B2. GULF OF MAINE (GOM) WINTER FLOUNDER

TERMS OF REFERENCE

The following terms of reference were addressed for Gulf of Maine winter flounder stock:

1) Characterize status of GM winter flounder using the analytical tools that are most appropriate for available data. These may include sequential population analysis, surplus production, survey indices and relative exploitation indices, or length based models.

2) Where possible provide best estimates of exploitation rates (fishing mortality, relative exploitation), mean biomass, spawning stock biomass and characterize uncertainty associated with these estimates.

3) Develop yield per recruit and biological reference points.

4) Where possible, provide short-term and medium term projections of catch and stock size under status quo F and various proposed target fishing mortality rates (F20%, F25%, F30%, F40%, F0.01, Fmax, Fmsy) as appropriate.

5) Develop and recommend an overfishing definition for Gulf of Maine winter flounder that meets the standards of the Sustainable Fishery Act.

6) Develop research recommendations for improving assessment of winter flounder.

INTRODUCTION

The last assessment for Gulf of Maine winter flounder was an index based assessment reviewed at SARC 21 (NEFSC 1996). Low indices and the absence of large fish in the survey led SARC 21 to conclude that the stock was overexploited in the mid 1990s. The current benchmark assessment is based on a Virtual Population Analysis (VPA) with commercial/recreational landings and discard estimates from 1982-2001 and research survey abundance indices from 1982-2002.

Winter flounder (*Pleuronectes americanus*) is a demersal flatfish species commonly found in estuaries and on the continental shelf. The species is distributed between the Gulf of St. Lawrence and North Carolina, although it is not abundant south of Delaware Bay. Within the Gulf of Maine, winter flounder undergo migrations from estuaries, where spawning occurs in the late winter and spring, to offshore shelf areas of less than 60 fathoms. Winter flounder reach a maximum size of around 2.25 kg (5 pounds) and 65 cm, with the exception of Georges Bank where growth rate is higher and fish may reach a maximum weight up to 3.6 kg (8 pounds; Bigelow and Schroeder 1953).

Current fishery management is coordinated by the ASMFC in state waters and the NEFMC in federal waters. Winter flounder fisheries in state waters have been managed by Interstate Agreement under the auspices of the ASMFC Fishery Management Plan (FMP) for Inshore Stocks of Winter Flounder since approval in May, 1992. The plan includes states from Delaware to Maine, with Delaware granted *de minimus* status (habitat regulations applicable but fishery management not required). The Plan's goal is to rebuild spawning stock abundance and achieve a fishing mortality-based management target of $F_{40\%}$ (fishing rate that preserves 40% of the maximum spawning potential of the stock) in three steps: $F_{25\%}$ in 1993-1994, $F_{30\%}$ in 1995-1998, and $F_{40\%}$ in 1999 and later years through implementation of compatible, state-specific regulations.

Coastal states from New Jersey to New Hampshire have promulgated a broad suite of indirect catch and effort controls. State agencies have set or increased minimum size limits for recreationally and commercially landed flounder (10-12 in and 12 in, respectively); enacted limited recreational closures and bag limits; and instituted seasonal, areal, or state-wide commercial landings/gear restrictions. Minimum codend mesh regulations have been promulgated in directed winter flounder fisheries: 6 in MA. New Hampshire prohibits the use of mobile gear in state waters with the exception of small mesh trawling in the shrimp fishery.

Winter flounder in the Exclusive Economic Zone (EEZ) are managed under the Northeast Multispecies Fishery FMP developed by the NEFMC. The principle catch of winter flounder in the EEZ has recently occurred as bycatch in directed trawl fisheries for Atlantic cod, haddock, and yellowtail flounder. The management unit encompasses the multispecies finfish fishery that operates from eastern Maine through Southern New England (72° 30'). At least one offshore stock, on Georges Bank, has been identified. The FMP extends authority over vessels permitted under the FMP even while fishing in state waters if federal regulations are more restrictive than the state regulations.

The Multispecies FMP was implemented in September, 1986, imposing a codend minimum mesh size of 5.5 in (previously 5.1 in) in the large-mesh regulatory area of Georges Bank and the offshore portion of Gulf of Maine. There were closed areas and seasons for haddock and yellowtail flounder. In the western Gulf of Maine, vessels were required to enroll in an Exempted Fisheries Program in order to target small-mesh species such as shrimp, dogfish, or whiting. The bycatch restrictions specified area and season and limited groundfish bycatch to 25% of trip and 10% for the reporting period. In southern New England waters, the groundfish bycatch on vessels fishing with small mesh was not limited in any way. There was a 11 in minimum size for winter flounder which corresponded with the length at first capture (near zero percent retention) for 5.5 in diamond mesh. Although the Multispecies FMP was amended four times by 1991, it was widely recognized that many stocks, including winter flounder, were being overfished.

Time-specific stock rebuilding schedules were a part of Multispecies FMP Amendment 5 which took effect in May, 1994. The rebuilding target for winter flounder, a so-called "large-mesh" species, was $F_{20\%}$ within 10 years. Along with a moratorium on issuance of additional vessel permits, the cornerstone of Amendment 5 was an effort reduction program that required "large-mesh" groundfish vessels to limit days at sea, which would be reduced each year. There was an exemption from effort reduction requirements for groundfishing vessels less than 45 feet in length and for "day boats" (from 2:1 layover day ratio requirement). Draggers retaining more than the "possession limit" of groundfish (10%, by weight, up to 500 lbs) were required to fish with either 5.5 in diamond or square mesh in Southern New England or 6 in throughout the net in the regulated mesh area of Georges Bank/ Gulf of Maine, respectively. The possession limit was allowed when using small mesh within the western Gulf of Maine (except Jeffreys Ledge and Stellwagon Bank) and in Southern New England. Vessels fishing in the EEZ west of 72° 30' (the longitude of Shinnecock Inlet, NY) were required to abide by 5.5 in diamond or 6 in square codend mesh size restrictions consistent with the Summer Flounder FMP. The minimum landed size of winter flounder increased to 12 in, appropriate for the increased mesh size in order to reduce discards. There were many additional rules including time/area closures for sink gillnet vessels, seasonal netting closures of prime fishing areas on Georges Bank (Areas I and II), and on Nantucket Shoals to protect juvenile yellowtail flounder.

At the end of 1994, the NEFMC reacted to collapsed stocks of Atlantic cod, haddock, and yellowtail flounder on Georges Bank by recommending a number of emergency actions to tighten existing regulations reducing fishing mortality. Prime fishing areas on Georges Bank (Areas I & II), and the Nantucket Lightship Area were closed. The NEFMC also addressed expected re-direction of fishing effort into Gulf of Maine and Southern New England while, at the same time, developing Amendment 7 to the Multispecies FMP. Under Amendment 7, days-at-sea controls were extended, and any fishing by an EEZ-permitted vessel required use of not less than 6 in diamond or square mesh in Southern New England east of 72° 30'. Framework 27 in 1999 increased the square mesh minimum size to 6.5 in in the Gulf of Maine, Georges Bank, and Southern New England mesh areas. Amendment 9 revised the overfishing definitions for New England groundfish, and new overfishing definitions for SNE/MA winter flounder were recommended by SARC 28 (NEFSC 1999).

STOCK STRUCTURE

Although stock groups consist of an assemblage of adjacent estuarine spawning units, the ASMFC FMP originally defined three coastal management units based on similar growth, maturity and seasonal movement patterns: Gulf of Maine, Southern New England and the Mid-Atlantic. Boundaries for a total of four winter flounder stock units as originally defined in the ASMFC management plan (Howell et al., 1992) were:

Gulf of Maine: Coastal Maine, New Hampshire, and Massachusetts north of Cape Cod

Southern New England: Coastal Massachusetts east and south of Cape Cod, including Nantucket Sound, Vineyard Sound, Buzzards Bay, Narragansett Bay, Block Island Sound, Rhode Island Sound, Rhode Island coastal ponds and eastern Long Island Sound to the Connecticut River, including Fishers Island Sound, NY.

Mid-Atlantic: Long Island Sound west of the Connecticut River to Montauk Point, NY, including Gardiners and Peconic Bays, coastal Long Island, NY, coastal New Jersey and Delaware.

Georges Bank

In the current and previous assessments (e.g., NEFSC 1996, ASMFC 1998, NEFSC 1999) the Southern New England and Mid-Atlantic units have been combined into a single stock complex for assessment purposes. A review of tagging studies for winter flounder (Howell 1996) indicates dispersion (and hence mixing) has occurred between previously defined Southern New England and Mid-Atlantic units. Howell (1996) noted that differences in growth and maturity among samples from Southern New England to the Mid-Atlantic may reflect discrete sampling along a gradient of changing growth and maturity rates over the range of a stock complex. Differences in growth rates within the Mid-Atlantic units were observed to be greater than differences between Mid-Atlantic and Southern New England units (Howell, 1996). In offshore waters, the length structure of winter flounder caught in NEFSC research surveys is similar from Southern New England to New Jersey. Most commercial landings are obtained in these offshore regions (greater than 3 miles from shore).

Stock Boundaries and associated Statistical Areas

The Gulf of Maine stock complex extends along the coast of eastern Maine to Provincetown, MA, corresponding to NEFSC commercial fishery statistical division 51 (Figure B2.1). Recreational landings from Maine, New Hampshire and northern Massachusetts (northern half of Barnstable County and north to New Hampshire border) are associated with this stock complex.

The Southern New England/Mid-Atlantic stock complex extends from the coastal shelf east of Provincetown, MA southward along the Great South Channel (separating Nantucket Shoals and Georges Bank) to the southern geographic limits of winter flounder. NEFSC commercial fishery statistical areas within this boundary are 521 and 526, and statistical divisions 53, 61, 62, and 63. The corresponding recreational areas are southern Massachusetts (the southern half of Barnstable County; Dukes, Nantucket and Bristol counties), Rhode Island, Connecticut, New York, New Jersey, Delaware, Maryland and Virginia. NEFSC survey strata included for this stock extend from the waters of outer Cape Cod to the south and west.

The Georges Bank stock extends eastward of the Great South Channel, including statistical areas 522, 525, and 551-562.

FISHERY DATA

Landings

Commercial landings from 1964-1981 was taken directly from the SARC 21 assessment (NEFSC 1996). Landings from 1981-1993 was estimated from the weighout data and landings from 1994-2001 comes from a proration of dealer and vessel trip report (VTR) data (Table B2.1).

Commercial landings were near 1,000 mt from 1964 to the mid 1970s. Thereafter commercial landings increased to a peaked of 2,793 mt in 1982, and then steadily declined to a record low of 253 mt in 1999. Landings have remained near 500 mt since 1999 (Table B2.1, Figure B2.2). Otter trawl was the primary gear use during 1964-1985; > 95% of the landings (Table B2.2, Figure B2.2). Since 1985 the proportion of landings coming from gillnets has increased, and has averaged 25% since 1990. Over 95% of the landings came from Massachusetts since 1997 (Table B2.3, Figure B2.3). The proportion of winter flounder commercial landings taken in Maine has decrease from an average of 25 percent of the landings in the early 1980s to less than 5% of the landings from 1995-2001. Over 90% of the commercial landings came from statistical area 514 since 1996 (Table B2.4, Figure B2.4). Commercial landings are taken relatively constant over the year (Table B2.5, Figure B2.5). There has been a decrease in the proportion of the landings in the large market category in the last few years (Table B2.6, Figure B2.6).

Recreational landings reached a peak in 1981 of 2,554 mt but declined substantially thereafter (Table B2.7, Figure B2.7). Landings have been less than 100 mt since 1995, with the lowest estimated landings in 1998 of 30 mt. Landings in 2001 for the Gulf of Maine winter flounder were 43 mt. The proportion of recreational landings from Maine has decreased similarly to the commercial landings (Tables B2.8-9). The proportion of recreational landings taken by halfyear has fluctuated from 1981 to 2001 (Tables B2.10-11).

Landed Age Compositions

Commercial fishery

Length samples of winter flounder are available from both the commercial and recreational landings. In the commercial fishery, annual sampling intensity varied from 4 to 310 mt landed per sample during 1982-2001. Overall sampling intensity was adequate, however temporal and market category coverage in some years was poor (Table B2.12). Samples were pooled to halfyear when possible. In 1982 mediums were pooled with unclassified by halfyear; in 1985 and 1995 smalls were pooled with mediums; the large sample from 1998 was also used to characterize 1999; and the 2001 large samples were used to characterize the 1999 large market category. Sampling coverage may have been poor but length frequency samples appeared relatively constant over time and there was a substantial amount of overlap between market categories which helped justify the pooling used in the assessment. Length data from the obsever data was used to supplement length data of unclassified fish. The large number of lengths sampled in the observer data for gillnet trips were used to characterize the gillnet proportion of the landings from 1990-2001 (Table B2.13). There has been a slight shift in the commercial catch at length to larger fish since 1982. The total amount of fish aged in the commercial landings varied from 130 to 1,182 ages (Table B2.14).

Recreational fishery

Recreational landings at length were estimated seasonally (January-June and July-December) from 1982-2001 using the Marine Recreational Fisheries Statistics Survey (MRFSS). Recreational length sampling intensity varied from poorly sampled years in the beginning of the time series (1982-1987 average of 375 mt per 100 lengths) to relatively good sampling from the late 1980s to early 1990s (1988-1997 average of 109 mt per 100 lengths), and more recently

(1998-2001) the sampling intensity has decreased to an average of 179 mt per 100 lengths. Combined Massachusetts Division of Marine Fisheries (MADMF) spring and NEFSC spring surveys and the NEFSC fall survey were used to age recreational length frequencies by halfyear from 1982-2001.

Discard estimates and age compositions

Commercial fishery

Discards were estimated for the large mesh otter trawl (1982-2001), gillnet (1986-2001), and northern shrimp fishery (1982-2001; Table B2.15). Discard data for the small mesh trawl fishery was judged inadequate for estimating discards (Tables B2.15-16). Discard rates in the small mesh trawl fishery were assumed to be the same as for large mesh trawls and to have the same size distribution.

The survey culling ogive method was used in estimating both the discard magnitude and discard proportion at length for the large mesh trawl fishery on a yearly basis from 1982-1993 (Mayo et al. 1992). VTR data was used to estimate the discard magnitude from 1994-2001, and the survey method used to estimate only the discard proportion at length for these years (Table B2.17). Survey length frequency data (MADMF survey spring and fall) were smoothed using a three point moving average, then filtered through a mesh selection ogive (Simpson 1989) for 5 in mesh (1982), 5.5 in mesh (1983-1993), and a 6 in mesh (1994-2001). The 5.5 and 6 in mesh selection curve were calculated using the 5 inch curve adjusted to an L_{50} for 5.5 and 6 in mesh respectively. The choice of mesh sizes was based on sizes used in the American Plaice assessment for the Gulf of Maine (O'Brien and Esteves 2001). The mesh filtering process resulted in a survey length frequency of retained winter flounder. A logistic regression was used to model the percent discarded at length (culling ogive) from 1989-2000 observer data (Figures B2.8-9), and the resulting percentages at length were applied to the survey numbers at length data to produce the survey-based equivalent of commercial kept and discarded winter flounder. The 1989-1993 average percentage discard at length was applied to 1982-1993. The 1995-2000 average percentage discard at length was applied to 1994-2001. The survey numbers per tow at length "kept" were then regressed against commercial numbers landed at length. The linear relationship was calculated for those lengths common to both length frequencies and fitted with an intercept of zero. The slope of the regression provided a conversion factor to re-scale the survey "discard" numbers per tow at length to equivalent commercial numbers at length. The resulting vector of number of fish discarded at length was multiplied by a discard mortality rate of 50% (as averaged in Howell et al., 1992) to produce the vector of fish discarded dead at length per year. The number of dead discards at length was summed across lengths (and corresponding weight at length) to produce the annual total number and weight of commercial fishery discards for 1982-1993. NEFSC combined spring and fall survey age-length keys were applied to convert discard length frequencies to age.

The ASMFC Winter Flounder Technical Committee has considered NEFSC Fishery Observer data (OB), and NER Vessel Trip Report (VTR) data as sources of information to use in the estimation of commercial fishery discards (Tables B2.15-18). The Committee examined the characteristics of both the Fishery Observer and VTR discard data (number of trips/tows sampled, frequency distributions of discards to landings ratio per trip, mean and variance of annual/half-year discards to landings ratios), and concluded that the VTR sum discard to landed ratio aggregated over all trips provided the most reliable data from which to estimate large mesh trawl discards. VTR large mesh trawl gear discards to landings ratios were applied to the total commercial trawl fishery landings to estimate discards in weight from 1994 to 2001. The Fishery Observer length frequency samples were judged inadequate to characterize the proportion discarded at length for the trawl fishery and the length proportion from the survey method (described above) was used to characterize the size distribution of discarded fish (Table B2.16).

Fishery Observer discarded to landing ratios (annual total discards for all trips to annual total landings for all trips) were used for estimating gillnet discard rates, and observer discarded to days fished ratios (shrimp season total discards for all trips to total shrimp fishery days fished for all trips) were used for estimating shrimp discards, since landings of winter flounder in the shrimp fishery is prohibited (Table B2.18). Estimated annual total days fished in the shrimp fishery was calculated as in Wigley et al. 1999. Discard estimates in the shrimp fishery were based on a shrimp fishery season (December-April). The shrimp season catch at age was then adjusted to the appropriate calendar year and age using the proportion of calendar year landings. The average ratio for shrimp discards from 1989 to 1992 (before Nordmore grate requirement) was used for years (1982-1988) when observer data were not available. The 1989-1993 average gillnet ratios were used for 1986 to 1988.

The observer length frequency samples for gillnet and the northern shrimp fishery were used to characterize the proportion discarded at length. Total lengths from shrimp fishery observer discard data from 1989-1992 were used to characterize years 1982-1988 and total lengths from 1993-1997 were used for years 1998 to 2001. Total gillnet lengths from 1990-1993 were used to characterize years 1986 to 1989. Gillnet lengths in 1990 and 1992 were used to supplement lengths in 1991. The sample proportion at length, converted to weight, was used to convert the discard estimate in weight to numbers at length. As in the southern New England stock (NEFSC 1999), the resulting number of fish discarded at length was multiplied by a discard mortality rate of 50% (as averaged in Howell et al., 1992) to produce the number of fish discarded dead at length for all estimated commercial discard sources. Ages were determined using NEFSC/MADMF spring and NEFSC fall survey age-length keys.

Recreational fishery
A discard mortality of 15% was assumed for recreational discards (B2 category from MRFSS data), as assumed in Howell et al. (1992). Discard losses peaked in 1982 at 140,000 fish. Discards have since declined reaching a low in 1999 of 7,000 fish. In 2001, 15,000 fish were estimated to have been discarded (Table B2.7, Figure B2.7). Since 1997, irregular sampling of the recreational fisheries by state fisheries agencies has indicated that the discard is usually of fish below the minimum landing size of 12 inches (30 cm). For 1982-2001, the recreational discard has been assumed to have the same length frequency as the catch in the MADMF survey below the legal size and above an assumed hookable fish size (13 cm). When a size limit did not exist from 1982-1984 it was assumed that all fish discard were below 23 cm based on some length frequency information of discarded fish from the American Littoral Society tagging data. The recreational discard for 1982-2001 is aged using NEFSC/MADMF spring and NEFSC fall

survey age-length keys.

Mean Weights at Age in the Catch

Mean weights at age were determined for the landings and discards in the commercial and recreational fisheries (Figure B2.10). Length frequencies (cm) for each component were converted to weight (kg) using length-weight equations derived from NEFSC survey samples:

Spring surveys: $wt = 0.00000997 * length^{3.055236}$
Fall surveys: $wt = 0.00000925 * length^{3.095188}$

The equations from the spring and fall surveys were applied to catches during the corresponding time periods. The annual mean weights at age from the commercial and recreational fisheries were used in the virtual population analysis and yield per recruit calculations.

Total Catch

Estimates of the individual catch and mean weights at age components which made up the total catch are present in Tables B2.19 through B2.30 and Figure B2.11. The total catch during this period has varied from a high of 5,034 mt (14.2 million fish) in 1982 to a low of 300 mt (0.6 million fish) in 1999 (Tables B2.31-32). The total catch estimates include commercial and recreational landings and discards (Figure B2.12). Total catch and mean weights at age as aggregated for input to the VPA (ages 1-8+) are presented in Tables B2.33 and B2.34 (Figure B2.13). A summary of how the catch at age is was constructed can be seen in Table B2.35.

RESEARCH SURVEY ABUNDANCE AND BIOMASS INDICES

Research surveys

Mean weight and number per tow abundance indices were determined from spring (1979-2002) and fall (1979-2002) NEFSC and MADMF bottom trawl surveys (Table B2.36). Winter flounder are not found in the central Gulf of Maine and these strata (24, 28, 29, 37, and 36) were dropped from the index (Figures B2.14-15). Indices from the NEFSC spring and fall surveys were based on tows in offshore strata 26, 27, 38 to 40 and inshore strata 58 to 61, 65, and 66 (Figures B2.16-19). A longer spring (1968-2002) and fall (1963-2002) NEFSC survey index was also calculated which was limited to just offshore strata (26,27,38,39,40) since inshore strata were not sampled prior to 1979 in the Gulf of Maine (Figures B2.18-19). All MADMF strata sampled north of Cape Cod (25-36) were included in the index (Figures B2.20-21).

Survey trends by individual strata in the NEFSC survey suggests a decreasing trend in the northern part of the stock off the coast of Maine and an increasing trend in the southern stock component off Massachusetts which mirrors the trend seen in the landings by state and statistical area (Figures B2.16-17). Higher catches of winter flounder are seen in the MADMF survey with individual strata following similar trends. All of the indices generally dropped from the beginning of the time series in the early 1980s to a low point in the early to mid- 1990s, then increase slightly in the late 1990s (Table B2.36). All of the indices generally show increases during 1998 and 1999. Similar trends were seen between the inshore/offshore index and the index limited to just the offshore strata regardless of the increased variability in the offshore series due to less fish inhabiting the deeper waters of the offshore strata (Figures B2.18-19).

The Seabrook Nuclear Power Plant in New Hampshire has conducted a monthly bottom trawl survey at 3 fixed stations in Southern New Hampshire since 1975. Four replicate tows using a shrimp trawl were made at each station once per month from 1975-1983. Sampling changed to two replicate tows twice per month in 1985. Length data was collected from 1985-2001 with the exception of 1993. The monthly survey was broken down to a spring and fall survey. The Fall survey index was not used for tunning due to a lack of sampling in more recent years at one of the three stations because of the presence of lobster gear. In addition, appropriate age data in the fall does not exist for aging the smaller fish caught in this survey. MADMF spring survey ages were used to age the Seabrook spring index. This survey also shows an increase in the number of fish in the late 1990s (Figure B2.22).

MADMF catches a larger proportion of smaller fish than the NEFSC surveys. Survey numbers at age is summarized in Tables B2.37 through B2.41. No MADMF age data are currently available for the fall survey or for 2002 in the Spring. The NEFSC age data was used to age missing ages in the MADMF survey.

ESTIMATES OF MORTALITY AND STOCK SIZE

Natural Mortality

Instantaneous natural mortality (M) for winter flounder was assumed to be 0.20 and constant across ages as in the SNE winter flounder stock. Commercial catch at age included fish to age 13, under conditions of relatively high fishing mortality. If M = 0.25, less than 5% of the population would reach age 12 under conditions of no fishing mortality. Therefore, the SARC felt that M = 0.2, which represents a maximum age of 15, was representative of the stock.

Maturity

The VPA assessment uses the maturity schedule as published in O'Brien et al. (1993) for winter flounder north of Cape Cod, based on data from the MADMF spring trawl survey for strata 25-36 (state waters east and north of Boston and Cape Cod Bay) sampled during 1985-1989 (n = 215 males, n = 320 females). Those data provided estimates of lengths and ages of 50% maturity of 27.6 cm and 3.3 yr for males, and 29.7 cm and 3.5 yr for females, and estimated proportions mature at age as follows:

Age	1	2	3	4	5	6	7+
Males	0.00	0.04	0.34	0.87	0.99	1.00	1.00
Females	0.00	0.01	0.16	0.86	0.99	1.00	1.00

The female schedule (with the proportion at age 2 rounded down to 0.00 and the proportion at age 5 rounded up to 1.00) was used in the present VPA and YPR assessment.

The SARC has examined NEFSC spring trawl survey data over the 1981-2001 period in an attempt to better characterize the maturity characteristics of the Gulf of Maine winter flounder. Data were analyzed in 5-6 year blocks (1981-1985, 1986-1990, 1991-1995, and 1996-2001) and for the entire time period (1981-2001), for each sex and combined sexes (Tables B2.42-43). Observed proportions mature at age were tabulated, and from those data maturity ogives at length and age were calculated to provide estimated proportions mature at age.

In general, the NEFSC maturity data for the sexes combined indicated earlier maturity than the MADMF data, with L50% values ranging from 21-24 cm, rather than from 28-29 cm, and with 50% maturity for age 2.5 fish, rather than 50% maturity for age 3.3 fish (Table B2.42). To investigate the apparent inconsistency between the MADMF and NEFSC maturity data, the SARC compared the two data sets over the same time periods (1981-1985, 1986-1990, 1991-1995, 1996-2001, and 1981-2001) and area of survey coverage (MADMF strata 25-36; NEFSC inshore strata 58-66). For comparable time periods and geographic areas, the NEFSC maturity data still consistently indicated a smaller size and younger age of 50% maturity than the MADMF data. NEFSC L50% and A50% values range from 21-25 cm and about 2.5 yr, while the MADMF values range from 28-29 cm and about 3.3 yr (Table B2.44, Figure B2.23). The difference is still nearly a full age class difference at 50% maturity. These results are very similar to the differences seen between the MADMF and NEFSC surveys for the southern New England winter flounder stock.

Given that both length and age vary in the same direction, it seems unlikely that the differences could be attributed to aging differences between the two data sets. The comparison of MADMF and NEFSC maturity estimates over the same time period and location suggests the observed difference is not due to immature and mature fish in the 20 - 30 cm size-class being segregated by area e.g., mature fish in that size interval tending to occupy inshore areas during the spring with immature fish tending to remain offshore. The difference between MADMF and NEFSC surveys is consistent over time. The differences may be due to differences in interpretation of maturity stage for fish sizes between 20-30 cm between MADMF and NEFSC survey staff.

The SARC considered these data and analyses and the possible causes for the noted inconsistencies, and concluded that more detailed spatial and temporal analyses and/or a maturity workshop on the interpretation of maturity stages is needed before revisions to the maturity schedule can be adopted. Therefore, the maturity at age schedule published by O'Brien et al. 1993 was used for this assessment.

Virtual Population Analysis

Tuning

The Virtual Population Analysis (VPA) was tuned (calibrated) using the NEFSC Woods Hole Fisheries Assessment Compilation Toolbox (FACT) version 1.50 of the ADAPT VPA (Conser and Powers 1990). Abundance indices at age were available from several research surveys: NEFSC spring bottom trawl ages 1-8+, NEFSC fall ages 1-8+ (advanced to tune January 1 abundance of ages 2-8+), 1-5, Massachusetts spring ages 1-8+, Massachusetts fall ages 0-8+ (advanced to tune January 1 abundance of ages 1-8+), and Seabrook spring trawl survey ages 1-8+. Survey indices were selected for inclusion in VPA tuning based on consideration of the partial variance in a VPA trial run including all indices, residual error patterns from the various trail runs, and on the significance of the correlation among indices and with VPA abundance estimates from the trail run including all indices. A conditional non-parametric bootstrap procedure (Efron 1982) was used to evaluate the precision of fishing mortality and spawning stock biomass. A retrospective analysis was performed for terminal year fishing mortality, spawning stock biomass, and age 1 recruitment.

VPA diagnostics

The SARC considered 6 different configurations of tuning indices with the catch at age estimated to 8+ from 1982 to 2001. Run GOMWFS36_ALL was the initial trial including all indices. The results of the VPA were not sensitivity to the method used in estimating large mesh discards i.e. using the survey method only or using the survey method and vtr data to estimate discards (run GOMWFS36_survey). In addition, VPA result were not sensitivity to excluding all discards from the catch at age (GOMWFS36_no_dis). In general, tuning indices were excluded if they exhibited high partial variance (indicating a lack of fit within the VPA model) and low correlation with other indices with similar spatial and temporal characteristics and with the VPA estimates of stock size.

Run GOMWFS36_2 excluded six indices with high partial variance within the VPA and low correlation with other indices and/or the VPA estimates of stock size, resulting in improvements both in overall fit (Mean Square Residual (MSR) reduced by 25%) and in the precision of the stock size estimates. Run GOMWFS36_3 dropped an additional five indices from the GOMWFS36_2 configuration, resulting in some improvements in fit but this run also resulted in a decrease in the precision around age-1 stock numbers at age. Run GOMWFS36_no_age1 has the same survey indices as GOMWFS36_3, but did not estimate stock size at age 1, and provided virtually the same results. Therefore, GOMWFS36 _2 was the run adopted as final by the SARC, and is the basis for all further analyses (Table B2.45).

Fishing Mortality, Spawning Stock Biomass, and Recruitment

During 1982-1995, fishing mortality (fully recruited F, ages 5-6) has varied between 0.5 (1983) and 1.9 (1995). Fishing mortality has declined to a range of 0.06-0.14 during 1999-2001 (Figure B2.24). Accounting for the uncertainty of the 2001 estimate, there is an 80% probability that F in 2001 was between 0.12 and 0.16 (Table B2.46, Figure B2.25). Spawning stock biomass (SSB) declined from 4,790 mt in 1982 to a record low of 666 mt in 1995. SSB has increased since 1995 to 5,866 mt in 2001 (Figure B2.26). Accounting for the uncertainty of the 2001 estimate, there is an 80% probability that SSB in 2001 was between 5,203 mt and 6,581 mt (Figure B2.25). Recruitment declined continuously from 11.8 million age-1 fish in 1982 to 3.2 million in 1993. Recruitment then averaged 7.8 million fish during 1995-2002 (Figure B2.26).

Retrospective analysis
A retrospective analysis of the VPA was conducted back to a terminal catch year of 1995 (Table B2.45b, Figure B2.27). The Gulf of Maine winter flounder VPA does exhibit a retrospective pattern in F from 1993 to 1998. Retrospective fishing mortality rates underestimate the current values by an average of 56% from 1993-1998. The most likely cause of this pattern is a combination of factors including under-reporting of the landings, mis-classification of the landings by stock area, and underestimation of the discards. There is a tendency for an overestimation of SSB during the late 1990s. For 1993-1998, retrospective SSB levels overestimate current values by an average of 92%.

Precision of Stock Size, F, and SSB estimates
The precision of the 2002 stock size, fishing mortality at age in 2001, and SSB estimates from VPA was evaluated using bootstrap techniques (Efron 1982). Five hundred bootstrap iterations were realized in which errors (differences between predicted and observed survey values) were resampled. Bootstrap estimates of stock size at age indicate a bias of less than 5% for age 1-2 and a bias less than 4% for ages 3-8+. Bootstrap standard errors provide stock size CVs ranging from 16% at age 7 to 48% at age 1 (Table B2.46).

Bootstrapped estimates of spawning stock biomass indicate a CV of 9%, with low bias (bootstrap mean estimate of spawning stock biomass of 5,945 mt compared with VPA estimate of 5,866 mt). There is an 80% probability that spawning stock in 2001 was between 5,203 mt and 6,581 mt (Figure B2.25).

The bootstrap estimates of standard error associated with fishing mortality rates at age indicate good precision. Coefficients of variation for F estimates ranged from 16% at age 7 to 37% at ages 1. There is an 80% probability that fully recruited F for ages 5-6 in 2001 was between 0.12 and 0.16 (Figure B2.25).

BIOLOGICAL REFERENCE POINTS

The ASMFC Winter Flounder Technical Committee followed the parametric modeling approach done for SNE winter flounder by the NEFSC Working Group on the Re-Evaluation of Biological Reference Points for New England Groundfish (RPWG; NEFSC 2002) in estimating biological reference points for Gulf of Maine winter flounder. The RPWG (NEFSC 2002) estimated biological reference points using yield and SSB per recruit (Thompson and Bell 1934) and Beverton-Holt/Ricker stock-recruitment models (Beverton and Holt 1957, Brodziak et al. 2001, Mace and Doonan 1988).

Yield and Spawning Stock Biomass per Recruit

The yield and SSB per recruit analyses was estimated by the Technical Committee for Gulf of Maine winter flounder. Natural mortality was assumed to be 0.2. The proportion mature was taken from O'Brien et. al (1993). The average partial recruitment pattern form 1999-2001 was used for ages 1 to 4. Full recruitment was assumed for 5 and older. The average catch weight from 1999-2001 was used for ages 1 to 7 and the Rivard weights were used for the stock weights for ages 1 to 7. An estimated von bertalanffy model for female Gulf of Maine winter flounder using MADMF data from Witherell and Burnett (1993) was used to estimate catch and stock weights for ages 8 to 15. The von Bertalanffy model for females was used since survey data indicates a skewed sex ratio for older ages. The yield and SSB per recruit analyses indicate that $F_{40\%}$ and $F_{0.1}$ = 0.26 (Table B2.47, Figure B2.28). F_{max} was estimated to be 0.69.

Empirical Nonparametric approach

If $F_{40\%}$ is assumed to be an adequate proxy for Fmsy, then the fishing mortality threshold is 0.26. This fishing mortality rate produces 0.8333 kg of spawning stock biomass per recruit and 0.1977 kg of yield per recruit (including discards). Since the VPA estimates of recruitment does not increase greatly with increasing spawning stock size, the mean of the time-series of recruitments (1982-2001) is assumed to be representative of recruitment levels expected at maximum sustainable yield (MSY). Thus, recruitment of 6.705 million fish results in an estimate of 5,587 mt of spawning stock biomass (SSBmsy proxy) and 1,326 mt of MSY.

Parametric Model Approach

Maximum likelihood fits of the 10 parametric stock-recruitment models to the Gulf of Maine winter flounder VPA estimates for 1982-2001 are listed below (Table B2.48). The model acronyms are: BH = Beverton-Holt, ABH = Beverton-Holt with autoregressive errors, PBH = Beverton-Holt with steepness prior, PABH = Beverton-Holt with steepness prior and autoregressive errors, PRBH = Beverton-Holt with recruitment prior, PRABH = Beverton-Holt with recruitment prior and autoregressive errors, RK = Ricker, ARK = Ricker with autoregressive errors, PRK = Ricker with slope at the origin prior, PARK = Ricker with slope at the origin prior and autoregressive errors. The six hierarchical criteria are applied to each of the models to determine the set of candidate models (NEFSC 2002).

1. Parameter estimates must not lie on the boundary of their feasible range of values.
2. The estimate of MSY lies within the range of observed landings.
3. The estimate of S_{msy} is not substantially greater than the nonparametric proxy estimate.
4. The estimate of F_{msy} is not substantially greater than the value of F_{max}.
5. The dominant frequencies for the autoregressive parameter, if applicable, lie within the range of one-half of the length of the stock-recruitment time series.
6. The estimate of recruitment at S_{max}, the maximum spawning stock size proxy input to the stock-recruitment model, is consistent with the value of recruitment used to compute the nonparametric proxy estimate of S_{msy}.

The fifth criterion is not satisfied by the ABH, PABH, PRABH, ARK, and PARK models. The RK, and ARK models do not satisfy criterion 4. The stock-recruitment data does not support overcompensatory effects at SSB predicted by the PRK model (Ricker model with slope at the origin prior). The three remaining models are BH, PBH, and PRBH. All three models estimated a high steepness parameter. The AIC assigns the greastest probability to the BH model (Figure B2.29). However similar point estimates of MSY, F_{msy}, and S_{msy} are estimated by all three models. The standardized residual plot of the fit of the BH model to the stock-recruitment data shows that the standardized residuals generally lie within $\pm$ two standard deviations of zero.

The SARC selected the parametric Berverton-Holt (BH) model for estimating biological reference points for Gulf of Maine winter flounder; MSY = 1,543 mt, F_{msy} = 0.43, SSB_{msy} = 4,104 mt. The SARC concluded that the high steepness estimates from the Beverton-Holt models were within the feasible biological range and therefore estimating F_{msy} using the (BH) parametric approach was preferred over assuming $F_{msy} = F_{40\%}$ in the empirical nonparametric approach. The high steepness estimate also likely resulted in similar estimates of SSB_{msy} between the empirical and parametric approach.

PROJECTIONS FOR 2002-20012

Stochastic projections were made based on 500 bootstrapped VPA realizations of stock size in numbers at age in 2002.   The stochastic forecasts only incorporate uncertainty in 2002 stock sizes due to survey variability and assume current discard to landings proportions. Partial recruitment to the fishery and percentage discarded were estimated as the mean of VPA estimates for 1999-2001. For consistency with the partial recruitment averages, mean weights at age in the stock, landings, and discards were similarly estimated as the weighted (by number landed) geometric mean weight at age from 1999-2001.

Parametric approach

Assuming F in 2002 will be equal to F in 2001 (F2002 = 0.14), landings are expected to be about 961 mt in 2002. At this status quo F, spawning stock biomass is projected to continue to increase to 7,623 mt in 2002. If fishing mortality rate is increased to F_{msy} = 0.43 in 2003 spawning stock will decrease to 4,258 mt by 2013 with 50% probability which is slightly above the B_{msy} = 4,104 mt estimate (Table B2.49).

If F in 2002 is assumed to be 15% less than F in 2001 (F2002 = 0.12), due to the impact of management measures implemented in response to court orders during 2002, then landings are expected to be about 831 mt in 2002. At this reduced F, spawning stock biomass is projected to continue to increase to 7,655 mt in 2002. If fishing mortality rate is increased to F_{msy} = 0.43 in 2003 spawning stock will decrease to 4,260 mt by 2013 with 50% probability which is slightly above the B_{msy} = 4,104 mt estimate (Table B2.49, Figure B2.30).

CONCLUSIONS

The Gulf of Maine winter flounder stock is not overfished and overfishing is not occurring (Figure B2.31). Fully recruited fishing mortality in 2001 was 0.14 (exploitation rate = 12%), about 67% below F_{msy} = 0.43. There is an 80% chance that the 2001 F was between 0.12 and

0.16. Spawning stock biomass was estimated to be 5,900 mt in 2001, about 44% above B_{msy} = 4,100 mt. There is an 80% chance that the spawning stock biomass was between 5,200 mt and 6,600 mt in 2001.

Spawning stock biomass declined substantially from 4,800 mt in 1982 to700 mt in 1995, but has increased to about 5,900 mt in 2001 due to reduced fishing mortality rates since 1996. Recruitment to the stock has been near or above average since 1995.

For 1993-1998 retrospective fishing mortality rates underestimate the current values by an average of 56%. The most likely cause of this pattern is a combination of factors including under-reporting of the landings, mis-classification of the landings by stock area, and underestimation of the discards. For 1993-1998, retrospective SSB levels overestimate current values by an average of 92%. While the GOM winter flounder VPA provides uncertain estimates of current F and SSB, it provides a better determination of stock status than reliance on survey indices alone. However, recent spatial distribution of both commercial landings and survey catches indicates that most of the recent stock rebuilding has taken place off the Massachusetts coast, with little evidence of rebuilding off the Maine coast.

Biological reference points for Gulf of Maine winter flounder were estimated using empirical, non-parametric and parametric stock-recruit modeling approaches. The yield and SSB per recruit analyses indicate that $F_{40\%}$ = $F_{0.1}$ = 0.26 and F_{max} = 0.69. A parametric Beverton-Holt stock-recruitment model estimated values of F_{msy} = 0.43, B_{msy} = 4,100, and MSY = 1,500 mt. The SARC recommends that the parametric model reference points be adopted as the basis for the ASMFC and NEFMC FMP overfishing definitions.

SARC COMMENTS

The SARC noted that a single survey length-weight relationship has been used for SNE-MA, GOM and GB winter flounder stocks, and suggested stock-specific parameters be explored in the next assessment.

The VPA indicates substantial rebuilding of the stock since 1995. The stock status of GOM winter flounder is somewhat unique among GOM groundfish stocks, as it is currently at a relatively high stock biomass and apparently subject to relatively low fishing mortality. The recent spatial distribution of commercial landings and survey catches indicates that most of the recent stock rebuilding has taken place off the Massachusetts coast, with little evidence of rebuilding off the Maine coast. This situation may be attributed to the restrictive regulations imposed in recent years in the areas where much of the current biomass is concentrated (e.g. area closures and gear and vessel restrictions in statistical areas 513 and 514).

The GOM winter flounder VPA, like the SNE-MA analysis, exhibits a retrospective pattern of underestimating fishing mortality (averaging 56%) and overestimating SSB (averaging 92%) during the period 1993-1998. The observed retrospective pattern is likely caused by under-reporting or under-estimating the catch. The SARC concluded that, while the GOM winter flounder VPA provides uncertain estimates of current F and SSB, it provides a better determination of stock status than would reliance on survey indices alone.

As this is a new, benchmark analytical assessment for GOM winter flounder, biological reference points based on the analytical results have been estimated for the first time. The SARC discussed options for the analyses to be used as the basis for defining overfishing. It was noted that the ASMFC Winter Flounder Technical Committee preferred the empirical non-parametric approach, based on concerns over the relatively high stock resilience (i.e. relatively high estimates of the model steepness parameter, and therefore the estimated F_{MSY}) of the stock inferred from the stock-recruitment models. The SARC agreed with the Technical Committee's conclusion to reject the Ricker stock-recruitment model estimates of reference points, based on: 1) the lack of evidence of population dynamics (e.g. cannibalism, high degree of spatial interference among adults and recruits) that would justify a high degree of density-dependent compensation in recruitment; and 2) the lack of VPA or hindcast stock-recruitment estimates at biomass levels where there might be such compensation. The SARC concluded that the Beverton-Holt stock-recruitment model provided reasonable reference points for the stock, and recommended that they be adopted as the basis for the ASMFC and NEFSC FMP overfishing definitions.

SOURCES OF UNCERTAINTY

1) Stock-specific landings data for 1994 and later are derived by proration from Vessel Trip Report data and are considered provisional.

2) The lack of a long time series of survey coverage in inshore New Hampshire and Maine waters, where winter flounder are abundant, is a source of uncertainty. The small number of survey tows in inshore Massachusetts strata in the NEFSC survey results in uncertainty in the index.

3) Length frequency sampling intensity of the commercial and recreational fishery landings has been low in some recent years, and likely increases the uncertainty of the estimated landings at age.

4) Observer sampling intensity of the commercial trawl fishery has been low. Shrimp fishery discard sampling has been discontinued in recent years. Commercial fishery discard estimates are based on rates provided by fishers in the Vessel Trip Reports, owing to inadequate Fishery Observer sampling.

5) Scales and otoliths collected by the MADMF fall survey are not aged. In addition, the MADMF 2002 spring survey scales and otoliths were not aged, which likely resulted in an underestimation of the high incoming recruitment evident from the length frequency distributions in the Fall 2000 and Spring 2002 surveys.

6) Differences in the age at maturity between the MADMF and NEFSC spring surveys are a source of uncertainty.

7) The Gulf of Maine winter flounder VPA exhibits a retrospective pattern of underestimating F from 1993 to 1998 and overestimating SSB during the late 1990s.

RESEARCH RECOMMENDATIONS

New

1) The MADMF fall survey does collect winter flounder otoliths and scales, so ageing such material should be undertaken.

2) Increase the number of tows and/or consistently sample inshore strata in the NEFSC bottom trawl survey.

3) Increase MRFSS length sampling intensity in the recreational fishery.

4) Increase temporal and market category coverage of length sampling in the commercial landings.

5) Increase the intensity of observer sampling especially with small- and large-mesh trawl gear.

6) Examine the sources of discrepancy between NEFSC and MA survey maturity estimates.

7) Initiate periodic maturity staging workshops, involving State and NEFSC trawl survey staff.

8) Incorporate the results from the MEDMR research trawl survey (begun in 2001) into the assessment as they become available.

9) Investigate derivation of stock-specific parameters for the next assessment.

10) Attempt use of a forward projection (statistical catch at age model) in the next assessment.

Old

1) Examine the implications of anthropogenic mortalities caused by pollution and power plant entrainment in estimating yield per recruit, if feasible.

2) Examine growth variations within the Gulf of Maine, using results from the Gulf of Maine Biological Sampling Survey (1993-1994).

3) Further examine the stock boundaries to determine if Bay of Fundy winter flounder should be included in the Gulf of Maine stock complex.

Old: completed

1) Process archived age samples from NEFSC surveys and commercial landings, and develop an analytical age based assessment.

2) Estimate biological reference points for Gulf of Maine winter flounder.

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