B. GEORGES BANK WINTER FLOUNDER

TERMS OF REFERENCE

The Steering Committee of the 34th Northeast Regional Stock Assessment Workshop established the following terms of reference for the Georges Bank winter flounder assessment:

1. Update the status of the Georges Bank winter flounder stock through 2000 and characterize the variability of estimates of stock size and fishing mortality.

2. On the basis of anticipated catches and abundance indicators in 2001, estimate stock size at the beginning of 2002 and provide projected estimates of catch and spawning biomass for 2003-2004 at various levels of F.

3. Evaluate and re-estimate the overfishing definition reference points for Georges Bank winter flounder.

SUMMARY

The most recent assessment of the Georges Bank winter flounder stock was conducted during autumn of 1998, at SARC/SAW 28, and represented an initial age-based assessment of the stock. Based on the results of a Virtual Population Analysis (VPA), for 1982-1997, it was concluded at SAW 28 that the stock was overexploited and at a low level of biomass. Relative to the Amendment 9 control rule, overfishing was occurring in 1997. Spawning stock biomass levels and the age composition of the stock were noted to have improved since 1993, but recruitment, particularly the 1995 and 1996 year classes, was poor.

Winter flounder inhabiting Georges Bank represent a discrete offshore stock distributed in the shallower areas of the Bank. There is some directed fishing on the stock, but exploitation is primarily as by-catch, in the large and small mesh otter trawl fisheries, and to a lesser degree in the sea scallop dredge fishery. Management measures directed at other principal stocks in the New England groundfish complex, including area closures, mesh size restrictions, effort controls, and retention restrictions on specific gear sectors, have likely effected the condition of the Georges Bank winter flounder resource.

During 1964-1977, the Georges Bank winter flounder stock was exploited by the United States (U.S.), Canada, and the former Soviet Union (USSR). However, total landings have been dominated by the U.S. fishery since 1964. Total landings during the 1970s and 1980s ranged between 1,800 and 4,500 mt. Since 1989, total landings (U.S. and Canada) have been less than 2000 mt, and in 1995, declined to their lowest level (800 mt) since 1964. Otter trawl gear accounted for greater than 95% of the total landings during most years. Landings from the scallop dredge sector increased to 5-7.8%, during 1989-1997, but declined to approximately 1% during 1998-2000 as a result of bycatch limitations in the sea scallop dredge fishery. Discarding occurs in both the otter trawl and scallop dredge fisheries. Data were insufficient to estimate either the magnitude of discards or to characterize their size or age distribution.

Annual indices of relative abundance and biomass from research vessel bottom trawl surveys are quite variable. The U.S. autumn and Canadian spring bottom trawl surveys indicate that biomass and abundance have steadily increased since 1998. The U.S. spring survey indices show similar increases, with the exception of a decline in the 2001 indices. All three surveys indicate that age 2 recruitment has been low since the appearance of 1994 year class.

The most reliable estimates of stock biomass and fishing mortality were obtained from an ASPIC surplus production model. Mean biomass has increased steadily since 1994, reaching 8,800 mt in 2000, and fishing mortality rates have been declining since 1996, to 0.21 in 2000.

A Virtual Population Analysis (VPA), calibrated with research survey indices from 1982-2000, was reviewed, but not adopted by the SARC to evaluate stock status. Model fit was poor (high CVs on stock size at age), there were inconsistent patterns in mean weights at age and fishing mortality rates at age, and a retrospective pattern was present in estimated fishing mortality rates in recent years. The primary reason for these factors was insufficient sampling, in the primary port of New Bedford, to reliably characterize the age composition of the landings.

A second age-based model (WIN), which involved a forward-projection of the catch-at-age, was also reviewed. However, the SARC decided that further sensitivity testing of the model was warranted.

The ASPIC model results were also used to re-estimate biological reference points. Maximum sustainable yield (MSY) was estimated as 3,020 mt and B_{MSY} was estimated at 9,355 mt. Proposed threshold and target biomass proxies (in survey-based equivalents of kg/tow) were estimated as 1.25 and 2.49, respectively. The corresponding survey proxy equivalent threshold and target fishing mortality rates are 1.21 and 0.91, respectively. Relative to the proposed harvest control rule, the stock is not overfished and overfishing is not occurring ($B_{1998\text{-}2000\ proxy}$ = 2.29, $F_{1998\text{-}2000\ proxy}$ = 0.65).

INTRODUCTION

Winter flounder (*Psueudopleuronectes americanus*) is a demersal flatfish species distributed in the Northwest Atlantic from Labrador to Georgia (Bigelow and Schroeder 1953, Klein-MacPhee 1978). Although primarily distributed in shallow inshore waters where estuarine habitat serves as important spawning and nursery areas, winter flounder are also distributed on some shallow offshore banks, at depths less than 80 m, such as Nantucket Shoals and Georges Bank. Adult winter flounder feed primarily on benthic invertebrates including annelids (predominately polychaetes), cnidarids, and anthoza (Langton and Bowman 1981). Principal predators include striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), goosefish (*Lophius americanus*), spiny dogfish (*Squalus acanthias*), and sea raven (*Hemitripterus americanus)*; (Dickie and McCraken 1955, Grosslein and Azarovitz 1982). Spawning peaks on Georges Bank during March and April, as evidenced by the presence of spawning condition fish in the Northeast Fisheries Science Center (NEFSC) spring research vessel bottom trawl survey and high densities of eggs and larvae detected by MARMAP ichthyoplankton surveys (Pereira *et al.* 1999).

Stock Structure

Tagging studies, differences in life history characteristics, and meristic studies all provide evidence for discrete stocks of winter flounder in the U.S. waters of the Northwest Atlantic. Winter flounder on Georges Bank have considerably higher growth rates than fish from inshore waters (Bigelow and

Shroeder 1953, Lux 1973), and historically, the Georges Bank stock was considered as a separate species (*Psudopleuronectes dignabilis*; Kendall 1912). Meristic studies indicate that fin ray counts differ for fish from Georges Bank and inshore areas indicating further evidence for a discrete offshore stock (Perlmutter 1947, Lux *et al.* 1970). Extensive tagging studies of winter flounder indicate little mixing of fish between Georges Bank and inshore areas (Coates *et al.* 1970, Howe and Coates 1975) , providing further evidence for discrete stock structure (Pierce and Howe 1977).

For this assessment, the Georges Bank winter flounder stock boundaries used to evaluate fisheries data included U.S. statistical areas 522, 525, 551, 552, 561, and 562 (Figure B1), which correspond to Canadian unit areas 5Zh, j, m, and n.

<u>Fishery Description</u>

Winter flounder, often known as blackback or lemon sole within the fishing industry, are harvested primarily using otter trawl gear, and landings occur in a directed fishery as well as by-catch in fisheries targeting other species. Bycatch landings and discards occur in trawl fisheries targeting other groundfish species and in the scallop dredge fishery. Although recreational landings are a significant source of fishing mortality in inshore waters for the Southern New England stock complex, recreational landings from the Georges Bank stock are insignificant and are not included in this assessment.

<u>Management History</u>

Over the past 25 years, management of the commercial fishery for Georges Bank winter flounder has focused on minimum size limits and management measures (seasonal and year-round area closures, mesh size regulations, effort control measures, and fleet capacity reduction programs) primarily intended to address management needs for other demersal species (Atlantic cod, haddock, and yellowtail flounder). Seasonal spawning closures of haddock spawning grounds, which increased in temporal and spatial coverage since their inception in 1970 (Clark 1976), have provided some measure of protection for the stock.

Winter flounder was included in the New England Fishery Management Council's Atlantic Groundfish Fishery Management Plan (1977-1982). The initial plan established a minimum commercial size limit (11 inches, 28 cm), imposed minimum mesh sizes for trawls, and established spawning stock biomass per recruit targets. In 1982 the Council adopted an Interim Groundfish Plan, which established a minimum mesh size of 130 mm (5 1/8"). In 1983 the minimum mesh size was increased to 140 mm (5.5") In 1986 the Council's Multispecies Fishery Management Plan increased the minimum legal size to 30 cm (12 in) and imposed seasonal area closures. Amendment 5, adopted in 1994, and Amendment 7, adopted in 1996, established effort controls (days at sea limits), further increased minimum mesh size to 142 mm (6" diamond or square mesh), imposed trip limits for regulated groundfish bycatch in the sea scallop fishery, and prohibited small-mesh fisheries from landing regulated groundfish. In December 1994 two large areas on Georges Bank were closed to fishing on a year-round basis to protect overfished groundfish species. These areas include both the eastern and western edges of the distribution of winter flounder on the bank. Since June of 1994, vessel operators have been required to submit their catch and effort information, by gear type and statistical area, on Vessel Trip Reports (VTR) and dealers have been required to submit reports of groundfish purchases. Prior to this mandatory reporting requirement, landings and fishing effort data were collected by port agents who interviewed a percentage of the fishing fleets.

Amendment #9 to the Multispecies Fishery Management Plan was approved in 1999 and resulted in a revision of the overfishing definition in accordance with the Sustainable Fisheries Act (SFA). The Overfishing Definition Review Panel (Applegate *et al.* 1998) recommended a control rule for Georges Bank winter flounder derived from survey-based proxies of MSY-reference points. Biomass-based reference points were based on the NEFSC Autumn research survey biomass index (stratified mean kg per tow) and fishing mortality reference points were based on an exploitation index (catch/NEFSC Autumn research vessel biomass index).

The SFA also required regional fishery management councils to describe and identify essential fish habitat (EFH), to specify actions to conserve and enhance EFH, and to minimize the adverse effects of fishing on EFH. Congress defined EFH as "those waters and substrate necessary to fish for spawning, breeding, feeding or growth to maturity." EFH for Georges Bank winter flounder is described in Pereira *et al.* (1999).

THE FISHERY

Commercial Landings

Fisheries data evaluated for this assessment included U.S. statistical areas 522, 525, 551, 552, 561, and 562 (Figure B1) and the corresponding Canadian unit areas 5Zh, j, m, and n. Prior to 1985, U.S. landings also occurred in statistical areas 551 and 552, which are now located within Canadian waters. Prior to 1977, commercial landings of Georges Bank winter flounder were reported from the United States, Canada, and distant water fleets including the former Soviet Union. From 1964 to 1971, total landings increased, reaching a peak of 4,500 mt in 1972 (Figure B2, Table B1). Landings declined from 1971 to 1976, before increasing sharply to 3,600 mt in 1977. Commercial landings were high during 1980 -1984 (averaging 3,800 mt/yr), but declined sharply in 1985 to 2,200 mt. Landings have been less than 2,000 mt since 1985, with the exception of landings from the strong 1984 year class in 1987 and 1988. Landings in 1995 (760 mt) were the lowest recorded since 1964, but have ranged between 1,00 mt and 1,800 mt since then. U.S. landings have been the dominant component of the total landings since the late 1960's. Canadian landings ranged between 0.1% and 2.8% of the total landings during 1970-1993. Since 1994, total landings have been lower and Canadian landings have been increasing, representing 5-10% of the total landings.

During 1982-1993 approximately 20-25% of the U.S. landings occurred during quarter one. However, since 1995, less than 5% of the landings have occurred during quarter one (Figure B3). The SARC investigated this change in the temporal distribution of the landings by examining whether it might be an artifact of the proration scheme (stratification by month and state), which came into use in mid-1994. Information on vessel tonnage class (a proxy for vessel size) was included in the proration scheme to evaluate the potential impact on distribution by stock if larger vessels tend to fish more often on Georges Bank than in the other two winter flounder stock areas (southern New England and Gulf of Maine). The SARC found that this proration revision had little effect on the amount of landings assigned to the stock. Other potential causes for the change in seasonal landings pattern might be a reduction in fishing effort during quarter one, either due to boats having expended their days at sea allocations for the fishing year or due to fewer offshore trips due to increases in bad weather and potential loss of days at sea during the winter. No definitive explanation for the fishing pattern change could be determined by the SARC.

Otter trawls have been the dominant gear accounting for greater than 98% of landings in the U.S. fishery through 1985 and 100% of the Canadian landings (Table B2). During 1985-1991, the proportion of landings taken by scallop dredges increased steadily, from less than 1% to 7.8%. The proportion of total landings accounted for by scallop dredges subsequently declined during 1994-1997, to around 5%, and to less than 1% since 1998, possibly due to U.S. groundfish retention limits imposed on the scallop fishery. Tonnage class 3 (51-150 GRT) otter trawlers generally account for approximately 60-80% of U.S. landings, while tonnage class 4 (151-500 GRT) otter trawlers generally account for all but a few percent of the remaining U.S. landings (Table B3).

Since 1982, U.S. landings have been reported as eight market categories (unclassified, lemon sole, small, large, extra-large, large/mixed, medium, and peewee), based primarily on fish size. Three categories (lemon sole, small, and large) comprised approximately 85% of the commercial landings from 1982-2000 (Table B4). Prior to 1997, fish classified as mediums represented 1-3% of the U.S. landings, but landings of medium fish has since increased to 7-10 %. Canadian landings are not reported by size.

<u>Commercial Discards</u>

Commercial discarding has occurred in the otter trawl and scallop dredge gear sectors due to marketability (size and condition), minimum size limit regulations, and groundfish retention limits in some small mesh fisheries and the scallop fishery. Discard information is available from two primary sources: the sea sampling database, which summarizes information collected by trained observers aboard commercial vessels, and the Vessel Trip Reports (VTR) database, which contains discards reported by vessel operators.

Sea sampling data are available for 1989-2000 and represent the most reliable source of information available for estimating commercial discards. During 1989-2000, the total number of Georges Bank otter trawl trips where winter flounder weights were collected ranged from 3 to 17 trips annually (Table B5). Sea sampling of scallop dredge trips occurred during 1992-2000, but observations are very limited, ranging from 1 to 9 trips available annually where weights of landed and discarded winter flounder were sampled. Based on this limited amount of information, estimated total discards in the trawl gear sector ranged from 1.2 to 24.9 mt annually, representing 0.2 to 1.6% of the otter trawl landings. Limited sampling of sea scallop trips precludes even preliminary estimates of discards for this fleet sector. Discards in the sea-sampled scallop dredge trips that occurred in the Georges Bank groundfish closure areas during 2000 were also examined. The SARC determined that the temporal and spatial distribution of these trips was limited and, as a result, could not be used to produce a reliable estimate of discards from the entire scallop dredge fishery during 2000 (Table B6, Figure B4).

Length frequency information available in the sea sampling database were examined to determine the feasibility of partitioning discard weight estimates into numbers at length. During 1989-2000, the number of discarded winter flounder measured annually by the Sea Sampling Program ranged from zero in 1997 to 103 in 2000 (Table B7). These data were determined to be insufficient, at SARC 28 (NEFSC 1999), to characterize the overall length frequency distribution of the discarded portion of the catch. The number of discarded winter flounder measured in the scallop dredge gear sector during 1992-2000 was insignificant in every year except 1997, when 239 discarded winter flounder were measured in the second quarter and a total of 274 were measured across all quarters. Based on the limited data available to either estimate the magnitude of total discards or to characterize their size distribution, it was concluded at SARC 28 (NEFSC 1999) that it would be inappropriate to generate estimates of discards from these data. The SARC determined that the additional 21 otter trawl and 14 scallop dredge trips sampled during 1998-2000 were inadequate to attempt to re-estimate discards from either fishery (Tables B5 and B7).

Commercial operator-reported discards in the VTR database, available during the 2nd quarter of 1994-2000, represented the next best available source for estimating discards. Reporting rates in the VTR database are known to be incomplete because many operators fail to reliably report discards. To avoid problems associated with incomplete reporting, we estimated discard ratios using VTR data based on a subset of logbook records that reported at least 1 pound of discards for any species (NEFSC 1997, Brown 2000). By using this subset to characterize discard ratios, three basic assumptions were made: 1) it is highly unlikely that a groundfish trip could operate within the Georges Bank stock area without generating discards of some species, 2) for those trips where discards were reported, discards of winter flounder were reliably reported, and 3) the ratio of landed to discarded weight from this VTR subset was representative of the discarding behavior of the entire fleet. Thus, the VTR subset used to estimate discard ratios included: 1) trips reporting both landings and discards of winter flounder, 2) trips reporting winter flounder discards but no landings, and 3) trips reporting winter flounder landings and discards for some other species.

For the otter trawl gear sector, the number of trips included in the discard ratio estimate ranged from 73 to 182 trips annually (Table B8). During 1994-1997, total discards estimated from the VTR in the trawl gear sector ranged from 7 to 22 mt annually, representing 0.5 to 3.0% of the otter trawl landings. The number of scallop dredge trips where discards of winter flounder were reported was much lower, ranging from 17-112 trips annually.

A third approach to estimating discards was attempted during the SARC 28 stock assessment (NEFSC 1999). This approach involved using a combination of commercial sea sample data and research vessel survey data to estimate the total numbers discarded at length (Mayo *et al.* 1992). However, the results were not considered reliable because during nearly half the years sampled, fewer than 70 fish were captured in the U.S. research bottom trawl surveys, resulting in length frequency distributions which may not be representative of the population. In addition, the limited discard length frequency information available from sea sampling resulted in a poor determination of the discard selectivity ogive used in the analysis. Even if the number discarded at length could be reliably estimated, the number of age determinations for sublegal-sized winter flounder from the survey data is limited.

In summary, survey, vessel trip report, and sea sampling data were insufficient to produce reliable estimates of the magnitude or age composition of winter flounder discards occurring in the Georges Bank otter trawl or scallop dredge fisheries. However, both the sea sampling and vessel trip record approaches produced consistent information concerning the magnitude of discards occurring in the otter trawl and scallop dredge fisheries. Both approaches produced relatively low estimates of discards relative to landings (sea sampled trips: 0.2% to 1.6%; VTR trips: 0.5 to 3.0%) for the otter trawl fishery.

Although discarding of winter flounder in the sea scallop dredge fishery could not be estimated due to poor sea sampling coverage of this fishery, a SARC 28 analysis of the spatial overlap between exploitable scallop resources and winter flounder indicated little spatial overlap. As a result of the uncertainty in both the underlying data and the performance of the discard estimation approaches, no commercial discards were included in the catch-at-age analyzed in this assessment.

Sampling Intensity of Commercial Landings

There is no commercial sampling program for Canadian landings of Georges Bank winter flounder. Poor sampling intensity of U.S. landings prior to 1982 precluded extension of the landings at age time series prior to 1982 (Table B4). Since 1982, U.S. landings of Georges Bank winter flounder have been reported for 8 market categories (unclassified, lemon sole, small, large, extra-large, large/mixed, medium, and peewee). However, three categories (lemon sole, small, and large) comprised 85% of the landings during 1982-2000. Based on similarities in length frequency distributions across years, peewee and medium market categories were combined with the small market category, extra-large was combined with lemon sole, and large/mixed was combined with the large market category to estimate the catch-at-age during most years (Table B9). Since 1982 annual sampling intensity for the three combined market categories ranged from 10 to 902 mt of landings per sample. During 1982-1992 sampling intensity was lower for lemon sole than for the small and large market categories. Since 1993, sampling intensity of all market categories has been poor in the primary port of New Bedford. During 1998 and 1999 sampling of was inadequate to characterize the age composition of the landings for the catch-at-age. There were no lemon sole samples collected during either year and only one large sample was collected during the two years. The large and lemon sole market categories during these two years represented 44% and 48% of the total U.S. landings, respectively. In addition, sampling of the small market category during 1998 and 1999, which comprised 44% and 38% of the U.S. landings, respectively, consisted of three and four samples, respectively.

Landings at Age

Age composition of the 1982-2000 commercial landings from Georges Bank were estimated by applying commercial age-length keys to quarterly commercial numbers at length, aggregated by market category. During 1993-2000, landings at age data was pooled across quarters to varying degrees, due to insufficient length frequency sampling (Table B10). During 1998 and 1999 sampling was so poor that landings at age data had to be pooled across all quarters and market categories. In addition, the 1998 and 1999 landings at age matrix was supplemented with winter flounder length data from all otter trawl trips in the sea sampling database for those years. The length frequency distributions of the 1998 catch-at-age and the sea samples of winter flounder were similar. Mean weights at age were estimated by applying the length-weight equations to the quarterly length frequency samples by market category. Total numbers landed per quarter were estimated by applying the mean weights to the quarterly landings by market category and prorated according to sampled length frequencies. Numbers at age were summed over market category for each quarter and annual estimates of landings at age were obtained by summing values across quarters. Landings from both the unclassified market category for U.S. landings and total reported Canadian landings were assumed to have the same age composition as the sampled U.S. landings, and the estimated landings at age was adjusted to incorporate these landings. The unsampled portion of the landings generally accounted for less than 10% of the total landings at age.

Estimated total landings at age for 1982-2000, for age 1-10+ fish, are summarized in Table B11. Landings of age 2-4 fish dominate the landings, and two relatively large year classes appear to track well through the landings at age matrix. Landings of age 1 fish are insignificant except in 1995 when 264,000 age 1 fish were estimated. Examination of the U.S. commercial samples indicated that large numbers of age 1 fish were present in multiple samples occurring in the third and fourth quarters of 1995. In addition, relatively large numbers of the 1994 cohort were landed as age 2 fish in 1996 and age 3 fish in 1997. Estimated landed weight (mt) of Georges Bank winter flounder by age and year is also summarized in Table B11.

<u>Mean Weights at Age</u>
Mean length and weight at age from the analysis of total landings at age are summarized in Table B12. The effects of poorly-sampled landings are evident in the mean weight at age table as some of the smallest fish in the time series appear in all age groups during 1998, particularly in the age 4 and older fish. The poor sampling since 1993 is also evidenced by the decrease in mean weight of some cohorts as they age (e.g. 1993 cohort at age 4 in 1997 and age 5 in 1998; 1994 cohort at age 3 in 1997 and age 4 in 1998).

STOCK ABUNDANCE AND BIOMASS INDICES

<u>U.S. Landings per Unit of Effort Indices</u>
Landings per unit of effort (landed metric tons per day fished, LPUE) indices were computed by tonnage class using data from the dealer database, for 1964-1993, for all otter trawl trips landing winter flounder (Table B13)and for directed trips (trips with >= 50% winter flounder landings) (Table B14). LPUE indices for all trips increased during 1964-1980 and those for directed trips fluctuated without trend during this time period.(Figure B5). After 1980, LPUE indices for all trips and directed trips declined sharply, reaching their lowest levels in the time series in 1993.

The LPUE time series was not updated beyond 1993 because the methodology for collecting landings and fishing effort data changed to logbook reporting (VTR database).

U.S. Research Vessel Bottom Trawl Survey Indices

The Northeast Fisheries Science Center (NEFSC) of the U.S. National Marine Fisheries Service has conducted a depth-based, stratified random bottom trawl survey of continental shelf waters (maximum sampling depth of 366 m) from the Scotian Shelf to Cape Hatteras, during autumn, since 1963 (Azarovitz 1981, Despres *et al.* 1988, Azarovitz *et al.* 1997). A spring survey has been conducted during March-April since 1968. Catch data from these surveys were used to estimate changes in abundance (stratified mean number per tow) and biomass (stratified mean weight (kg) per tow) of winter flounder on Georges Bank. The strata set used to calculate these indices included NEFSC offshore strata 13-22 (Figure B6). Significant changes in the catchability of winter flounder, due to a trawl door change in 1985, necessitated adjusting pre-1985 indices with standardization coefficients of 1.46 for numbers per tow and 1.39 for weight per tow (NEFSC 1991). Fishing power experiments indicated no significant differences in the catchability of winter flounder between the two research vessels (*Delaware II* and *Albatross IV*) used during the survey time series (NEFSC 1991).

Winter flounder distribution during the U.S. spring and autumn surveys was evaluated in relation to the survey strata boundaries used to define the stock area. Numbers per standardized tow, for fish $\leq$ 40 cm and > 40 cm (mean length of age 4 fish), were plotted for 1982-2000. Figure B7 indicates that winter flounder exhibit a seasonal habitat preference. In comparison with the spring survey, larger numbers of fish from both size categories are distributed outside the Georges Bank survey strata boundaries, in stratum 23, during the autumn of some years and this phenomenon is more predominant in fish from the larger size category. During the spring surveys, fish from both size categories are distributed throughout survey strata 16, 19 and 20. Despite these migrations outside the stock area boundaries, the SARC concluded that winter flounder from stratum 23 should be excluded from the computations of U.S. survey indices. If included, the SARC was concerned that catches in stratum 23 may include fish from the Gulf of Maine and southern New England winter flounder stocks, which grow much more slowly than fish from the Georges Bank stock.

Standardized, stratified abundance and biomass indices for Georges Bank winter flounder from the U.S. spring and autumn research vessel bottom trawl surveys are shown in Table B15. Abundance and biomass indices exhibit a considerable amount of variability but generally exhibit intermediate levels of abundance from the early 1960s to early 1980s. Since the mid-19802 levels of abundance have declined (Figure B8). Both surveys indicate an increasing trend in abundance and biomass since the early 1990s, but abundance and biomass indices from the spring survey show a decline in 2001. Stratified mean numbers at age for the NEFSC spring and autumn surveys are shown in Tables B16 and B17, respectively. Although these indices are highly variable, larger cohorts appear to track through the numbers at age matrix for the 1985, 1987, and 1994 cohorts.

Canadian Research Vessel Bottom Trawl Survey

The Department of Fisheries and Oceans (DFO) of Canada, has conducted a stratified random bottom trawl survey on Georges Bank since 1987. The Canadian survey is conducted during February or early March and occupies stations in both U.S. and Canadian waters. In comparison to the U.S. surveys, station densities in the Canadian spring surveys are generally higher on the Canadian side of Georges Bank and along the southern flank (Figure B9).

Canadian survey indices of abundance and biomass were computed using strata set 5Z1-4 rather than the SARC 28 strata set of 5Z1-8 (Figure B10). The SARC determined that use of the 5Z1-4 strata set was more appropriate because these strata were sampled during all years included in the time series and because these strata lie entirely within the boundary of the stock area. It was noted that the use of this strata set would omit some winter flounder catches from the western portion of the stock area, but would ensure that winter flounder catches from the southern New England stock were not included in the survey indices. Relative abundance and biomass indices for strata 5Z1-4 were computed by staff from the DFO as stratified mean numbers and weights (kg) per tow, respectively, for 1987-2001 (B15, Figure B8).

Stratified mean numbers per tow at age from the Canadian spring survey are presented in Table B18. Winter flounder captured during the Canadian survey are counted and measured, but are not aged. U.S. spring survey and commercial age keys from quarter one were used to partition stratified mean numbers at length into stratified mean numbers at age. During most years, sufficient age determinations were available from U.S. spring survey data to partition stratified mean numbers at length from the Canadian survey into numbers at age. However, U.S. commercial age keys from the first quarter of the corresponding year were applied for fish larger than 48 cm during 2000 and greater than 39 cm during 2001. The application of commercial age keys will provide unbiased estimates of catch at age if both the U.S. commercial fleet and the Canadian survey are catching fish that grow at the same rate. This assumption appears to be valid because the principal winter flounder habitat is located on the U.S. side of Georges Bank and sampling in the Canadian survey occurs across the entire Bank.

The Canadian spring surveys indicate a pattern in year class strength that is different from the U.S. spring surveys (Figure B11). Stratified mean numbers per tow of age two fish from the U.S. spring survey indicate that the 1981, 1983, 1985, and 1994 year classes were above average. The SARC discussed the fact that the diameter of the cookies on the Canadian trawl are smaller than those used on the U.S. trawls. As a result, the Canadian trawl may not be able to sample winter flounder habitat in the center of the Bank (U.S. survey strata 19 and 20) where the bottom is uneven. All three surveys indicate poor year class strength since the 1994 year class.

MORTALITY AND MATURATION

Natural Mortality

Natural mortality was assumed to be constant and equal to 0.2 throughout the time series used in this assessment. This assumption would seem appropriate given the observation of maximum ages in the population that occasionally exceed 15 years and, when applying the 3/M “rule of thumb”, results in a similar estimate of natural mortality.

Total Mortality

Estimates of instantaneous total mortality (Z) and fishing mortality (F) were estimated from the NEFSC Spring and Autumn surveys

(1981-2000) and the Canadian Spring survey (1988-2000). Due to high interannual variability in the survey indices, pooled estimates of mortality rates were estimated based on three-year moving averages (Table B19). Total mortality (Z) was calculated as F + M, where M = 0.2 and:

F from spring surveys = ln(∑age 4+ for years i to j / ∑age 5+ for years i+1 to j+1)

F from autumn surveys = ln(∑age 3+ for years i-1 to j-1 / ∑age 4+ for years i to j)

The three surveys exhibited different trends in total mortality rates. The U.S. autumn survey indicated a decline in total mortality rates since 1992 and the U. S. spring survey indicated a decline since 1997. Total mortality rates derived from the Canadian spring survey indices declined during 1990-1997. Since 1997, total mortality rates estimated from the U.S. surveys have declined, but those estimated from the Canadian survey show an increase during 1998 and 1999, followed by a decline in 2000. A geometric mean of the two U.S. surveys indicates a decline in total mortality since the early 1990s (Figure B12).

Maturity

Maturation determinations for female winter flounder were collected on the NEFSC Spring survey from 1982-2001. The annual number of maturation determinations is limited, particularly in terms of those for age 2 and 3 fish which determine the character of the maturation relationship at age. A logistic regression approach (O'Brien *et al* 1993) was used to estimate the proportion of females mature at age for 1982-1998 (Table B20) and resulted in an estimation of age at 50% maturity of 1.83 years (Brown *et. al* 2000). The resulting maturity ogive (0.00 at age 1, 0.62 at age 2, 0.92 at age 3, 1.00 at age 4) was assumed constant during 1982-2000 and used in the VPA contained herein.

ESTIMATES OF STOCK SIZE AND FISHING MORTALITY

The SARC reviewed the results of a Virtual Population Analysis and a non-equilibrium surplus production model (ASPIC) that represented updates of the SARC 28 versions of these analyses (NEFSC 1999). The results from a second age-structured model that involved forward-projection of the catch-at-age data were also reviewed.

ASPIC Model

A non-equilibrium surplus production analysis was completed using ASPIC software (Prager 1993, 1994). The model was used to estimates stock biomass and fishing mortality rate trajectories during 1964-2000 and to re-estimate biological reference points. Initial biomass (*B1*), *MSY*, intrinsic rate of increase (*r*), and catchability (*q*) for each biomass index were estimated via nonlinear least squares of biomass index residuals.

Stock biomass indices available for model calibration included stratified mean weight per tow indices for the following research vessel bottom trawl surveys: the NEFSC autumn (1964-2000), NEFSC spring (1968-2001) and Canadian spring surveys (1987-2001). In all model runs, indices from both of the spring surveys were lagged back one year and used as an end-of-year index. (Table B21) An update of the final run accepted at SARC 28, which included all three survey indices, was conducted. However, Canadian survey strata 5Z1-4 were included rather than strata 5Z1-8 and this change resulted in a negative

R^2 value for the Canadian survey series. The same result also occurred when the SARC 28 model was re-run with biomass indices from Canadian survey strata 5Z1-4. As a result, the Canadian spring survey indices were omitted from the final run (Run 3) examined by the SARC, which included total landings during 1964-2000 and the NEFSC spring (1968-2001) and autumn (1964-2000) survey biomass indices.

The results from Run 3 of the surplus production analysis indicated a reasonable fit to the input data (Table B22). A maximum sustainable biomass (MSY) of 3,020 mt was estimated to be produced by a biomass (B_{msy}) of 9,355 mt. A time trajectory of results from the surplus production model indicates that yield has been below the estimated surplus production since 1994 (Figure B13). Relative estimates of mean biomass (B_t/B_{MSY}) declined sharply during 1977-1994, but increased since then to a level near B_{MSY} in 2000. Relative fishing mortality rates (F_t/F_{MSY}) showed the opposite pattern (Figure B14).

A retrospective analysis of Run 3 of the ASPIC model, for terminal years 1995-2000, indicated there was no retrospective pattern in the annual estimates of average biomass or fishing mortality rates (Figure B15). However, the retrospective analysis indicated that estimates of F_{MSY} and B_{MSY} were more variable than the annual estimates of fishing mortality and biomass as a result of the high variability in the estimates of *r* (Table B23).

<u>Virtual Population Analysis</u>

The ADAPT VPA calibration method (Parrick 1986, Gavaris 1988, Conser and Powers 1990) was used to estimate terminal stock abundance for ages 2-6 and to derive age-specific estimates of fishing mortality in 2000 and stock sizes at the beginning of 2001. The catch at age in the VPA consisted of combined U.S. and Canadian landings during 1982-2000 for ages 1-6 with a 7+ age group. Indices available to calibrate the VPA included stratified mean number per tow at age indices from the U.S. Spring research vessel survey (1968-2001, ages 1-7), the Canadian Spring research vessel survey (1987-2001, ages 1-7), and the U.S. Autumn research vessel survey (1982-2000, ages 0- 6) brought forward one age and one year.

A summary of the various model calibrations, including key diagnostics and terminal year results, is presented in Table B24. All four runs contained only sea sampling data in the 1999 catch-at-age. Runs 3 and 4 were conducted to determine the effects of the different calibration indices on the model results. It was concluded from the poor fit of Runs 3 and 4 that all three surveys were important in tuning the model. The SARC determined that Run 2, which included estimates for ages 2-6 and the U.S. Spring survey indices (ages 1-7), the Canadian Spring survey indices (ages 4-7), and the U.S. Autumn survey indices (ages 3-6, brought forward one age and one year), represented the run with the best fit. This calibration was successful in reducing the coefficients of variation (CVs) on the older ages (4-6), but the diagnostics of all the runs were relatively poor (Table B24).

The VPA results indicated that stock numbers declined during 1982-1993, from approximately 26 million fish to 8 million fish. Stock size doubled between 1993 and 1999, then declined to13 million fish in 2000 (Table B25).

After 1993, the pattern of fishing mortality at age became erratic. In 1998 and 1999, the effects of poor characterization of the catch at age during these years is indicated by high fishing mortality rates on the younger age groups rather than the older ones (Table B25).

Mean biomass of age 1+ fish declined during 1982-1994, but has increased steadily since then. Spawning stock biomass declined from levels exceeding 8,000 mt in the early 1980's to less than 2,000 mt in 1994 and 1995, but since then has increased to almost 6,000 mt in 2000 (Table B26). In the early 1980s, spawning stock biomass consisted of a wide range of ages and the youngest mature ages (2 and 3) comprised less than 40% of the total spawning stock biomass. The age structure of the spawning stock biomass became truncated in the mid 1980s to mid 1990s, when age 2 and 3 fish comprised 45-75% of the spawning stock biomass.

A retrospective analysis of VPA Run 2 was performed, from 2000 to 1993, by sequentially re-analyzing the ADAPT calibration after removing the terminal year of input data. Retrospective patterns for fishing mortality rates indicate a pattern of underestimation during the terminal year that increases in severity back to 1997 (Figure B17a). There was no evidence of retrospective patterns in terminal year spawning stock biomass or age 2 recruitment (Figures B17b and B17c).

Based on relatively poor fit of the VPA (high CVs on stock size at age), inconsistent patterns in mean weights at age and fishing mortality rates at age, and a retrospective pattern in fishing mortality in recent years, the SARC did not adopt the VPA results as a basis for evaluating current stock status.

In general, trends in average stock biomass and biomass-based fishing mortality rates were similar between the VPA and ASPIC models during 1982-2000 (Figure B17). The results from both models indicate a steady increase in biomass during 1994-2000 and a substantial decrease in fishing mortality since 1993.

Forward Projection of Catch at Age

A second age-structured population dynamics model, based on forward projection of population numbers at age, was conducted as an exploratory analysis (Fournier and Archibald 1982, Methot 1990, Ianelli and Fournier 1998, Quinn and Deriso 1999). The underlying methodology, including the population dynamics model, statistical estimation approach, model diagnostics are presented in the redfish section of the SARC 33 Consensus Summary Report (NEFSC 2001).

The SARC suggested that this model may provide insight into the dynamics of the stock in future assessments, but that further sensitivity testing of the model under different assumptions and configurations is warranted.

BIOLOGICAL REFERENCE POINTS

Current

The current control rule defines MSY-based fishing targets and thresholds, incorporating the results of an ASPIC surplus production model (Applegate *et al.* 1998), and was adopted by the New England Fishery Management Council (NEFMC) in

Amendment 9 to the Northeast Multispecies Fishery Management Plan. As a result of the imprecision of absolute estimates of biomass and fishing mortality from the ASPIC model, biological reference points are defined in terms of survey-based equivalents. The ASPIC model estimate of B_{MSY} is multiplied by the autumn survey *q* estimated from the ASPIC model to convert to a survey-based equivalent. The current target biomass level is defined as a B_{MSY} proxy that equals 2.73 kg/tow. The current threshold biomass proxy is defined as 50% of the target B_{MSY} proxy and equals 1.37 kg/tow. Target and threshold fishing mortality proxies are defined as exploitation indices calculated as catch/autumn survey biomass index. The current threshold fishing mortality rate is defined as an F_{MSY} proxy that equals 1.13 and is calculated as the ASPIC estimates of MSY/B_{MSY}. The current target fishing mortality rate is defined as 75% of the threshold fishing mortality proxy and equals 0.84. Stock status is defined as an exploitation index and is calculated as a three-year, moving average of the autumn survey biomass indices divided by a three-year, moving average of the catches.

Proposed

Biological reference points were re-estimated based on the results of an updated ASPIC model (Run 3), biomass indices from the NEFSC autumn bottom trawl survey, and commercial fishery landings (Table B27). The target biomass index was calculated as the product of the ASPIC model estimate of B_{msy} (9.355 thousand mt) and the estimate of the NEFSC autumn bottom trawl survey biomass index catchability coefficient (q = 0.2658), providing an index of B_{msy} of 2.49 (= 9.355 * 0.2658). The threshold biomass index of 1.24 was calculated as 50% of the target biomass index.

The threshold fishing mortality index of 1.21 was calculated as the quotient of the ASPIC model estimate of MSY (3.020 thousand mt) and the index of B_{msy} (2.49), or (3.020/2.49). The target fishing mortality index of 0.91 was calculated as 75% of the threshold fishing mortality index.

Average relative exploitation indices (3-year average catch/3-year average autumn survey biomass index) were above the revised $F_{threshold}$ during 1981-1995 but have since declined to 71% of the of the F_{target} (Figure B18, Table B28). During 1998-2000, the three-year average relative exploitation index was 0.65. Relative to the proposed harvest control rule, the stock is not overfished and overfishing is not occurring ($B_{1998\text{-}2000\ proxy}$ = 2.29, $F_{1998\text{-}2000\ proxy}$ = 0.65) (Figure B19).

PROJECTIONS

Projections of stock size were not performed based on the ASPIC model results because of the inability to explicitly model recruitment.

CONCLUSIONS

The Georges Bank winter flounder stock was not overfished and overfishing was not occurring in 2000. Stock biomass in 2000 was 92% of the re-estimated B_{MSY} target and fishing mortality in 2000 was 71% of the re-estimated fishing mortality rate target. Fishing mortality rates were very high during 1984-1993, but have been declining since 1994. Stock biomass has been increasing steadily since 1994. US and Canadian research surveys indicate recruitment has been below average since 1994. Research survey indices indicate the age structure became truncated in the early 1990s but is beginning to broaden.

SARC COMMENTS

The SARC recommended investigating possible day/night catch differences for winter flounder in the survey which might explain some of the variation in the survey index. The SARC noted that the large market categories were not adequately sampled in recent years (1998-1999). Over 40% of the landings occur in the large market categories. If length distributions are relatively stable within market category, using market category length information from adjacent years may be a better way for pooling instead of combining market categories on an annual basis. This could be investigated. The SARC commented that not incorporating discard estimates in the VPA may produce a biased estimate of removals.

Discussion occurred on why the VPA was rejected, i.e., unstable mean weights at age, retrospective pattern in fishing mortality, failure to track cohorts in the catch at age matrix, low catchability in the surveys. Why the VPA uses all three survey indices while the accepted ASPIC run 3 used only the US indices was also discussed. It was noted that the Canadian survey uses a flatfish net which prevents the survey from sampling the hard bottom habitat in the center of Georges Bank where smaller winter flounder (ages 1-3) are concentrated. The Canadian survey is comprised of mostly larger winter flounder sampled on the eastern part of Georges Bank. Therefore, the Canadian and US surveys may be measuring different components of the population.

The SARC noted that all three models (VPA, ASPIC, and the forward projecting age-structure model, WIN) produced similar trends. However the SARC could not explain why the forward projecting age-structure model results were scaled about two times higher in terms of biomass.

The SARC discussed the utility of the forward projecting age-structure model. The SARC felt the model provides valuable insight to the dynamics of the stock. However concern was expressed with the sensitivity of the model to different assumptions and model configuration. The SARC recommended that more work on the sensitivity of the model to assumptions and model configuration be performed. The choice of error structure (lognormal) used to model F deviations was discussed. Sensitivity of the model is to the initial population size was also questioned. Some SARC members felt that the stock was not at virgin biomass levels in the early 1960s. The SARC recommended investigating the existence of landings data prior to 1964 which should be incorporated in the model. An investigation on why the model was so sensitive to small deviations in natural mortality was also suggested. The SARC discussed the model's estimation of fishery and survey selectivity patterns. Differences in estimated selectivity between the fall and spring survey may be an artifact of the fall survey being a longer time series and the accumulation of older fish in the catch at age matrix at the beginning of the time series.

Further examination of the sensitivity of the model to selectivity should be examined.

The SARC considered the estimation of reference points. It was suggested that estimation of reference points should be decoupled from the analysis of stock status to avoid changes in reference point targets each time the stock is assessed. The SARC recommended that an analysis of the performance of control rules be done.

The SARC reviewed a retrospective analysis on the ASPIC model and noted that estimates of B_{msy} and F_{msy} were more variable than estimates of F and biomass. The SARC accepted ASPIC run 3 which uses the Spring and Fall US surveys. The survey based reference point proxies were updated using the q's from ASPIC run 3 and the status of the stock was determined using survey-based indices of current biomass and F. The SARC recommended that absolute estimates from ASPIC be used directly (without translations to survey proxies) in the future to estimate biological reference points and evaluation of stock status. The SARC concluded that no projections should be run at this time since the VPA was not accepted and ASPIC model projections were thought to be unreliable due to poor recruitment in recent years.

SOURCES OF UNCERTAINTY

1. Sampling of U.S. commercial landings in the primary port of New Bedford was insufficient during 1998 and 1999, such that the age composition of the catch could not be accurately characterized and a reliable Virtual Population Analysis could not be conducted. Inadequate sampling of winter flounder in the Canadian landings was also a source of uncertainty in the catch at age.

2. There is some uncertainty about the Canadian landings because of the non-targeted nature of the Canadian fishery and the tendency to report landings of some flatfish species including winter flounder as unclassified flounders.

3. The Canadian fishery has no formal sampling program to estimate the size and age composition of Canadian landings. This assessment assumed that the size and age composition of Canadian landings was identical to the overall size and age composition in the U.S. fishery. However, selectivity patterns in the two fisheries may be different.

4. Canadian spring survey indices do not include winter flounder catches from the eastern half of strata 5Z6 and 5Z7. The western boundary of the Georges Bank winter flounder stock area bisects both strata. In addition, US survey indices do not include winter flounder catches from stratum 23 which is comprised of catches from both the Georges Bank and the Southern New England stock.
5. The lack of discard estimates, due to insufficient sampling, results in uncertainty of total fishery removals from the stock.

6. Abundance and biomass indices in the US bottom trawl surveys exhibit a considerable amount of variability. The overall low catchability of winter flounder in the U.S. surveys on Georges Bank is a source of concern.

RESEARCH RECOMMENDATIONS

1. Increase the sampling of commercial landings (number of samples by market category and quarter) especially at the primary port of New Bedford.

2. Improve sampling of discards of winter flounder in the otter trawl and scallop dredge fisheries.

3. Examine the distribution of winter flounder resources in Stratum 23 in the US survey and the prospects for splitting this stratum across the stock area boundary. Differences in growth rates between the two stocks is evident from aging which can be used to determine the location of the boundary. The intensity of age sampling for winter flounder from stratum 23 should be increased to carry out this task. This boundary determinations should be coordinated for all species where the stock boundary is split across the area 521/526 - 522/525 boundary, particularly yellowtail flounder. Similar work should be conducted in strata which cover more than one stock in the Canadian survey.

4. Using the VTR database, derive a second LPUE time series for directed trips and all trips.

5. Work on the forward projecting age-structure model should be continued. The sensitivity of the model to different assumptions and model configurations should be examined further. For instance, sensitivity of the model to small deviations in natural mortality, initial population size, and differences in the estimated selectivity patterns between the surveys should be investigated. If available, landings data prior to 1964 should be incorporated in the model.

6. Measures should be taken to improve the representativeness of the U.S. survey indices for this stock and other Georges Bank flatfish stocks, either by changing the existing spring and autumn survey sampling design in key Georges Bank strata (e.g. a north-to-south split of stratum 23 and assigning random stations within each of the two substrata) or designing a standardized survey on Georges Bank that utilizes chartered commercial vessels. The logistics of extending the winter bottom trawl survey to cover all Georges Bank strata should also be examined.

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