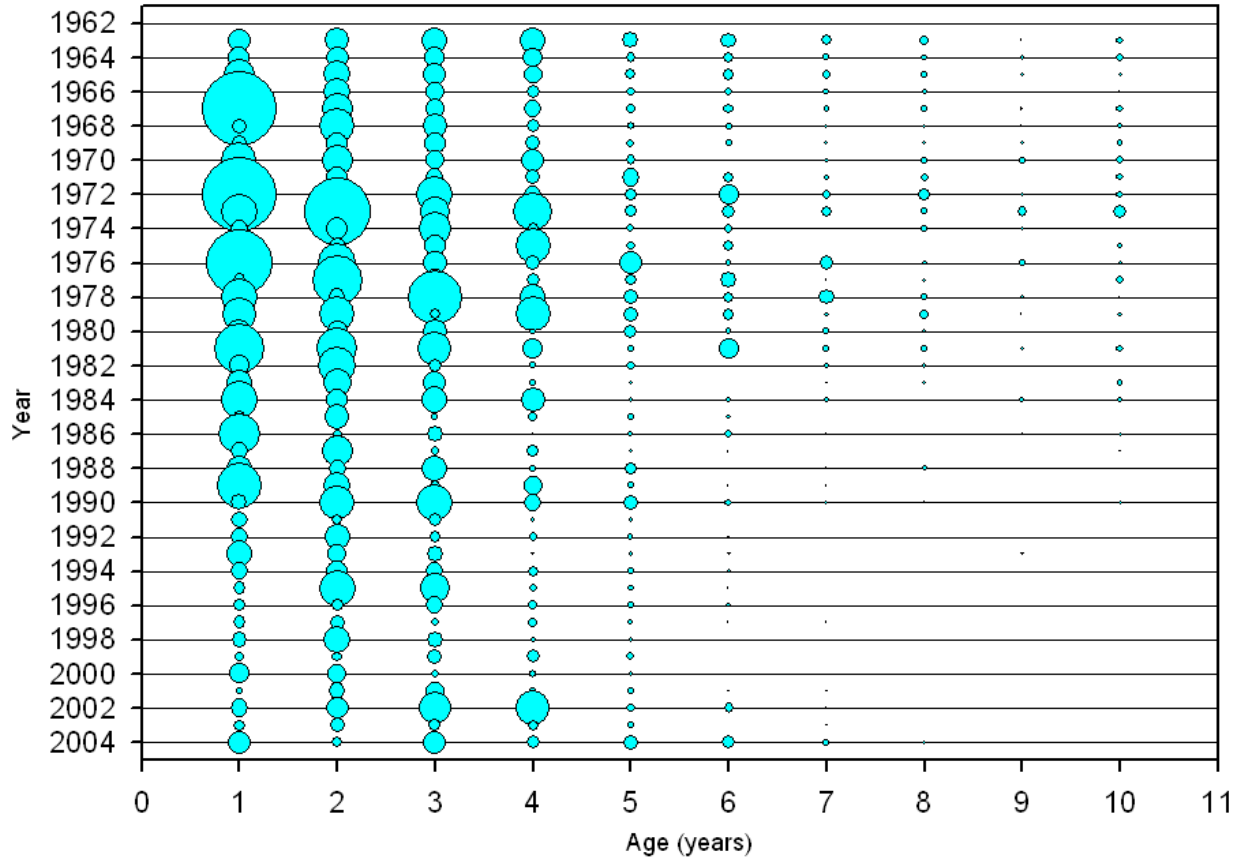


Figure 1.14 . Age structure of Georges Bank Atlantic cod population as indicated by autumn research vessel survey indices of abundance.

## Georges Bank Cod Trends in Landings and Fishing Mortality

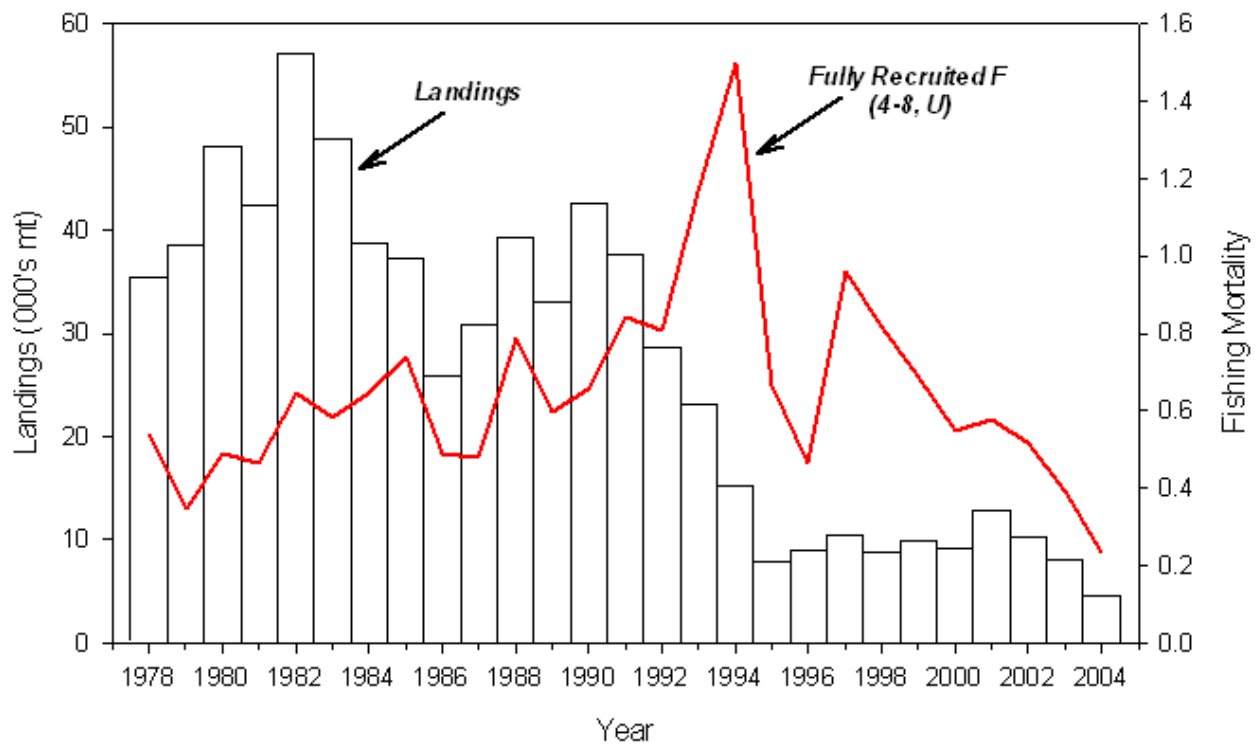
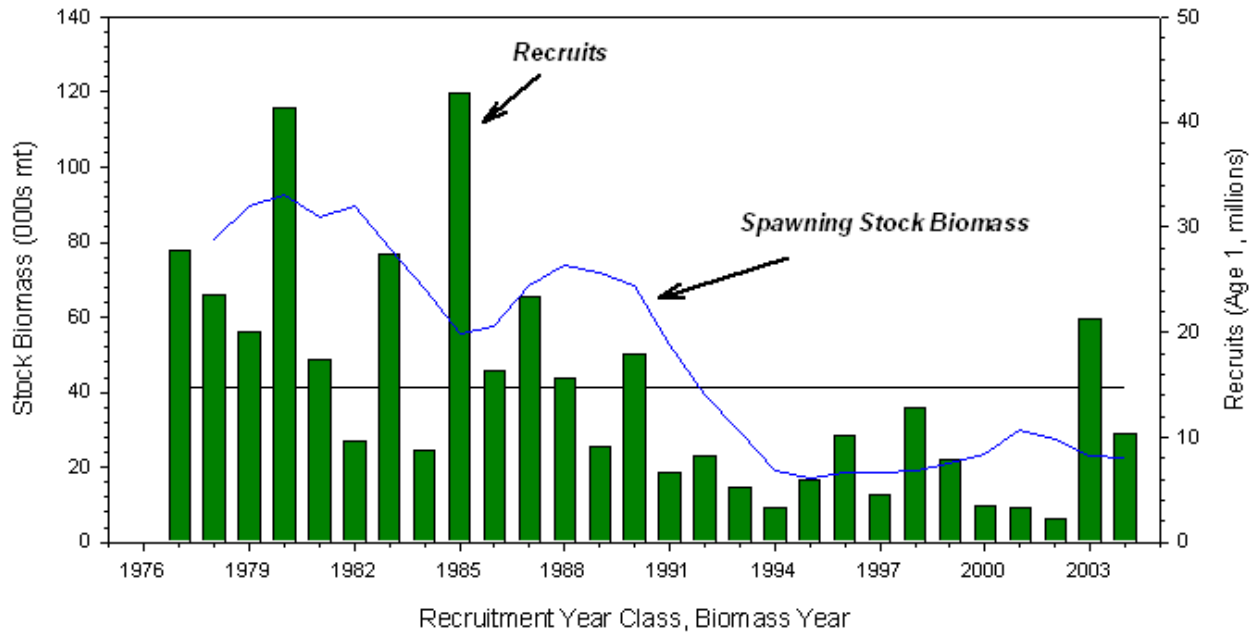


Figure 1.15. Trends in total commercial landings and fishing mortality for Georges Bank cod, 1978-2004.



## Georges Bank Atlantic Cod Trends in Recruitment and Biomass



**Figure 1.16** Trends in recruitment and biomass for Georges Bank Atlantic cod, 1978-2004. Horizontal line is the average recruitment for the time series.

### Georges Bank Atlantic Cod Yield and SSB per Recruit

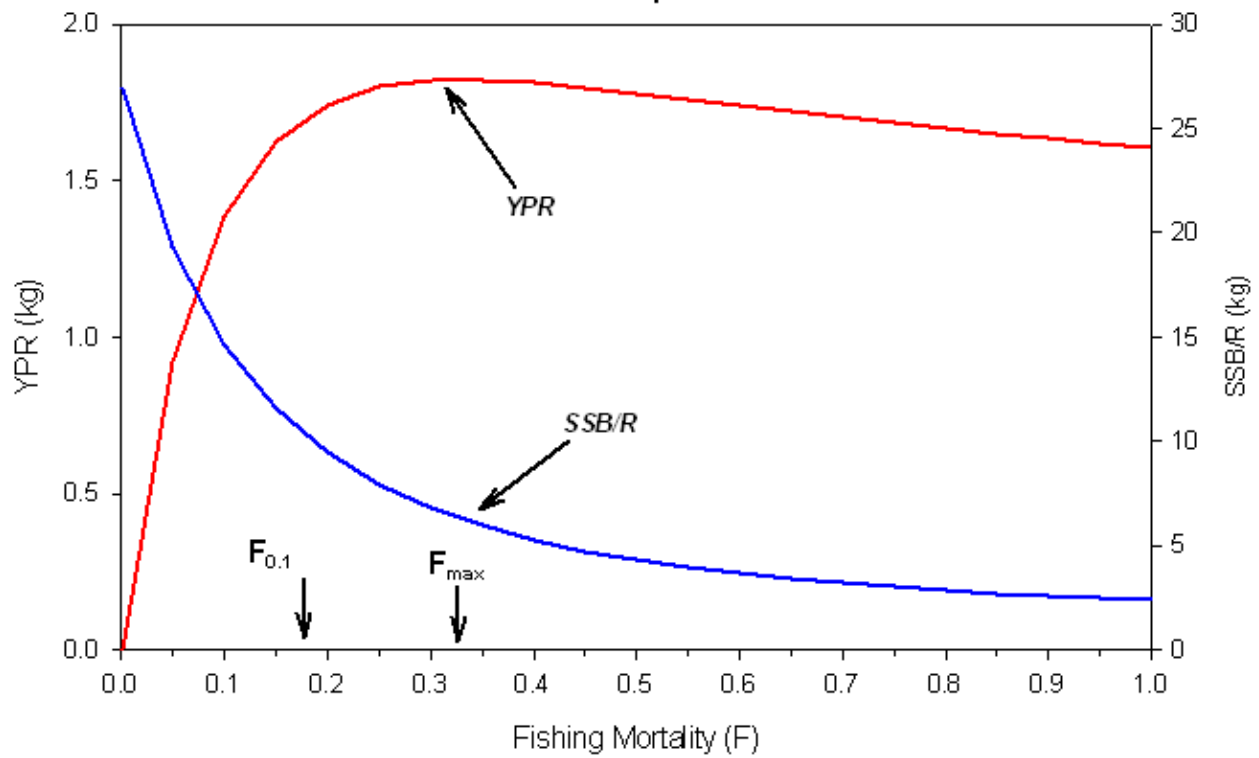


Figure 1.17 Yield and SSB per recruit reference points for Georges Bank based on data from O'Brien and Munroe (2001).

# Georges Bank Atlantic Cod

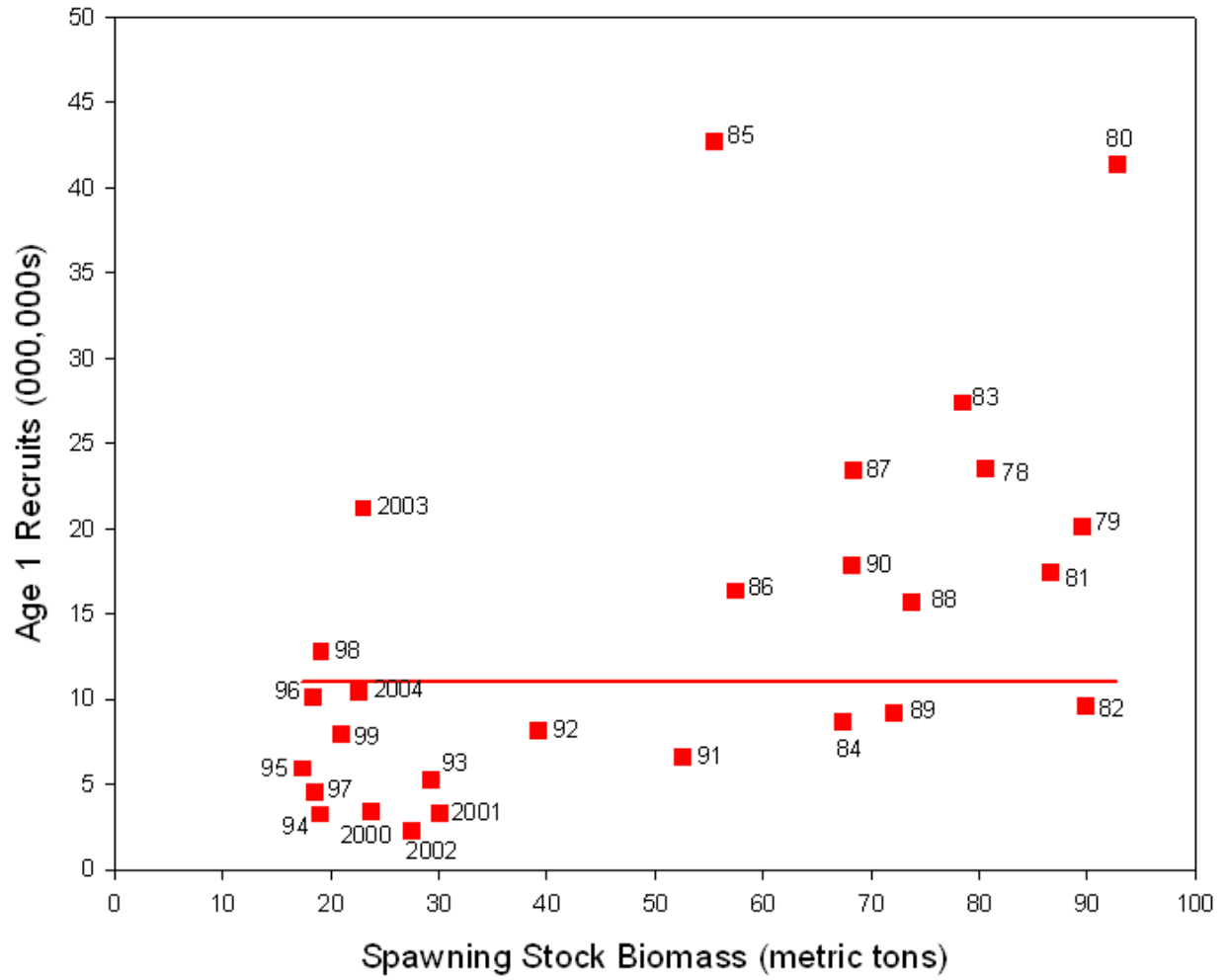


Figure 1.18. Spawning stock-recruitment scatterplot for Georges Bank Atlantic cod. Solid line represents the geometric mean recruitment.

## Georges Bank Cod

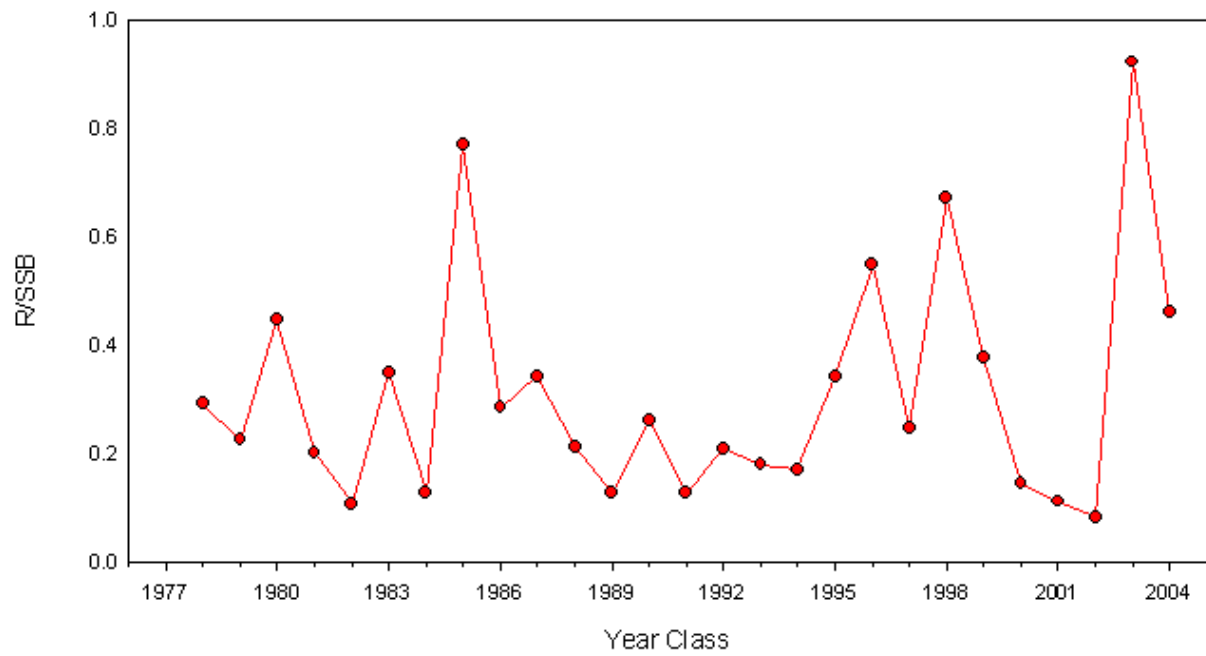


Figure 1.19. Trends in survival ratios (R/SSB) for Georges Bank cod.