TRAC Advisory Report on Stock Status

A Report of the Fourth Meeting of the Transboundary Resources Assessment Committee (TRAC), St. Andrews Biological Station, St. Andrews, New Brunswick, April 17-20, 2001

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U.S. DEPARTMENT OF COMMERCE
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Northeast Fisheries Science Center Reference Documents

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TABLE OF CONTENTS

INTRODUCTION

This *Advisory Report on Stock Status* provides results of the fourth meeting of the Transboundary Resources Assessment Committee (TRAC), held in St. Andrews, N.B.Canada April 17-20, 2001. The meeting was attended by 29 Canadian and USA scientists, managers and industry representatives. The primary purpose of the meeting was to review assessments of Georges Bank cod, haddock and yellowtail flounder management units and to prepare documentation required for management.

The TRAC process was initiated in 1998 as a forum for joint peer review of assessments for transboundary stocks of mutual interest to Canada and the United States. The process includes two working bodies, these being the Transboundary Assessment Working Group, or TAWG, consisting of Canadian and USA scientists and industry members, and the TRAC itself. The TAWG produces the assessments and addresses research recommendations and other needs as requested by the TRAC. The TRAC, consisting of Canadian and USA scientists, managers and industry members, reviews these assessments and other products and generates final reports on stock status. For Canada, this takes the form of Stock Status Reports (available from DFO Canada) for use in preparing management advice for the current fishing year (Canada typically opens its Georges Bank groundfish fishery June 1). For the USA, the primary products are advisory reports which are used in preparing management advice for the subsequent fishing year (here, the 2002 Fishing Year). These advisory reports consider stock status only, since projections of fishing mortality and stock size for the 2002 fishing year will require additional commercial landings information for 2001 and policy guidance on fishing mortality rates which will not be available until autumn.

The TAWG met in Woods Hole, MA March 19-22, 2001 and completed assessments for Georges Bank and South (Northwest Atlantic Fisheries Organization or NAFO Division 5Z and Subarea 6) cod, Georges Bank (5Z) haddock, and Georges Bank (5Z) yellowtail flounder, together with assessments for Eastern Georges Bank (5Zj,m) cod and haddock (Canadian and USA management units for Georges Bank yellowtail are the same). In addition, the TAWG also evaluated approaches used by both countries for determining biological reference points describing stock status. Statistical areas and stock boundaries for the USA assessments are given in Figure 1. The Canadian 5Zj and 5Zm areas coincide with USA statistical reporting areas 551-61 and 552-62, respectively.

The present meeting of the TRAC peer-reviewed these 5 assessments and completed advisory and stock status reports (advisory reports for the USA management units are given below). Complete assessment documents for the USA assessments will be published in the Northeast Fisheries Science Center reference document series. The TRAC also further reviewed procedures for determining biological reference points. The Proceedings of this meeting and other supporting documentation will be published separately.
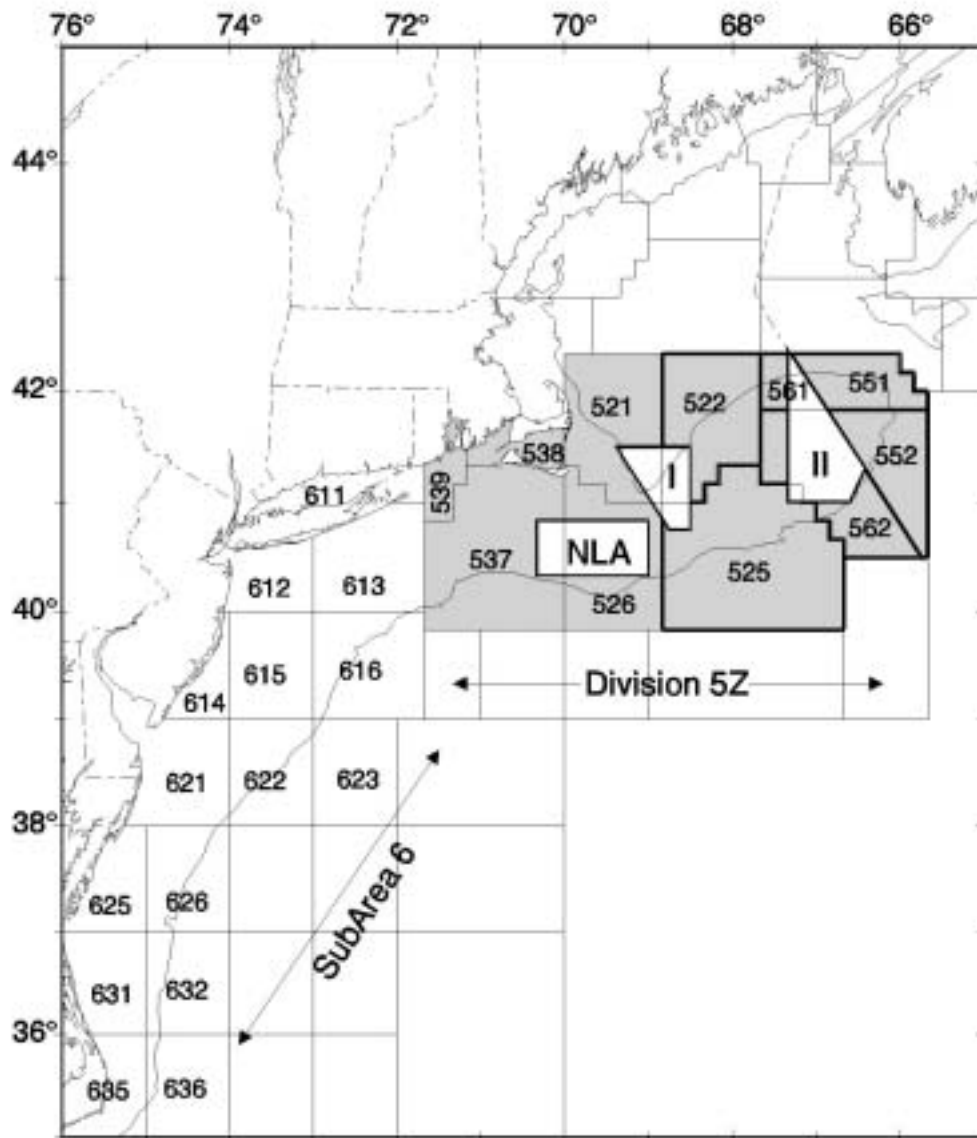
Figure 1.   Northeast statistical reporting areas included in Georges Bank cod, haddock and yellowtail assessments. Stock areas are as follows: cod, statistical areas 521 and higher (Northwest Atlantic Fisheries Organization or NAFO Division 5Z and Subarea 6); haddock, statistical areas 521-539 (shaded); and yellowtail, statistical areas 522, 525, 551-52, and 561-62 (dark border).

The evaluations of resource status presented in the following advisory reports are as mandated by the Sustainable Fisheries Act or SFA (PL 104-297) of 1996, now part of the Magnuson-Stevens Fisheries Conservation and Management Act or MSFCMA. National Standard Guidelines for the SFA require use of "status determination criteria" in the form of threshold levels for such evaluations. Overfishing is said to be occurring if fishing mortality (F) exceeds the Maximum Fishing Mortality Threshold (MFMT, or $F_{Threshold}$); and a stock is considered to be overfished if it falls below the Minimum Stock Size Threshold (MSST, or $B_{Threshold}$). The latter is usually $^1/_4$ to $^1/_2$ B_{MSY}, the stock biomass level which would be expected to produce maximum sustainable yield or MSY. Definitions in the following advisories are as proposed by the Overfishing Definition Review Panel (Applegate *et al.*1998), now in effect under Amendment 9 to the New England Fishery Management Council's Northeast Multispecies Fishery Management Plan or FMP. Because overfished stocks must be rebuilt, the Panel also proposed control laws or rules which specify how F should vary with biomass and provide both threshold and target levels determined by stock biomass levels relative to B_{MSY}. Note that $F_{Threshold}$ is a "limit" reference point indicating the point at which Fshould be constrained substantially and the probability for exceeding this value should be low. "Target" levels are reference points designed to ensure that F exceeds the threshold only rarely. Control rules for Georges Bank and South cod, Georges Bank haddock, and Georges Bank yellowtail flounder, and evaluations of stock status for 2000 in relation to these control rules, are given in the following advisory reports.

These stocks are managed under the FMP by both indirect and direct effort controls including a moratorium on permits and days-at-sea restrictions. Canadian management measures include total allowable catches (TACs) based on an $F_{0.1}$ management strategy (further information including projections of harvests in 2001 and stock size in 2002 is given in the DFO Stock Status Reports for 2001 referenced below). Measures for both countries are designed to keep F at levels which will promote stock rebuilding.

For further information

Applegate, A., S. Cadrin, J. Hoenig, C. Moore, S. Murawski and E. Pikitch. 1998. Evaluation of existing overfishing definitions and recommendations for new overfishing definitions to comply with the Sustainable Fisheries Act. Final Report of the Overfishing Definition Review Panel to the New England Fishery Management Council, 179 p.

DFO 2001. Eastern Georges Bank cod. DFO Sci. Stock Status Report A3-04 (2001).

DFO 2001. Eastern Georges Bank haddock. DFO Sci. Stock Status Report A3-08 (2001).

DFO 2001. Yellowtail flounder on Georges Bank. DFO Sci. Stock Status Report A3-15 (2001).

Restrepo, V.R., P.M. Mace and F. Serchuk. 1999. The precautionary approach: a new paradigm or business as usual? p. 61-70 *In*: NMFS. 1999. Our living oceans. Report on the status of U.S. living marine resources, 1999. U.S. Dep. Comm., NOAA Tech Memo. NMFS-F/SPO-41, 301 p.

DEFINITIONS OF TECHNICAL TERMS

ADAPT: A computer program used to optimally fit a virtual population analysis (VPA, see below) to abundance data.

Biological Reference Points: Specific values for variables that describe the state of a fishery, used to evaluate its status. These may include "target" reference points, corresponding to a desired result (e.g., maintaining a healthy biomass level), and "limit" reference points, or "thresholds" carrying an unacceptably high risk if exceeded. Examples are $F_{0.1}$, F_{MSY}, $F_{Threshold}$, and F_{max} .

Biomass-weighted F: An estimate of fishing mortality in which F estimates for each age group are weighted by corresponding stock biomass at age. This calculation is needed to make average F estimates from age structured assessments comparable to those obtained from surplus production modeling of all stock components.

B_{MSY}: The long-term average stock biomass level required to achieve Maximum Sustainable Yield or MSY, when the stock is fished at F_{MSY}.

$B_{Threshold}$ (Minimum Stock Size Threshold or MSST): One of two Status Determination Criteria specified in the National Standard Guidelines. At stock sizes below $B_{Threshold}$, the stock is considered to be overfished.

Control Rule: A protocol for specifying harvest rates in relation to stock status and limit and target reference points. Technically, a harvest strategy which, if implemented, would be expected to result in a long-term average catch approximating MSY. In the National Standard Guidelines, the "MSY Control Rule" is used to determine the limit fishing mortality, or Maximum Fishing Mortality Threshold (MFMT). Control rules are also known as "decision rules" or "harvest control laws" in some of the scientific literature.

Exploitation Pattern: The distribution of fishing mortality over the age composition of the fish population, determined by the type of fishing gear, areal and seasonal distribution of fishing, and the growth and migration of the fish. The pattern is expressed as a series of values ranging from 0.0 to 1.0.

Exploitation Rate: The proportion of a population at the beginning of the year that is caught during the year. For example, if 720,000 fish were caught during the year from a population of 1 million fish alive at the beginning of the year, the annual exploitation rate would be 0.72 or 72%. Note that this rate cannot exceed unity; obviously, more fish cannot die than were originally present.

Fishing Mortality Rate (F): That part of the total mortality rate applying to a fish population that is caused by fishing. Fishing mortality is usually expressed as an *instantaneous* rate, and can range to values exceeding unity, such as 2.0 or higher.

F_{max}: The fishing mortality rate that results in the maximum level of yield per recruit. This is the point beyond which growth overfishing begins.

F_{MSY}: The fishing mortality rate that produces MSY by taking a constant fraction of a stock that is fluctuating around B_{MSY}.

$F_{0.1}$: The fishing mortality rate at which the increase in yield per recruit in weight for an increase in a unit of effort is 10 percent of the yield per recruit produced by the first unit of effort on the unexploited stock (i.e., the slope of the yield-per-recruit curve for the $F_{0.1}$ rate is one-tenth the slope of the curve at its origin).

F_{Target}: The fishing mortality rate which (with some specified probability level) will prevent $F_{Threshold}$ from being exceeded.

$F_{Threshold}$ **(Maximum Fishing Mortality Threshold or MFMT):** One of two Status Determination Criteria, specified in the National Standard Guidelines. Exceeding $F_{Threshold}$ for one year or more constitutes overfishing.

Fully-recruited F: An estimate of fishing mortality for all age groups fully vulnerable to fishing.

Maximum Sustainable Yield (MSY): The largest long-term average catch or yield that can be taken from a stock or stock complex under prevailing ecological and environmental conditions.

Maximum Spawning Potential Reference Points: Reference points based on some fraction of maximum spawning potential (MSP) as determined from spawning stock biomass per recruit models, used to define overfishing. MSP is the spawning stock biomass per recruit in the absence of fishing; it is then reduced to a percentage of the maximum as F increases.

Mean Biomass: The product of mean abundance (numbers) and the average weight of individual fish. Mean abundance is calculated from abundance at the beginning of the year and the annual mortality rate, while average weights are derived from population size and weight at age data.

Mortality Rates: The rates at which fish die from fishing and/or natural causes. Biologists tend to work with *instantaneous* rates, in which time intervals are sufficiently short so as to allow separation of the primary components as instantaneous fishing mortality (F) and instantaneous natural mortality (M). Together the two equal instantaneous total mortality (Z); i.e. $Z = F+M$.

Natural Mortality Rate (M): That part of total mortality applying to a fish population that is caused by factors other than fishing. It is common practice to consider all sources together since they usually account for much less than fishing mortality. It is usually expressed as an instantaneous rate as noted above.

Nominal Catch: The sum of the catches that are landed (expressed as live weight or equivalents). Nominal catches do not include unreported discards.

Overfishing/overfished: According to the National Standard Guidelines, "overfishing occurs whenever a stock or stock complex is subjected to a rate or level of fishing mortality that jeopardizes the capacity of a stock or stock complex to produce MSY on a continuing basis." Overfishing is occurring if $F_{Threshold}$ is exceeded for a year or more. An "overfished" stock has been reduced below $B_{Threshold}$ requiring management actions to rebuild to the MSY level within an acceptable time frame.

Partial Recruitment: Patterns of relative vulnerability of fish of different sizes or ages due to the combined effects of gear selectivity and availability to the fishery.

Recruitment: The number of fish that survive (from birth) to a specific age or grow to a specific size.

Spawning Stock Biomass (SSB): The total weight of all sexually mature fish in the population.

Spawning Stock Biomass Per Recruit (SSB/R): The expected lifetime contribution to the spawning stock biomass for a recruit. For a given exploitation pattern, rate of growth, and rate of natural mortality, an expected equilibrium value of SSB/R can be calculated for each level of F and compared to the maximum level of SSB/R that would be realized if there were no fishing.

Status Determination Criteria: Objective and measurable criteria used to determine if overfishing is occurring or the stock is in an overfished state according to National Standard Guidelines.

TAC: Total allowable catch is the total regulated catch from a stock in a given time period, usually a year.

Virtual Population Analysis or VPA: A retrospective analysis of the catches from a given year class which provides estimates of fishing mortality and stock size at each age. A VPA takes natural mortality into account as well as removals from fishing. The method requires accurate statistics of catch by year, information on natural mortality, and a reasonably accurate estimate of F in the terminal year of the time series. This technique is used extensively in fishery assessments, since the conditions for its use are so common; many fisheries are heavily exploited, the annual catches for a year class can generally be determined, and the natural mortality rate is known within a fairly small range and is low compared with the fishing mortality rate.

Year class (or cohort): Fish in a stock born in the same year. For example, the 1987 year class of cod includes all cod born in 1987, which would be age 1 in 1988, age 2 in 1989, etc.

Yield per recruit (Y/R or YPR): The average expected yield in weight from a single recruit. Y/R is calculated assuming that F is constant over the life span of a year class. The calculated value is also dependent on the exploitation pattern, rate of growth, and natural mortality rate.

A. GEORGES BANK COD ADVISORY REPORT

State of Stock: Mean biomass in 2000 is above $B_{THRESHOLD}$ (1/4 B_{MSY} =27,000 mt) and biomass weighted fishing mortality is below F_{MSY} (0.32), therefore, the stock is not overfished and overfishing is not occurring, according to the Sustainable Fisheries Act (SFA) status determination criteria. Fully recruited fishing mortality declined from a record high of 1.47 (72% exploitation) in 1994 to 0.22 (18% exploitation) in 2000, slightly above $F_{0.1}$. (0.18) (Figure A1). Biomass weighted fishing mortality in 2000 was about twice the target F specified by the SFA control rule (Figure A4).   Although mean biomass has increased from the record low in 1995 it is still only about 36% of B_{MSY} (108,000 mt; Amendment 9) in 2000 (Figure A2 and A4). Spawning stock biomass has increased from the time series low in 1995 to 29,000 mt in 2000 (41% of the Amendment 7 rebuilding target) (Figure A2). Since the 1990 year class, the sizes of recruiting year classes have all been well below average. The 1997 and 2000 year classes are estimated to be the weakest in the time series. Without improved recruitment biomass rebuilding is unlikely. (Figure A2).

Catch and Status Table (weights in '000 mt, recruitment in millions): Georges Bank Cod

Year	1993	1994	1995	1996	1997	1998	1999	2000	Max[1]	Min[1]	Mean[1]
Total commercial landings[2]	23.1	15.2	7.9	8.9	10.4	8.8	9.9	9.2	57.2	7.9	29.5
US commercial landings[2]	14.6	9.9	6.8	7.0	7.5	6.9	8.1	7.6	40.1	6.8	21.5
Canada commercial landings	8.5	5.3	1.1	1.9	2.9	1.9	1.8	1.6	17.8	1.1	8.0
Discards			Discards occur but reliable estimates not presently available								
US recreational landings[3]	1.9	1.0	1.3	0.6	0.8	0.5	0.4	1.1	8.7	0.4	2.1
Catch used in assessment	23.1	15.2	7.9	8.9	10.4	8.8	9.9	9.2	57.2	7.9	29.5
Mean Biomass	35.6	28.1	26.6	30.3	34.4	32.8	35.6	38.5	135.2	26.6	75.2
Spawning stock biomass[4]	29.4	19.2	18.1	20.5	22.9	25.2	27.4	29.0	92.6	18.1	54.9
Recruitment (age 1)	8.4	6.3	4.3	7.6	10.3	3.2	7.3	4.9	42.8	3.2	15.7
F (ages 4-8, fully recruited, unweighted)	1.15	1.47	0.63	0.44	0.83	0.59	0.45	0.22	1.47	0.22	0.65
Exploitation rate	63%	71%	43%	34%	52%	41%	33%	18%	71%	18%	42%
F (age 1+, biomass weighted)	0.66	0.55	0.30	0.30	0.31	0.27	0.28	0.24	0.66	0.24	0.40

[1]Over period 1978-2000. [2] US landings for 1994-2000 are provisional. [3]Not used in assessment. [4]At beginning of the spawning season (i.e., March 1).

Stock Identification and Distribution: The Georges Bank cod stock is distributed primarily from the Northeast Peak of Georges Bank to Nantucket Shoals, with minor occurrence in the Southern New England and Mid-Atlantic regions. The distribution on the Northeast Peak spans the U.S.-Canada boundary.

Catches: Commercial landings increased in the late 1970s and early 1980s, peaking at a record high 57,200 mt in 1982. During 1983-1986, landings declined, but subsequently increased through 1990 (Figure A1). Total commercial landings declined to a record low of 7,900 mt in 1995 and have since remained relatively stable. Landings were 9,200 mt in 2000(Figure A1). Recreational landings have ranged from 400 mt to 8,700 mt accounting for 1-19% of the total cod catch.

Data and Assessment: An analytical assessment (VPA) of 1978-2000 commercial landings-at-age data was conducted assuming M=0.2. The VPA was calibrated using the ADAPT method with recruitment and abundance indices from NEFSC spring and autumn and Canadian spring bottom trawl survey catch-per-tow-at-age data. Discards and recreational catches were not included in the VPA. Precision associated with the estimates of fishing mortality, spawning stock biomass, and mean biomass in 2000 was evaluated (Figures A5 and A6 and A7).

Biological Reference Points: F_{MSY} (weighted by stock biomass at age) is estimated to be 0.32 and the MSY is estimated to be 35,000 mt from a B_{MSY} of 108,000 mt based on a surplus production model. Yield and SSB per recruit analyses , with an assumed M of 0.20, indicate that $F_{0.1}$ = 0.18 (15% exploitation), and the corresponding SSB per recruit is 40% of the maximum (Figure A3).

SFA Control Rule: When stock biomass is greater than B_{MSY} fishing mortality is not to exceed $F_{THRESHOLD} = F_{MSY}$;when biomass is between B_{MSY} and 1/2 B_{MSY} F will be defined by a 10 year rebuilding time period and when biomass is between ½ B_{MSY} and 1/4 B_{MSY} F will be defined by a five year rebuilding time period. F weighted by biomass is the metric for the SFA control rule.

Fishing Mortality: Fully recruited fishing mortality (ages 4-8,unweighted) doubled between 1979 and 1985 from 0.35 (27% exploitation) to 0.74 (48% exploitation), declined to 0.48 (35% exploitation) in 1986-1987, then increased to a record high of 1.47 (72% exploitation) in 1994. F has since declined to 0.22 (18% exploitation) in 2000 (Figure A1). There is an 80% probability that F in 2000 was between 0.18 and 0.25 (Figure A5). Biomass weighted F(ages 1+) has remained relatively stable since 1995 while fully recruited F has declined since 1997, indicating that younger cod are being exploited more heavily, particularly the 1996 and 1997 year classes (Figure A1).

Recruitment: Strong year classes were produced in 1980, 1983, and 1985. The 1990 year class was slightly above average, and all subsequent year classes have been well below average. The 1997 and 2000 year classes are the weakest year classes in the time series (1978-2000) (Figure A2).

Stock Biomass: Spawning stock biomass declined by about 40% between 1980 and 1985 (from 92,600 mt to 55,000 mt), increased in 1988 (74,000 mt), and then declined to a record low in 1995 (18,100 mt). SSB has since gradually increased to 29,000 mt in 2000, as a result of growth and survival of recent year classes rather than improved recruitment (Figure A2). There is an 80% probability that the SSB in 2000 was between 25,000 mt and 32,000 mt (Figure A6). Mean biomass trends were similar to SSB trends. There is an 80% probability that mean biomass in 2000 was between 33,000 mt and 43,000 mt (Figure A7)

Special Comments:
1. Retrospective analysis indicates a pattern of inconsistencies in the last year in which estimates of F are less than revised estimates of F and estimates of SSB are more than revised estimates of SSB.

2. Low levels of sampling of U.S. landings of large cod and discards contribute to the uncertainty in estimates of the size and age composition of the U.S. catch. U.S. port sampling for large cod has been chronically low, threatening to undermine the integrity of the stock assessment. VTRs and at sea observations by the Sea Sampling program are inadequate to reliably estimate the quantity of discard or characterize the size and age compositions.

3. There is a problem of mixing reference points and metrics of stock status that are based on different models (surplus production vs. dynamic pool) e.g. $F_{MSY} = 0.32$ corresponds to a maximum spawning potential (MSP) of 16.5% at fully recruited F = 0.47, which is less than 20% MSP at fully recruited F = 0.41.

Sources of Information: O'Brien, L and N.J. Munroe. 2001. Assessment of the Georges Bank Atlantic cod stock for 2000, NEFSC Ref. Doc. 01-xx. Overfishing Definition Review Panel. 1998. Evaluation of existing overfishing definitions and recommendations for new over fishing definitions to comply with the SFA. O'Brien L. and S.X. Cadrin. 1999. Assessment of the Georges Bank Atlantic cod stock for 1998, NEFSC Lab. Ref. 99-03.

Georges Bank Atlantic Cod

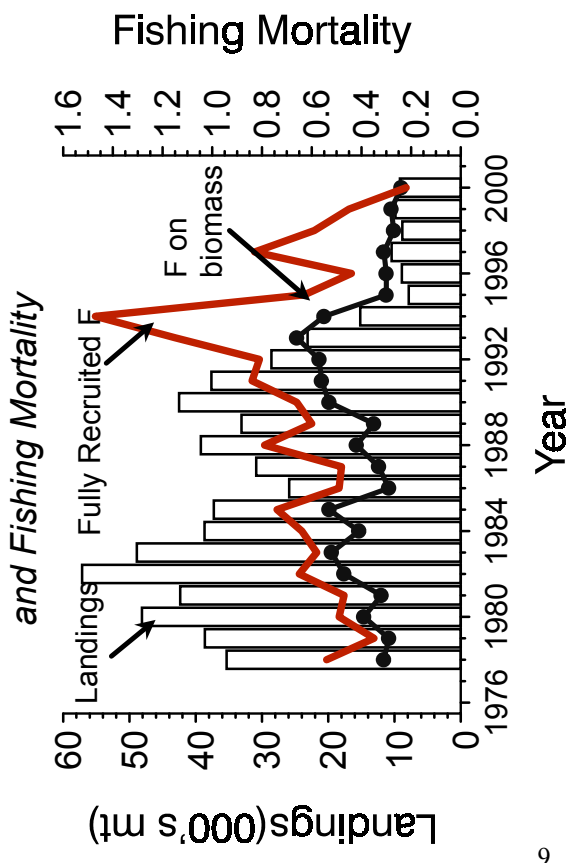**A1** *Trends in Total Commercial Landings and Fishing Mortality*
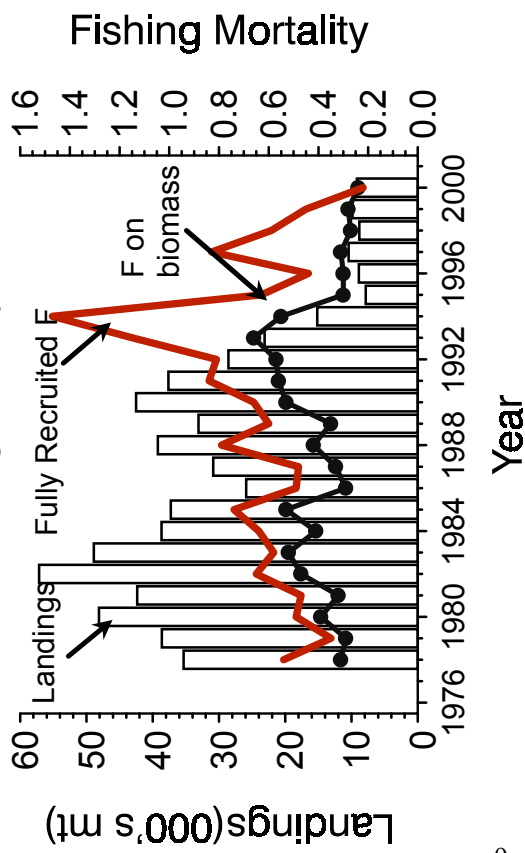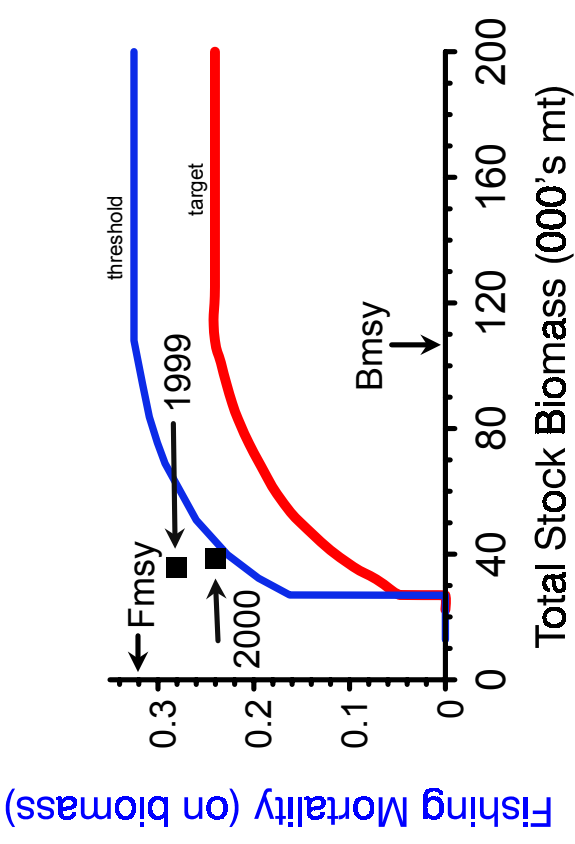
A2 *Trends in Biomass and Recruitment*
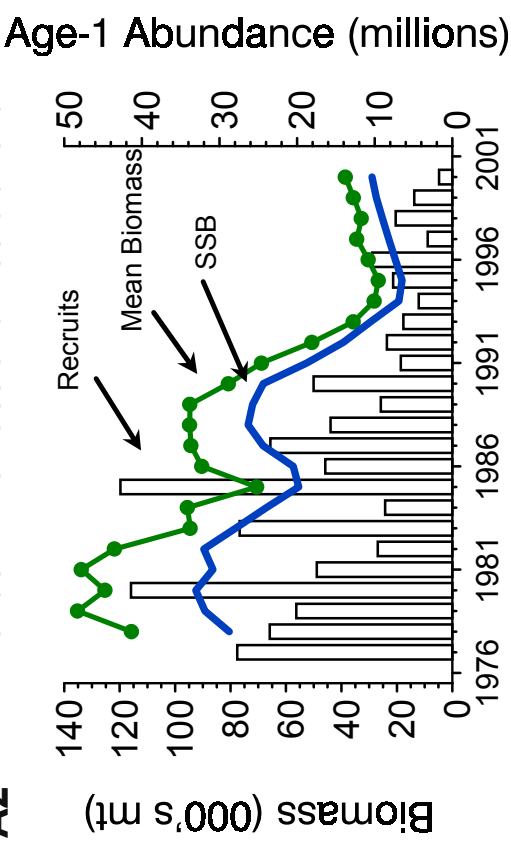
A3 *Yield and Spawning Biomass per Recruit*

A4 *Harvest Control Rule and Recent Stock Status*

Georges Bank Atlantic Cod
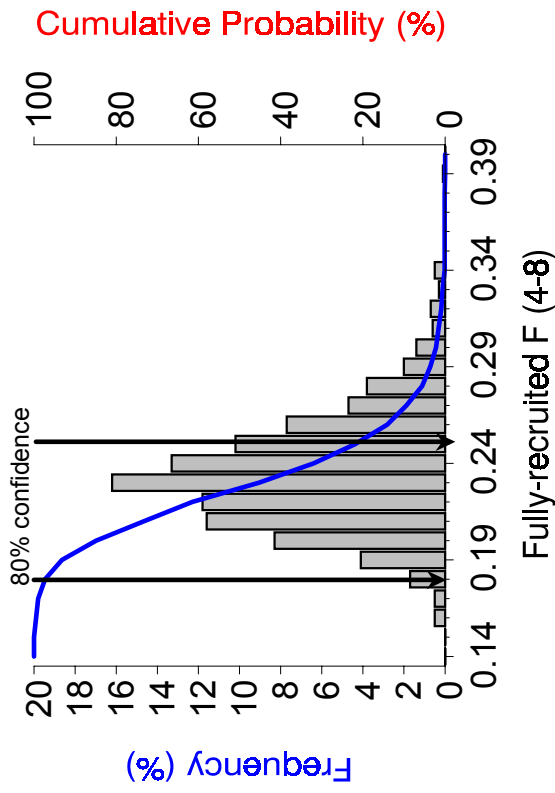
A6 *Precision of 2000 SSB Estimate*

Cumulative Probability (%)

Frequency (%)

Spawning Stock Biomass (000's mt)

80% confidence

A5 *Precision of 2000 F Estimate*

Cumulative Probability (%)

Frequency (%)

Fully-recruited F (4-8)

80% confidence

A7 *Precision of 2000 Mean Biomass Estimate*

Cumulative Probability (%)

Frequency (%)

Mean Biomass (000's mt)
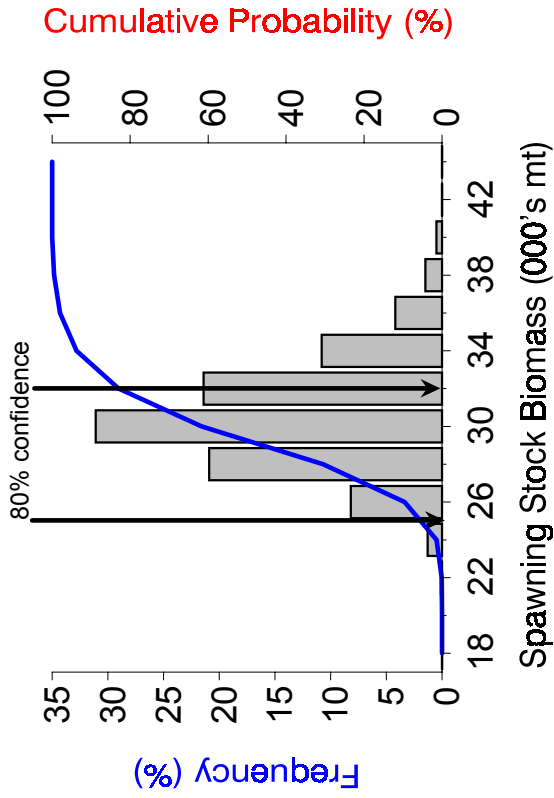
80% confidence
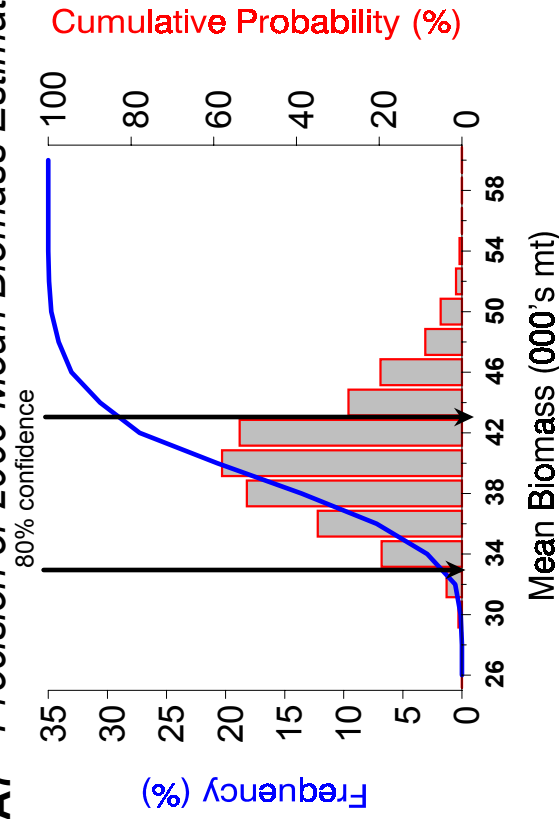
B. GEORGES BANK HADDOCK ADVISORY REPORT

State of Stock: Spawning stock biomass in 2000 was greater than the $SSB_{threshold}$ (½ B_{MSY} proxy = 53,000 mt, which is 50% of the spawning stock biomass expected to produce maximum sustainable yield) and fully recruited fishing mortality in 2000 was less than $F_{threshold}$ ($F_{MSY\ proxy}$ or $F_{0.1}$ = 0.26); therefore, the stock is not overfished and overfishing is not occurring according to the Sustainable Fisheries Act status determination criteria. Fully recruited fishing mortality has been reduced from pre-1994 levels, but has increased slightly in each of the past three years and is approaching the target fishing mortality for a rebuilt stock specified by the SFA control rule (Figure B4). The stock is recovering from an overexploited condition and spawning stock biomass has increased more than 5-fold from 1993 record low levels due to higher survivorship and improved recruitment since 1992.   The 2000 estimate (64,100 mt) is approximately 61% of the spawning stock biomass estimated to produce maximum sustainable yield (105,000 mt). The age structure of the population is continuing to expand and age 4+ biomass is at its highest level since 1982. The 1996 year class (20.7 million fish at age 1) has recruited to the fishery and comprised approximately 25% of the spawning stock biomass and 34% of the landings in 2000. Although there is uncertainty about the estimated sizes of the 1998 (39.6 million fish at age 1) and 2000 (57.3 million fish at age 1) year classes, they are currently estimated to be the largest since 1978. These year classes provide opportunities for both moderate increases in harvest and continued rebuilding of spawning stock biomass.

Catch and Status Table (weights in '000 mt, recruitment in millions): Georges Bank Haddock

Year	1993	1994	1995	1996	1997	1998	1999	2000	Max[1]	Min[1]	Mean[1]
Landings											
US commercial[2]	0.7	0.2	0.2	0.3	0.9	1.8	2.8	3.4	52.9	0.2	12.2
Canada landings	3.7	2.4	2.1	3.6	2.7	3.4	3.7	5.4	18.3	0.5	5.1
Other commercial	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	82.6[3]	0.0[3]	10.7[3]
Total landings	4.4	2.6	2.3	4.0	3.6	5.2	6.5	8.8	150.4	2.3	21.0
Discards											
US commercial discards	N/A	0.5	0.1	0.3	0.6	0.1	N/A	N/A	N/A	N/A	N/A
Catch used in assessment	4.4	3.1	2.4	4.3	4.3	5.3	6.5	8.8	150.4	2.4	21.8
Spawning stock biomass[4]	11.3	15.1	24.4	30.2	37.5	45.0	53.4	64.1	180.5	11.0	48.2
Recruitment (age 1)	13.9	13.5	10.7	11.0	20.7	13.8	39.6	19.6	471.9	0.4	9.2[5]
F(ages 4-7, fully recruited unweighted)	0.42	0.35	0.14	0.17	0.12	0.14	0.16	0.19	0.61	0.11	0.34
Exploitation rate	31%	27%	12%	14%	10%	12%	13%	16%	42%	9%	26%

[1] Over period 1963-2000. [2] Data 1994 through 2000 are provisional. [3] Over period 1962-1976. [4] At beginning of the spawning season (April 1). [5] Geometric mean.

Stock Identification and Distribution: Georges Bank haddock are distributed from the Northeast Peak to Nantucket Shoals, with minor occurrence in the Southern New England and Mid-Atlantic regions. Highest concentrations are currently found along the Northern Edge and Northeast Peak of Georges Bank. Historically, haddock were also abundant in the Great South Channel area of Georges Bank, and recent commercial landings and research vessel surveys suggest that abundance in this area has increased significantly.

Catches: Total commercial landings increased sharply in 1965 and 1966 as a result of strong recruitment and increased exploitation by distant water fleets commencing in the early 1960s. Landings declined to less than 6,000 mt between 1972 and 1976, but increased in the late 1970s to 27,500 mt in 1980. Total landings then declined to only 2,300 mt in 1995, but have since increased to 8,800 mt in 2000 (Figure B1). Discards have been periodically estimated and added to the catch when levels were significant. Estimates of regulatory discarding occurring from 1994-1998 in response to U.S. trip limits are included in the current assessment. Landings by U.S. vessels are almost exclusively by otter trawl while Canadian landings are taken by otter trawl and longline gear. Recreational landings from this stock have been negligible.

Data and Assessment: An analytical assessment (VPA) was conducted incorporating 1931-2000 commercial catch-at-age data, assuming natural mortality (M = 0.2). The VPA was calibrated using the Adapt method using Canadian spring, and U.S. spring

and autumn survey numbers at age. The precision and uncertainty associated with the estimates of fishing mortality and spawning stock biomass in 2000 were quantitatively evaluated (Figures B5-B6).

Biological Reference Points: Yield and spawning stock biomass per recruit analyses, performed with an assumed M of 0.20, indicated that $F_{0.1} = 0.26$ (21% exploitation) and the corresponding equilibrium SSB per recruit is 40.9% of maximum (Figure B8). $F_{0.1}$ is used as a proxy for F_{MSY} and a spawning stock biomass level of 105,000 mt is used as a proxy for B_{MSY}.

SFA Control Rule: The SFA harvest control rule established SSB as a proxy for B_{MSY}, $F_{0.1}$ as a proxy for F_{MSY}, and fully recruited F (ages 4-7, unweighted) as the metric for fishing mortality (Figure B4). When SSB is greater than 105,000 mt (SSB_{MSY}), the threshold fishing mortality rate is $F_{0.1}$ (0.26, 21% exploitation) and the target fishing mortality rate is 75% of F_{MSY} proxy (0.20, 16% exploitation). As SSB declines below SSB_{MSY}, the threshold fishing mortality rate declines linearly from 0.26 to 0.00 at 1/2 SSB_{MSY} (52,500 mt), and the target fishing mortality rate declines linearly from 0.20 to 0.00 at 68,000 mt.

Fishing Mortality: Fully recruited fishing mortality remained between 0.28 and 0.45 (22% - 33% exploitation) during most of the 1980s and early 1990s before declining to 0.14 (12% exploitation) in 1995 (Figure B1). Fully recruited fishing mortality has remained at low levels ranging between 0.12 (10% exploitation) and 0.19 (16% exploitation) since 1995. There is an 80% probability that fishing mortality in 2000 is between 0.17 (14% exploitation) and 0.22 (18% exploitation) (Figure B5).

Recruitment: While recruitment has improved in the 1990s, recruitment since 1979 has been far below the historical average recruitment estimated for 1931 to 1960, when healthy stock conditions were observed. The 1998 (39.6 million) and 2000 (57.3 million) year classes are currently estimated to be the strongest since 1978; however, these year classes are only average to slightly below average relative to 1931-1960 levels. (See Special Comment #3). There is an 80% probability that age 1 stock size in 2001 (2000 year class) is between 36,900 and 88,000 fish (Figure B7).

Spawning Stock Biomass: SSB declined by 84% between 1978 and 1993 (69,700 mt to 11,300 mt). SSB began to increase in 1994 with higher survivorship and improved recruitment, and reached 64,100 mt by 2000 (Figure B2). There is an 80% probability that SSB was between 58,000 mt and 72,500 mt (Figure B6). Historically, SSB during the 1935-1960 period, when landings were sustained between 40,000 and 60,000 mt, was estimated to average 105,000 mt. The probability of strong recruitment is significantly greater when SSB exceeds 80,000 mt (Figure B3).
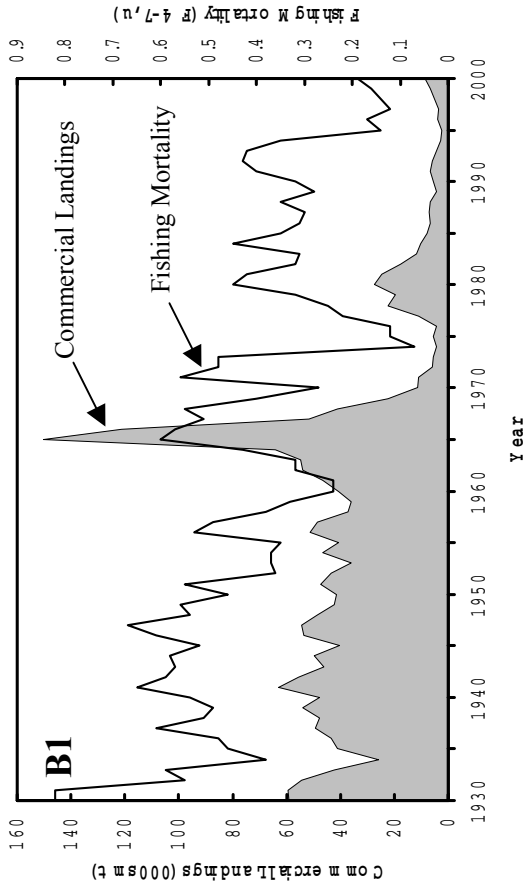
Special Comments:
1. Lack of paired market category samples from U.S. commercial landed trips and biological samples from eastern Georges Bank contribute to uncertainty in estimates of the size and age composition of the U.S. catch. The contribution of the 1996 year class to the 2000 U.S. catch at age may be underestimated due to pooling of samples from U.S. ports with different market category culling practices.

2. Vessel trip reports (logbooks) and at-sea observations are inadequate to reliably estimate the quantity of haddock discards or to characterize their size and age composition. Monitoring of discards in 2001 is particularly important because of the recruitment of the 1998 year-class.

3. There is uncertainty about the size of the 1998-2000 year classes. In the 1999 and 2000 assessments, there were significant downward revisions to estimates for the 1998 and 1999 year classes. The terminal year estimates of age 1 stock size are less certain in general due to variability in the research vessel survey data used to estimate these stock sizes (Figure B7). Since these age 1 stock sizes are incorporated into projections, forecasts of stock biomass are less certain, particularly when terminal year age 1 recruitment is estimated to be large, as it was for the 2000 year class.
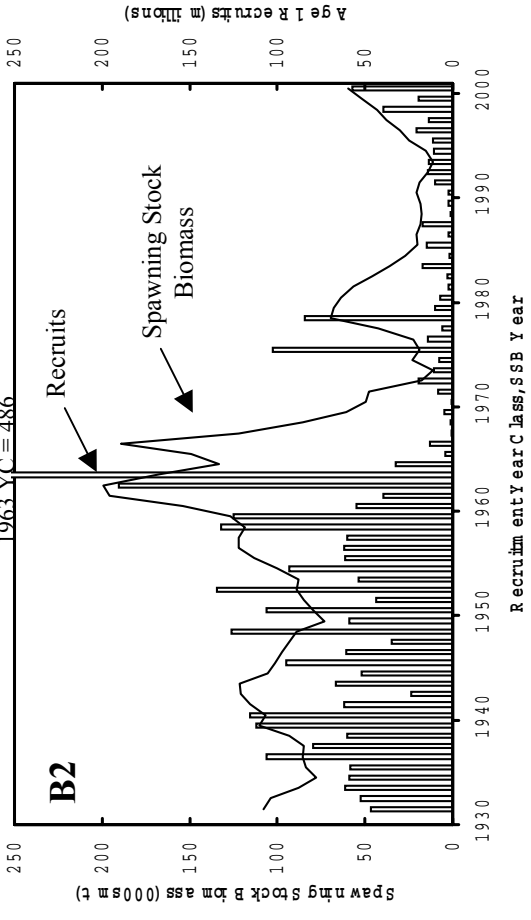
Source of Information: Brown, R.W. 2001. Assessment of the 5Z Georges Bank haddock stock, 1931-2000. NEFSC Ref. Doc. 2001-xx.
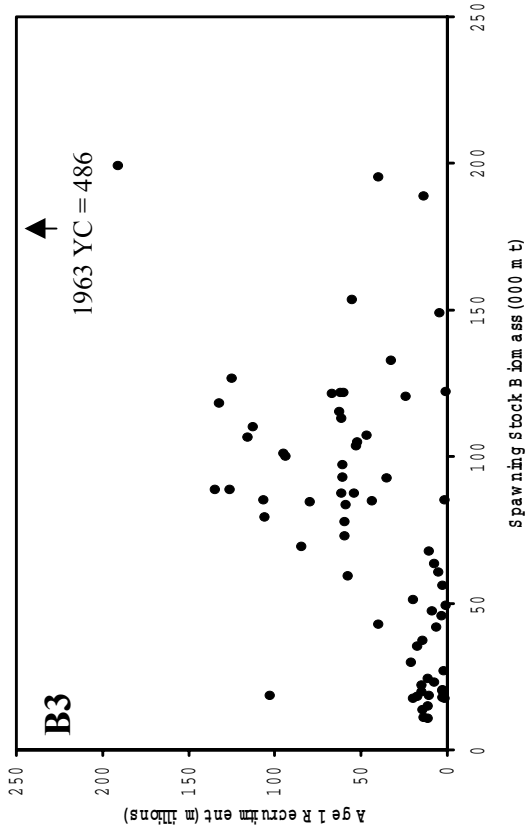
Georges Bank Haddock

Trends in Commercial Landings and Fishing Mortality

B1

Commercial Landings

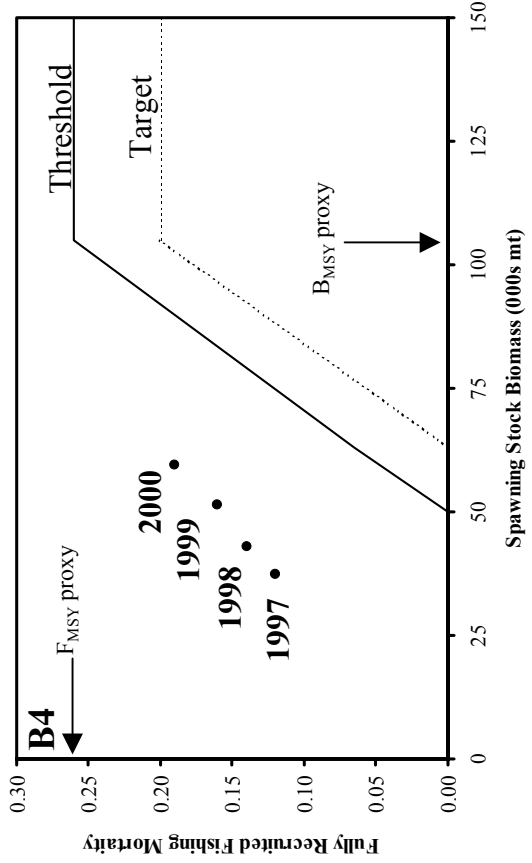Fishing Mortality

Year

Commercial landings (000s mt)

Fishing Mortality (F 4-7,u)

Trends in Biomass and Recruitment

B2

1963 YC = 486

Recruits

Spawning Stock Biomass

Recruitment Year Class, SSB Year

Spawning Stock Biomass (000s mt)

Age 1 recruits (millions)

Stock Recruitment Relationship

B3

1963 YC = 486

Spawning stock Biomass (000 mt)

Age 1 recruitment (millions)

Harvest Control Rule and Recent Stock Status

B4

Threshold

Target

B_{MSY} proxy

F_{MSY} proxy

2000

1999

1998

1997

Spawning Stock Biomass (000s mt)

Fully Recruited Fishing Mortality

17

Georges Bank Haddock

B5 — Precision of 2000 Estimate of Fishing Mortality

Frequency (%)

Cumulative Probability (%)

80% Confidence

Fishing Mortality (F 4-7, unweighted)

B6 — Precision of 2000 SSB Estimate

Frequency (%)

Cumulative Probability (%)

80% Confidence

Spawning stock Biomass (000s mt)

B7 — Precision of 2000 Year Class Estimate

Frequency (%)

Cumulative Probability (%)

80% Confidence

2000 Year Class Estimate (millions)

B8 — Yield and Spawning Stock Biomass per Recruit

Yield/Recruit (kg)

SSB/Recruit (kg)

YPR

SSB/R

F_{2000} $F_{0.1}$

Fully Recruited Fishing Mortality

18

C. GEORGES BANK YELLOWTAIL FLOUNDER ADVISORY REPORT

State of Stock: Overfishing is not occurring, and the stock is recovering from an overfished state, according to the Sustainable Fisheries Act (SFA) status determination criteria. In 2000, mean biomass was 56,000 mt, above the Amendment 9 rebuilding target (B_{MSY} = 49,000 mt). Although biomass increased, the age structure has also improved but remains truncated and dominated by younger ages. Fishing mortality was low (fully recruited F = 0.14, biomass weighted F = 0.12, which is well below the $F_{threshold} = F_{MSY}$ = 0.30, Figure C1). However, the exploitation rate on ages 2 and 3 has not declined proportionally and the partial recruitment to the fishery for these ages has increased. Spawning stock biomass (43,100 mt in 2000, Figure C2) has been increasing since 1995. Recruitment is strong, with an outstanding 1997 year class and above average 1996, 1998 and 1999 cohorts (Figure C2).

Catch and Status Table (weights in '000 mt, recruitment in millions): Georges Bank Yellowtail Flounder

Year	1993	1994	1995	1996	1997	1998	1999	2000	Max[1]	Min[1]	Mean[1]
US											
Landings[2]	2.1	1.6	0.3	0.8	1.0	1.8	2.0	3.7	15.9	0.3	7.3
Discards	1.1	0.1	0.0	0.0	0.1	0.1	0.5	0.4	5.6	0.0	1.5
Canada											
Landings	0.7	2.1	0.5	0.5	0.8	1.2	2.0	2.9	2.9	0.0	0.3
Discards[3]	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total catch	3.9	3.9	0.8	1.3	1.8	3.1	4.4	6.9	21.3	0.8	9.3
Mean Biomass[4]	6.7	4.8	5.8	9.9	18.4	35.3	52.1	56.0	56.0	3.3	15.0
SSB[4]	4.4	2.5	2.5	5.1	8.5	16.1	32.3	43.1	43.1	2.2	9.5
Recruitment (age 1)[4]	12.2	11.3	15.8	23.4	50.0	77.0	45.1	33.8	77.0	5.8	26.9
F (ages4+, fully recruited,unweighted)[4]	1.11	2.41	0.86	0.48	0.44	0.33	0.18	0.14	2.41	0.14	1.05
Exploitation rate (4+)[4]	62%	86%	53%	35%	33%	26%	15%	12%	86%	12%	65%
F(age1+,biomass weighted)[4]	0.50	0.90	0.14	0.13	0.10	0.09	0.09	0.12	1.25	0.09	0.54

[1]Over period 1963-2000, except as otherwise noted. [2]U.S. landings for 1994-2000 are provisional. [3]Canadian discards previous to 1996 are unknown, but considered to be small. [4]From VPA, 1973-2000

Stock Distribution and Identification: Yellowtail flounder inhabit relatively shallow waters (20-100 m) of the continental shelf of the northwest Atlantic from Labrador to Chesapeake Bay. Tagging observations, larval distribution, and geographic patterns of landings and survey data indicate that yellowtail flounder on Georges Bank comprise a relatively discrete stock. The Georges Bank yellowtail stock is defined as the entire Bank, east of the Great South Channel (U.S. statistical reporting areas 522, 525, 551, 552, 561, and 562).

Catches: Landings, which were predominantly taken by the U.S. fleet, averaged 14,200 mt during 1963-1976, with some taken by distant water fleets. Since 1975, only Canada and the U.S. have landed yellowtail (the Canadian fishery was initiated in 1993). U.S. landings declined to approximately 6,000 mt between 1978 and 1981. With strong recruitment and intense fishing effort landings rose to over 10,500 mt in 1982 and 1983. U.S. landings fell to a low of 1,100 mt in 1989, averaged 2,200 from 1990 to 1994 and dropped to record lows of 300 and 800 mt in 1995 and 1996. For the first time on record, the majority of Georges Bank yellowtail yield was landed by Canadian fishermen in 1995. In the late 1990s, total landings steadily increased, to 6,500 mt in 2000.

Discarding of small yellowtail has been an important source of mortality in the Georges Bank yellowtail population. The magnitude of discarded catch has generally been related to the size of recruiting cohorts, except in recent years, when increased mesh sizes appear to have reduced trawl discards. Beginning in 1999, discards increased when a U.S. scallop fishery was allowed in closed Area II under an exemption program with an allocated TAC of 387 mt in 1999 and 250 mt in 2000. Estimated bycatch from the exemption program was approximately 395 mt 1999 and 238 mt in 2000, nearly all of which was discarded. Total discards, including those under the exemption program, were estimated to be 484 mt in 1999 and 358 mt in 2000.

Data and Assessment: A virtual population analysis (VPA) of 1973-2000 commercial landings and discards at age was completed (assuming natural mortality, M = 0.2). Information on recruitment and stock abundance was obtained from DFO and NEFSC spring surveys, NEFSC autumn bottom trawl surveys, and NEFSC scallop surveys.

A non-equilibrium surplus production model was also used to assess the stock due to uncertainties in the age composition in recent years (see Special Comment #2). Input data included commercial landings and discards and data from the three bottom trawl surveys used in the VPA. Unlike the VPA, no information on age structure is required.

Biological Reference Points: $F_{0.1}$ has been estimated to be 0.25 (20% exploitation, Figure C3). The surplus production model estimated MSY to be 14,140 mt (see Special Comment #2) at a total stock biomass of 43,470 mt (B_{MSY}); F_{MSY} is 0.33 (which is F biomass weighted , ages1+). Amendment 9 states that MSY = 14,500 mt at B_{MSY} = 49,000 mt, and F_{MSY} is 0.30.

SFA Control Rule: The SFA control rule specifies a biomass target Bmsy , a biomass threshold (25% B_{MSY}), a F threshold (F_{MSY}), and F on biomass (1+,wb) as the metric for fishing mortality . When biomass exceeds B_{MSY}, target F is the tenth percentile of the F_{MSY} estimate. When biomass is between B_{MSY} and $1/2B_{MSY}$, threshold F is the F that allows rebuilding to B_{MSY} in 10 years at the estimated intrinsic rate of increase. When biomass is between ½ B_{MSY} and 1/4 B_{MSY}, F is the F that allows rebuilding to B_{MSY} in 5 years. When biomass is below 1/4 Bmsy, threshold F = 0 (Figure C4).

Fishing Mortality: The VPA biomass weighted F and the surplus production model F produced similar trends in exploitation rates. Fully-recruited F (ages 4-5, unweighted) was very high (averaged 1.2, 65% exploitation) during the 1973-1994 period, but declined in the late 1990s to 0.14 (12% exploitation) in 2000 (Figure C1). Exploitation rate on ages 2 and 3 has not declined proportionally and the partial recruitment to the fishery for these ages has increased. There is an 80% probability that fully-recruited F in 2000 was between 0.12 and 0.17 (10% to 14% exploitation, Figure C5). Biomass weighted F (1+,wb) generally exceeded F_{MSY} from the 1970s to 1994 but has sharply decreased to approximately 0.1 since 1996.

Recruitment: Age 1 abundance estimates from VPA indicate that four dominant year classes of at least 50 million were produced during 1973-1980. Abundance of all cohorts produced from 1981 to 1995 was less than 25 million at age 1. Recruitment increased in the late 1990s. The 1997 yearclass appears to be the strongest in the time series at 77 million age-1 abundance, and the 1996, 1998, and 1999 year classes are also above average (Figure C2).
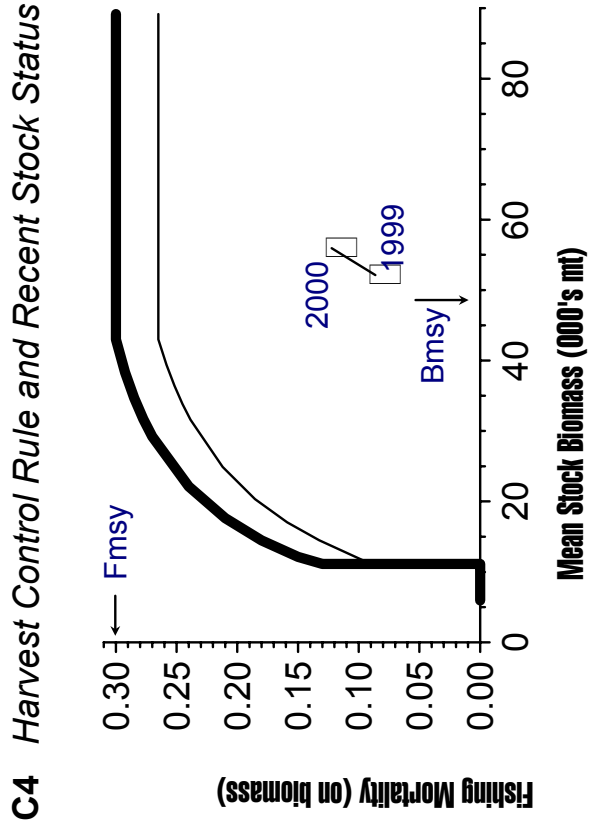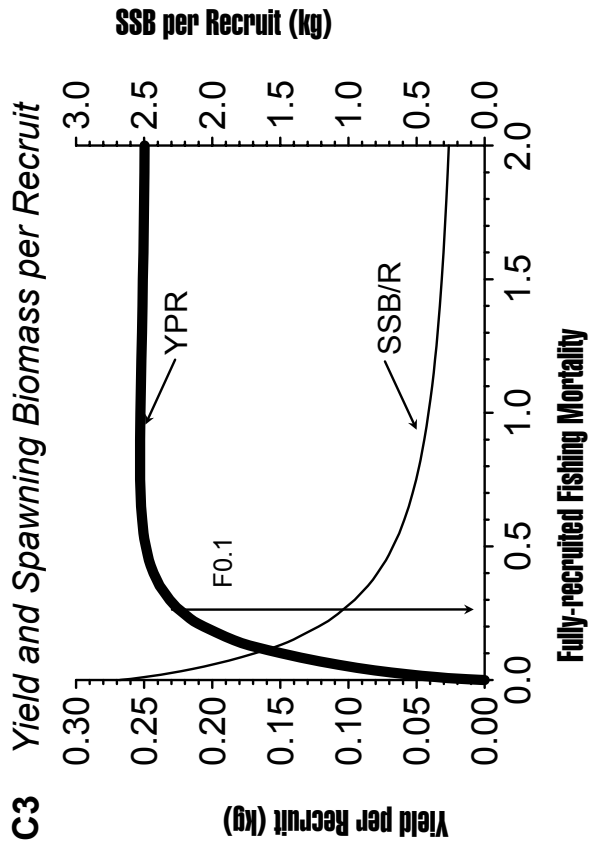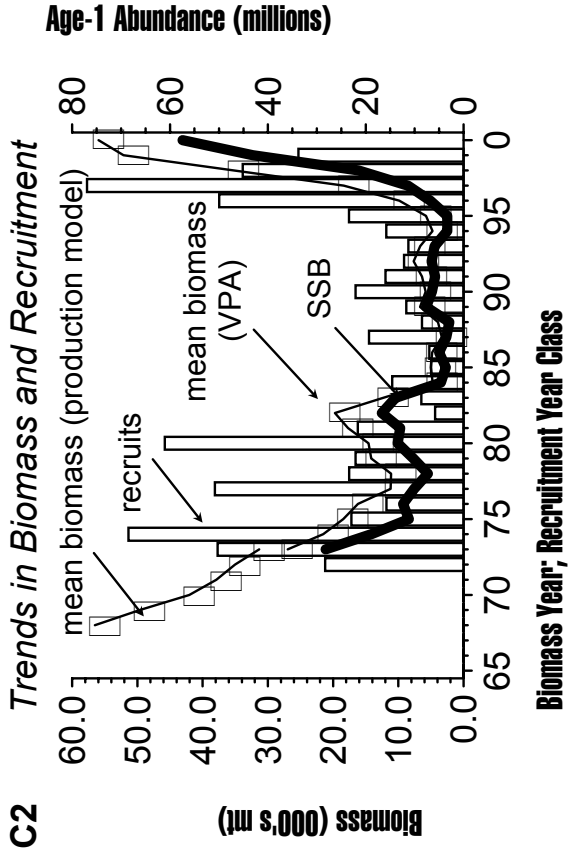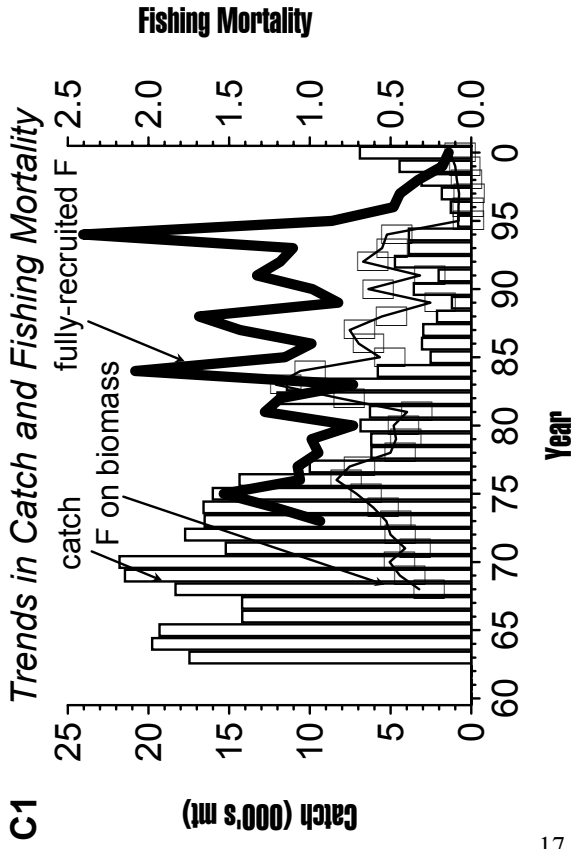
Stock Biomass: Spawning biomass was 21,000 mt in 1973, declined to less than 4,000 mt from 1984-1988, fluctuated below 6,000 mt from 1989 to 1996, and then steadily increased to 43,000 mt in 2000. Biomass has increased and the age structure has also improved but remains truncated and dominated by younger ages. There is an 80% probability that SSB in 2000 was between 37,000 mt and 50,500 mt (Figure C6). Trends in mean biomass (ages 1+) are similar to those for SSB. There is an 80% probability that mean biomass in 2000 was between 48,000 mt and 66,500 mt (Figure C7).

Special Comments:
1. Inadequate sampling of U.S. landings, the lack of sufficient discard samples in the U.S. fishery, and the absence of age determinations from the Canadian fishery contribute to uncertainty in estimates of size and age composition of the catch. and raise concerns about the reliability of VPA results. Retrospective analysis indicates a pattern of inconsistencies in which estimates of F in the last year of the VPA are less than revised estimates of F and estimates of SSB in the last year are more than revised estimates of SSB .

2. While the historical population reconstruction from the VPA and the surplus production model show concurrence, projections from the two models diverge significantly. The projection results from the surplus production model imply high equilibrium recruitment levels that are not consistent with historical estimates. Accordingly, only the VPA projections should be considered.
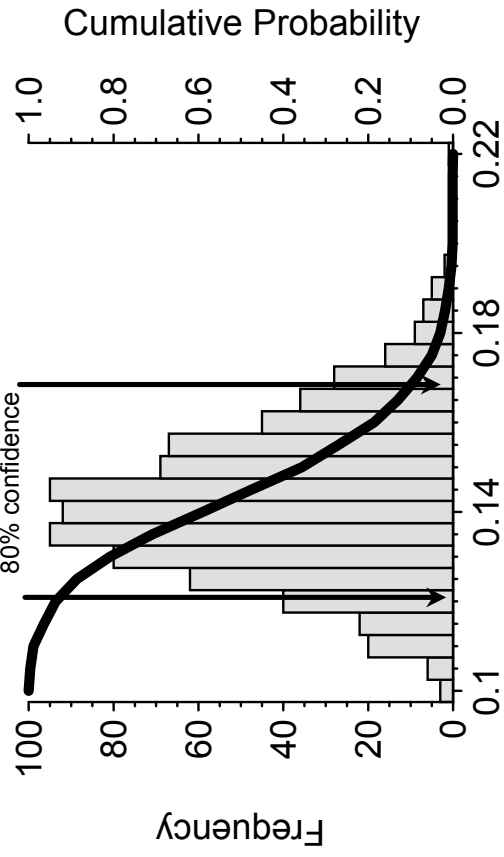
Source of Information: Stone, H.H., C.M. Legault, S.X. Cadrin, S. Gavaris, J.D. Neilson,, and P. Perley. 2001. Stock assessment of Georges Bank (5Zjmnh) yellowtail flounder for 2001. CSAS Res. Doc. 2001/068. 87 p.
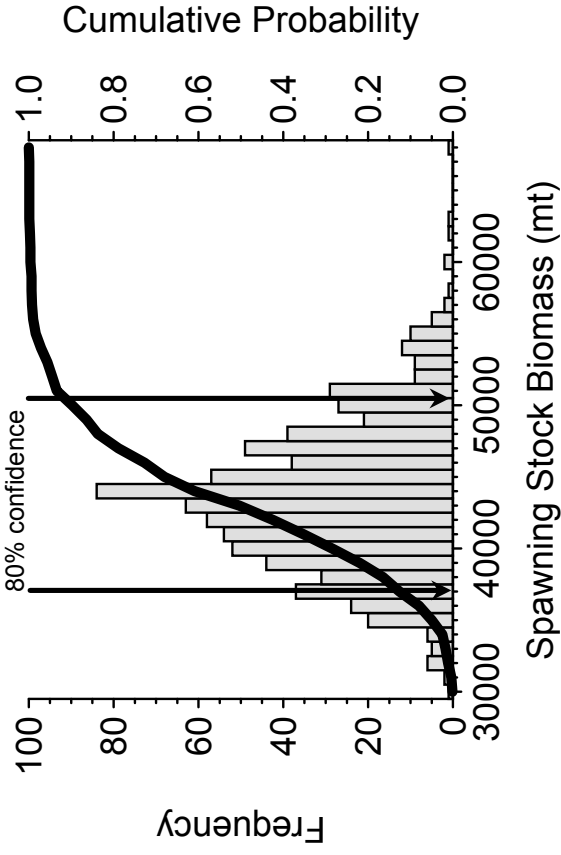
Georges Bank Yellowtail Flounder

C1 *Trends in Catch and Fishing Mortality*

Catch (000's mt)
Fishing Mortality
Year

fully-recruited F
catch
F on biomass

C2 *Trends in Biomass and Recruitment*

Age-1 Abundance (millions)
Biomass (000's mt)
Biomass Year; Recruitment Year Class

mean biomass (production model)
mean biomass (VPA)
recruits
SSB

C3 *Yield and Spawning Biomass per Recruit*

Yield per Recruit (kg)
SSB per Recruit (kg)
Fully-recruited Fishing Mortality

YPR
SSB/R
$F_{0.1}$

C4 *Harvest Control Rule and Recent Stock Status*

Fishing Mortality (on biomass)
Mean Stock Biomass (000's mt)

F_{msy}
B_{msy}
2000
1999

Georges Bank Yellowtail Flounder

C5

Precision of 2000 F Estimate

80% confidence

Fully-recruited F (4-5)

C6

Precision of 2000 SSB Estimate

80% confidence

Spawning Stock Biomass (mt)

C7

Precision of 2000 Mean Biomass Estimate

80% confidence

Mean Biomass (mt)

18