A2. CAPE COD – GULF OF MAINE YELLOWTAIL FLOUNDER

INTRODUCTION

Yellowtail flounder, *Limanda ferruginea,* inhabit the continental shelf of the northwest Atlantic from Labrador to Chesapeake Bay (Bigelow and Schroeder 1953, Collette and Klein-MacPhee 2002). Off the U.S. coast, commercially important concentrations are found on Georges Bank, off southern New England, and off Cape Cod (statistical areas 514 and 521; Figure A2.1). Cape Cod yellowtail inhabit shallow water (10-60 m) relative to offshore yellowtail stocks (Lux 1964). Spawning occurs during spring and summer, peaking in late May. Larvae are pelagic for a month or more, then develop demersal form and settle to the bottom. Yellowtail flounder on the Cape Cod grounds generally mature at age-3 (O'Brien et al. 1993) and grow to 58 cm total length.

A New England fishery for yellowtail flounder developed in the 1930s, coincident with a decline in winter flounder abundance, and the fishery expanded from southern New England to Georges bank and the Cape Cod grounds in the late 1930s and early 1940s (Royce et al. 1959, Lux 1964). On the Cape Cod grounds, yellowtail are generally caught in multi-species groundfish fisheries (principally by otter trawls) from late fall to spring, with some landings by gillnets in the winter and spring, but may also be specifically targeted in certain seasons (Royce et al. 1959).

Historically, landings from the Cape Cod grounds were a small portion of the total U.S. yellowtail landings. However, during the collapse of Georges Bank and southern New England stocks in the early 1990s (NEFSC 1994), the Cape Cod stock was the most productive of the U.S. yellowtail stocks (Overholtz and Cadrin 1998).

The available information on yellowtail flounder stock structure off the northeast U.S. indicates separate stocks on Georges Bank, off Cape Cod, and from southern New England to the Mid-Atlantic Bight. Distributional analyses indicate a relatively continuous distribution from the Mid Atlantic Bight to Nantucket Shoals, a concentration on Georges Bank, and a relatively separate concentration off Cape Cod (Royce et al. 1959). Geographic variation indicates that yellowtail off Cape Cod comprise a separate phenotypic stock than resources to the south (Begg et al. 1999). Tagging data indicate low dispersion from Cape Cod, Georges Bank and southern New England fishing grounds (Royce et al. 1959, Lux 1963). Descriptive information on early life history stages and circulation patterns suggest that yellowtail spawn in hydrographic retention areas, but there may be some advection of eggs and larvae from Georges Bank and Cape Cod to southern New England and the Mid Atlantic Bight (Sinclair 1988). In summary, yellowtail on the Cape Cod grounds can be considered a separate phenotypic stock (with some question on the northern boundary of the stock area). There is little evidence supporting separate stocks on the Cape Cod grounds and in the northern Gulf of Maine.

Management History

Over the past 25 years, the fishery for yellowtail flounder in federal waters has been managed under several regimes. From 1971 to 1976, national quotas were allocated by the International Commission for Northwest Atlantic Fisheries. From 1977 to 1982, the New England Fishery Management Council Atlantic Groundfish Fishery Management Plan established optimum yield thresholds for yellowtail west of 69^{o} longitude (which included Cape Cod and southern New England yellowtail stocks) and imposed minimum mesh size, spawning closures, and trip limits (Table A2.1). In 1982, the Council adopted an Interim Groundfish Plan, which established a minimum size limit of 28 cm (11 in) and a minimum mesh size of 130 mm (5 1/8"; with exemptions). In 1983, the minimum mesh size was increased to 140 mm (5.5"; with exemptions) 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 #4 to the Plan further increased the minimum legal size to 33 cm (13 in) in 1989. In 1993, finfish exclusion devices were required in the northern shrimp fishery to reduce groundfish bycatch. Amendments #5, #6, and #7 (1994-1996), limited days at sea, closed areas year-round, further increased minimum mesh size to 142 mm (6 in diamond or square; with fewer exemptions), imposed trip limits for groundfish bycatch in the sea scallop fishery, and prohibited small-mesh fisheries from landing groundfish. Framework #25 was an annual adjustment to the Multispecies Plan which prohibited bottom trawling in two areas of yellowtail habitat on the Cape Cod grounds in 1998: Massachusetts Bay was closed in March, and the waters off Cape Ann were closed in April. Other sections of the western Gulf of Maine were closed in May and June. The 'western Gulf of Maine closure' is too deep to protect yellowtail flounder. Amendment #9 was adopted in 1998 to revise the overfishing definition according to Sustainable Fisheries Act requirements. In 1999, minimum twine top mesh of scallop dredges was increased from 203mm to 254mm to reduce yellowtail bycatch.

The portion of the Cape Cod yellowtail stock found within the Massachusetts territorial sea is managed by the Massachusetts Division of Marine Fisheries under a suite of management measures. Since 1931, many coastal areas have been closed to bottom trawling year-round (e.g. Winthrop Head to Gloucester), or seasonally (e.g. Boston to Provincetown and Gloucester to New Hampshire). The state has had a succession of more stringent size limits beginning with a 11" minimum size in 1982. The size limit increased to 12" in 1986 and then to 13" in 1988. In 1986, 5" mesh codends were required for trawling within the 20 fathom contour in waters north of Cape Cod. In 1986, a winter flounder spawning closure to trawling and gillnetting extending approximately one to two miles from shore was established in waters from the New Hampshire border to Provincetown from February 1 to April 30 (extended to May 31 in 1990). In 1989, small mesh trawling was restricted to permitted fisheries targeting specific species. In 1991, minimum mesh size throughout the net was increased to 5 1/2" north and east of Cape Cod. Since November 1, 1992 a year-round night closure to mobile gear has abbreviated fishing effort by curtailing "trip fishing". Beginning in 1993, a Coastal Access Permit was required to fish mobile gear. The mesh size was increased again in 1994 to 6". A moratorium on new applicants for this permit was enacted in 1994 stemming an increase in effort into state waters. In 1995, the size limit for vessels fishing mobile gear was reduced from 90' registered length to 72' length over all. From 1995-1999, small mesh trawling in state waters north of Cape Cod was limited to an experimental whiting fishery with drastic ground gear modifications for bycatch reduction, prohibitions on groundfish retention and intensive sea sampling. Scallop dredge fisheries have been limited to 10' combined maximum dredge width since 1990. Gillnet fisheries in Massachusetts have a permit moratorium, 2400' maximum net length, 6" minimum mesh size and seasonally closed areas.

Assessment History

Yellowtail resources on the Cape Cod fishing grounds and in the northern Gulf of Maine have been assessed and managed separately. The Cape Cod yellowtail resource was initially assessed by descriptive summaries of catch, effort, catch samples, survey indices, yield per recruit modeling, and estimates of total mortality rate (Z) from survey and commercial age samples. The stock was more stable than the Georges Bank or southern New England stocks from the 1940s to the 1960s, based on patterns of landings and commercial catch rates (Royce et al. 1959, Lux 1964). However in the early 1970s, effort began to increase, and catch rates began to decline (Parrack 1974). Estimates of fishing mortality rate (F) during the 1970s were at or above the estimated level of maximum yield per recruit (Howe 1975). Although yield remained stable relative to offshore stocks, catch rates were at the lowest levels observed by the late 1970s (Sissenwine et al. 1978). For a brief period in the mid 1970s, the stock appeared to be stable (McBride and Sissenwine 1979). However, by the late 1970s, peak catches produced high mortality rates, the age structure appeared to be truncated, and catch rates continued to decrease (McBride et al. 1980, McBride and Sissenwine 1980, Clark et al. 1981). Despite some indications of good recruitment in early 1980s (McBride and Clark 1983, Clark et al. 1984), landings and relative abundance generally decreased in the 1980s (NEFC 1986). The 1987 year class was dominant and contributed to some rebuilding, however, the most recent descriptive assessment of Cape Cod yellowtail concluded that the stock was overexploited (Rago 1994). An age-based assessment indicated that F was high (>0.7) from 1985 to 1997 and biomass was much less than B_{MSY} (Cadrin et al. 1999). Updated assessments in 1999 and 2000 each indicated a reduction in F in the last year of the assessment (Cadrin and King 2000, Cadrin 2001), but the revised estimate of 1998 F remained high (1.0, Cadrin 2001). An updated assessment of the Cape Cod yellowtail flounder stock was prepared concurrently with this assessment for the Groundfish Assessment Review Meeting (Cadrin and King 2002).

Yellowtail flounder in the northern Gulf of Maine have not been analytically assessed. Royce et al. (1959) compiled yellowtail landings statistics for the scattered shoals in the northern Gulf of Maine in the 1940s, and Lux (1964) updated landings statistics through 1961. McBride and Sissenwine (1980) reported a substantial increase in yellowtail flounder landings from the northern Gulf of Maine during the 1970s, and described the sparse survey information available for yellowtail in the northern Gulf of Maine. This assessment combines catch and survey information from the Cape Cod grounds and the northern Gulf of Maine for a single-stock analysis.

FISHERY DATA

Commercial Landings

Commercial statistics for Cape Cod yellowtail flounder are from statistical areas 514 and 521, and northern Gulf of Maine yellowtail are from statistical areas 511, 512, 513 and 515 (Figure A2.1). U.S. commercial landings of yellowtail flounder were derived from dealer weighout reports and canvas data according to historical assessment reports (Royce et al. 1959, Lux 1964, Sissenwine et al. 1978, McBride et al. 1980, McBride and Clark 1983, NEFC 1986). Previous to 1994, landings were allocated to statistical area, month, and gear type according to interview data collected by port agents (Burns et al. 1983). For 1994, landings reported by dealers were allocated to stock area using fishing vessel logbook data, by fishing gear, port, and season (Wigley, et al. 1998). For 1995-1997, dealers' reported landings were prorated to stock area using a modified proration that included dealer codes (NEFSC 1998).

Annual landings generally increased from less than 1,000mt in the mid 1930s to a peak of 5,600mt in 1980 (Table A2.2, Figure A2.2). Landings decreased to approximately 1,200mt per year in the late 1980s, but peaked again in 1990 at 3,200mt with recruitment of the strong 1987 yearclass. Landings decreased to 800mt in 1993 and remained low through the 1990s, but rapidly increased to greater than 2,400mt in 2000 and 2001.

Landings at age of Cape Cod yellowtail flounder are described in Cadrin et al. (1999), Cadrin and King (2000, 2002) and Cadrin (2001), and sample sizes are reported in Table A2.3. Very few port samples are available for the northern Gulf of Maine yellowtail fishery (six samples from 1969, 1976, 1983, 1987, 1988 and 1991), and all market categories were not sampled in any year. Therefore, the age distribution of Cape Cod yellowtail landings, by half and market category, were assumed for northern Gulf of Maine landings. Landings at age, by region, are listed in Table A2.4.

Discarded Catch

Discards were estimated using discard to kept observations from 1989-2001 sea sampling for the trawl and gillnet fisheries and discard per effort for the shrimp and scallop fisheries as described in Cadrin et al. (1999). Discards at age of Cape Cod yellowtail flounder for 1985-1997 are described in Cadrin et al. (1999), and for 1998-2001 by Cadrin and King 2002 (Table A2.5a). Discards for the northern Gulf of Maine averaged 38% of Gulf of Maine yellowtail landings, primarily from the trawl fishery and the shrimp fishery prior to the Nordmore grate requirement in 1993 (Table A2.5b). Discards for 1985-1988 were approximated by assuming a 38% annual discard ratio.

Discards at age of Cape Cod yellowtail flounder are described in Cadrin et al. (1999) and Cadrin and King (2002; Table A2.6a). Discards at age for yellowtail in the northern Gulf of Maine were estimated using length observations from sea sampling (Table A2.6b; using pooled-year samples by half and gear for unsampled discards) and survey age-length keys for 1989-2001, by half-year. The proportion discard at age from the Cape Cod grounds were assumed for 1985-1988 discards in the northern Gulf of Maine. Total catch at age is dominated by age-3 and indicates a strong 1987 yearclass (Appendix A,

Figure A2.3). Mean weight at age of catch was relatively stable from 1985 to 1996, but has increased for ages 2+ in recent years (Figure A2.4).

ABUNDANCE AND BIOMASS INDICES

Stock Abundance and Biomass Indices

NEFSC survey strata for the Cape Cod grounds are offshore strata 25-27 and inshore strata 56-66 and strata for the northern Gulf of Maine are offshore strata 39 and 40 (Figure A2.5). The NEFSC spring and autumn bottom trawl surveys have sampled offshore strata since 1963 and 1968, respectively (Despres et al. 1988). However, sampling of inshore strata north of Cape Cod began in 1977. Yellowtail are consistently sampled in offshore stratum 27 by the spring survey, but were only caught in 4 years since 1963 by the fall survey. Therefore, the spring index includes offshore stratum 27, but the fall survey does not.

Survey biomass indices are somewhat noisy, but generally indicate high biomass in the late 1970s and early 1980s, a decline in the 1980s and a rapid increase in the late 1990s (Figure A2.6). The rapid increases in fall 1999 or spring 2000 do not appear to result from strong recruitment, because catches of all ages increased. Large survey catches were distributed throughout Cape Cod and Massachusetts Bays, Stellwagen Bank and Jeffreys Ledge (Figure A2.7).

The portion of survey biomass from northern Gulf of Maine is variable, but averages 11% throughout the survey time series (Figure A2.8). There appears to have been low abundance of yellowtail in the northern Gulf of Maine during the late 1960s, early 1970s, and middle 1980s. Age distribution of survey catches are potted in Figure A2.9 and listed in Table A2.8.

Correspondence among survey indices was assessed using correlations among normalized observations [Ln(x/mean); Table A2.7]. Correlations among survey series were weak to moderate with strongest correlations among indices for ages 2-4 (r=0.12 to 0.69). Normalized indices of catch per tow at age are illustrated in Figure A2.10.

MORTALITY AND STOCK SIZE

Virtual Population Analysis

Estimates of abundance from virtual population analysis of catch at age-1 to age-5+, 1985-2001, were calibrated using an ADAPT algorithm (Gavaris 1988) that estimated age 2-4 survivors in 2002 and survey catchability coefficients (q) using nonlinear least squares of survey observation errors. Abundance at age was calibrated with survey indices of abundance: spring and winter survey indices (age-1 to age-5+) were calibrated to January abundance, and fall survey indices (age-1 to age-4+) were calibrated to abundance for January of the next year. The instantaneous rate of natural mortality (M) was assumed to be 0.2 based on tag returns (Lux 1969), relationships of Z to effort

(Brown and Hennemuth 1971), and the oldest individual sampled in the stock area (age-14). Although catches of yellowtail older than age-8 are rare in commercial or research catches, the stock has been heavily exploited for seven decades. Maturity at age for Cape Cod yellowtail flounder was reported by O'Brien et al. (1993) from 1985-1990 NEFSC spring survey samples. Model Residuals are plotted in Figure A2.11.

Results indicate that F on ages 3+ decreased from a peak of 1.3 in 1988 to 0.28 in 1993, then increased to an annual average of 0.61 from 1995 to 2000 and was 0.75 in 2001 (Table A2.9, Figure A2.12). With the exception of the strong 1987 year class (29 million at age-1), recruitment has been stable, averaging 10 million at age 1. However, early indications are that the 2000 yearclass is well below average. Spawning biomass averaged 1,000mt during the late 1980s increased to a peak of 3,800mt in 1991 as the 1987 cohort matured, decreased to 1,600mt in 1998, and gradually increased to 3,200 mt in 2001. Retrospective analysis indicates a pattern of underestimating F, and overestimating SSB in the last five years (Figure A2.13).

Bootstrap analysis indicates that abundance estimates in 2002 were estimated with moderate precision (CVs=0.26-0.51). The 80% confidence limit for 2001 F is 0.59-0.95, and the 80% confidence limit for 2001 SSB is 2,500-4,000mt.

Biological Reference Points

Yield and biomass per recruit were calculated assuming the observed partial recruitment and mean weight at age for 1994-2001 (Thompson and Bell 1934). Results are reported in Table A2.10 and shown in Figure A2.14. A comparison of recently observed age distributions with the age distribution expected at $F_{40\%}$ shows a relative truncation in current age structure (Figure A2.15). Applying the approach used to estimate MSY proxies for Cape Cod yellowtail (NEFSC 2002), F_{MSY} is approximated as $F_{40\%MSP}$ (0.17). The SSB_{MSY} proxy is 12,600mt, calculated as the product of 40%MSP (1.192kg spawning biomass) and average recruitment (10.5 million). The MSY proxy is 2,300mt, derived as the product of yield per recruit at $F_{40\%MSP}$ (0.213kg) and average recruitment.

Projections

Stochastic projections at 85% of status quo F in 2002 and F=0.03 for 2003-2009 there is a 50% probability of rebuilding to SSB_{MSY} by 2009 (Appendix A, Figure A2.16). However, retrospective patterns indicate that projections may be optimistic.

WORKING GROUP DISCUSSION

Stock Structure

The WG reviewed seven working papers/presentations on yellowtail stock structure. With respect to spatiotemporal patterns of abundance, the WG noted that recruitment trends of Cape Cod and southern New England yellowtail indicated possible autocorrelation, as evidenced by a common series of several years of poor recruitment that might be indicative of a common stock. The WG noted that historical tagging data indicate weak movement between the Cape Cod, Georges Bank, and other areas, but strong mixing between Mid Atlantic and southern New England areas, that might be indicative of a common Mid Atlantic-southern New England stock. The WG noted limited evidence in the literature to separate Gulf of Maine fish from the Cape Cod stock. The WG supported the major conclusion of working paper A1 that information available from the literature indicates separate yellowtail flounder stocks on Georges Bank, off Cape Cod, and in the Southern New England-Mid Atlantic Bight area.

The Working Group reviewed the evidence available in the scientific literature for different assumptions about yellowtail flounder stock structure based on 1) geographic distribution of the fish and fishing patterns, 2) geographic variation of genetics, life history patterns, recruitment, and morphology, 3) movements and migration of ichthyoplankton and juvenile/adult fish, and 4) previous Amulti-approach@ assessments which considered many of these factors in developing stock structure assumptions for assessment. Geographic analyses indicate a relatively continuous distribution of yellowtail flounder from the Mid Atlantic Bight to Nantucket Shoals, a concentration on Georges Bank, and a relatively separate concentration off Cape Cod. Geographic variation in life history parameters indicates that yellowtail off Cape Cod comprise a separate phenotypic stock than resources to the south. Historical tagging data indicate less than 3% dispersion from Cape Cod, Georges Bank and southern New England fishing grounds. Descriptive information on early life history stages and circulation patterns suggest that yellowtail spawn in hydrographic retention areas, but that there may be some advection of eggs and larvae from Georges Bank and Cape Cod to Southern New England and the Mid Atlantic Bight.

The Working Group reviewed spatiotemporal patterns in the abundance of yellowtail for evidence of stock structure. The overwhelming pattern indicated by cluster analysis was a difference between northern and southern survey strata, with southern strata having peaks of abundance in the early and late 1980s and northern strata having a general increase abundance increasing in northern strata during the 1990s and having no trend in southern strata. The boundary between the two major clusters is between southwestern Georges Bank and Nantucket Shoals, particularly the southwestern part, where survey catches reflect both southern and northern peaks in abundance. The WG noted that the GIS and multivariate analyses did not provide strong evidence for separation of the CC and GOM stocks. The WG supported the major conclusions that 1) there are two major groups of NEFSC survey strata based on patterns of abundance over time, with a boundary on southwestern GB (northern: GOM, CC, and GB areas; southern: MA and SNE areas), and 2) the current analyses confirm earlier conclusions of separate Aharvest stocks@ on GB and off SNE. Correlation analysis of survey data generally confirmed the multivariate analysis by stratum. Survey indices and landings were strongly correlated between southern New England and the mid-Atlantic, not correlated between southern New England and Cape Cod or southern New England and Georges bank, and moderately correlated between Georges Bank and Cape Cod.

The Working Group reviewed geographic variation in growth and maturity of yellowtail as the basis for stock structure assumptions, using spatial and multivariate statistical analyses. A nineteen-year time series of NEFSC survey observations was analyzed to investigate patterns of variation in nine life history variables (male mean length at ages 2-4, female mean length at ages 2-4, male maturity at age-2, and female maturity at ages 2 and 3) among survey strata. Life history characters are strongly correlated and vary significantly among stock areas as well as 5-year time periods. The major pattern of variance was faster growth and maturation in southern stocks (GB, SNE, and MA) and slower growth and maturation in northern stocks (Scotian Shelf and CC). Life history characters are generally homogeneous within the southern areas and within the northern areas, with some intermediate observations in the CC area. One survey stratum east of Cape Cod was identified that had life history observations that were consistently more similar to observations in SNE than to other observations in the Cape Cod area. The WG supported the major conclusion that geographic patterns of variation in size at age and proportion mature at age indicate two phenotypic stocks of yellowtail flounder off the northeastern United States, with a boundary east of Cape Cod.

The Working Group reviewed information on morphometric (fish body measurement) variation of yellowtail flounder as the basis for stock structure assumptions, using image analysis and multivariate statistical analysis. Significant morphometric variation was found between sexes of yellowtail flounder and among eight geographic areas, from the Grand Bank to the Mid-Atlantic Bight. Yellowtail sampled off Newfoundland had relatively shorter bodies than those from south of Nova Scotia. Extrinsic classification accuracy of males and females to the correct Canadian area was 71-95%, but was lower for areas off the northeastern United States (43-76%). Females had relatively deeper abdomens and larger heads than males.

The WG noted that previous investigators (e.g., Lux 1963) found no significant differences in meristics (e.g., fin and ray counts) among U.S. stocks, supporting the current morphometric work. The WG also noted that the results of the morphometric work coincides with the differences in growth noted between U.S. and Newfoundland stocks. The WG supported the conclusion that morphometric variation among U.S. yellowtail flounder groups is not sufficient for accurate classification to stock area.

The Working Group reviewed an exploratory analysis of patterns of yellowtail larval drift for evidence of stock structure. Changes in the geographic distribution of yellowtail flounder eggs and larvae over the course of the spawning season suggest broad-scale larval drift. Evidence of similar distributional changes from the location of the spawners to that of the eggs, however, is confounded by limitations in survey timing. The WG supported the conclusion of working paper A4 that qualitative spatial analyses indicate a general southwesterly movement of yellowtail flounder larvae along the continental shelf of the northeastern United States.

The Working Group reviewed genetic analyses that attempted to find evidence for yellowtail flounder stock structure. The objective of this work is to define stocks based on genetic markers, using methods (RAPD-PCR) which can resolve DNA Afingerprints@ from the sampled muscle tissue of individual fish. Frequency patterns of DNA Abanding@ are obtained which are examined for differences between fish from the MA, SNE, GB, CC, and GOM stocks. Results for two DNA primers, which provided 28 characteristic bands, provided no evidence of extensive population structure for yellowtail flounder sampled from the MA to GOM areas. Future work will attempt to use other methods, such as the examination of nuclear and/or mitochondrial DNA, to look for differences among groups of yellowtail flounder.

The WG noted that the number of migrants per generation between the yellowtail stock areas, although probably low, is likely sufficient to prevent detection of significant genetic differences using RAPD-PCR. The WG noted that the expression of phenotypic differences may not be evident in the genome, or may be very difficult to detect (many different primers may have to be tested to find one that isolates the gene responsible for a given phenotypic expression). The WG supported the conclusion of presentation A6 that, at this time, yellowtail flounder stock differentiation must be based on factors other than genetics.

The current work reviewed by the WG indicates no genetic difference among yellowtail flounder on U.S. fishing grounds. Patterns over time in landings and survey indices suggest two harvest stocks with a boundary between Georges Bank and Southern New England. Differences in life history characteristics suggest two phenotypic stocks with a boundary off Cape Cod. The WG noted that the most important potential Amisalignments@ with respect to current or proposed stock definitions are in areas 521, 525, and 526 (and associated NEFSC survey strata 10, 13 and 25), where fish from adjacent stocks may overlap during times of abundance. However, the WG found no strong evidence in patterns of fishery landings, survey abundance indices, or life history parameters to suggest that revision of the current assignment to stock areas of these particular statistical areas or survey strata is appropriate. Further, the WG did not find significant justification for the inclusion of fish caught in area 4 (i.e., Canadian landings) to the CC-GOM stock. The WG concluded that current evidence indicates that three stock areas are appropriate for yellowtail flounder: 1) a GB stock including fish landed from NEFSC statistical areas 522, 525, 551-552, and 561-562, and associated NEFSC survey strata (i.e., the current stock definition used in U.S. and Canadian assessments), 2) a SNE-MA stock including fish landed from areas 526, 533-539, 541, and 611-639, and associated NEFSC survey strata, and 3) a CC-GOM stock including fish landed from areas 511-521, and associated NEFSC survey strata. Finally, the WG recommends that assessment scientists explore the potential to classify yellowtail in fishery and survey samples to stock in the Aoverlap/transition@ areas based on age structure characteristics.

<u>Stock Assessment</u>
The Working group discussed the sharp increase in catch and survey indices from 1999 to 2001. The Group speculated that rolling closures may have increased both survey and fishery catchability. Surrounding closures may have redirected effort onto Stellwagen Bank. The Group noted that sharp increases also occurred in historic landings (Figure A2.2).

The Working Group noted that sampling improved since last assessment, with samples in each market category and season. The mean weight at ages 3-5 increased in the catch.

The Group considered the possibility that mean weights were poorly estimated in early part of time series when sampling coverage was poor. Therefore, the Group agreed that as many years as possible should be included to derive the mean weights and partial recruitment at age for reference point estimation and projections.

The Working group agreed to revise the calibration configuration from previous assessments by including all age 5 and 6+ indices. The change was made to reduce the substantial positive bias in the age-5 abundance estimate when those indices were excluded.

The Working Group was concerned that projections may not be reliable because of retrospective error. They noted that retrospective inconsistencies are worst for older ages, but could not determine if the source of the errors was in the catch data or assumptions such as M or F on the oldest age. Although estimates from the assessment are imprecise and perhaps biased, the Group concluded that F is high. The truncated age structure in the surveys and catch confirm that mortality is high.

Despite the high F, stock size appears to be increasing. However, the same impression was given by recent assessments, only to have stock size estimates decrease when the assessments were updated. The Group noted that the problems in the assessment may result from the relatively short time series of catch at age and little contrast in the data.

The Group investigated the possibility that older fish are moving from the fishing and survey areas, giving the false impression of high mortality. Size distributions from the longest time series of survey data (fall survey, offshore strata 25, 26, 39 and 40; Figure A2.17) show that larger fish were sampled in the assessment strata in the 1960s, but recent length distributions are considerably smaller. More large fish were also sampled in the earliest years of the Massachusetts survey (Figure A2.18). The Gulf of Maine summer survey, which sampled the inshore strata of the western Gulf of Maine (1977-1981, inshore strata 68-90; Figure A2.19) caught a similar size distribution of yellowtail as the assessment strata. Survey catches in the central and eastern Gulf of Maine also caught a similar size distribution of yellowtail as the assessment strata (Figure A2.20), but inconsistently and at much lower densities than those in the assessment strata (e.g., since 1963, yellowtail were only caught twice in stratum 28, six surveys in stratum 29, six surveys in stratum 37 and once in stratum 38). Therefore, the assessment strata appear to reflect the size distribution throughout the Gulf of Maine, and no large yellowtail were sampled anywhere in the Gulf of Maine in recent years.

SARC DISCUSSION

The original ADAPT run used age 1-6+ catch at age formulation and exhibited a severe retrospective pattern for SSB and F. A comparison of ADAPT retrospective patterns from Cape Cod-Gulf of Maine and Cape Cod only exhibited little difference. The low numbers of age 5 in the catch and surveys did not appear to be sufficient to reliably estimate F on age 5. The GARM noted that the high F seems inconsistent with level or increasing SSB and increasing survey indices. A lot of discussion centered on how this could be possible, without a consensus regarding cause. It was suggested that the high F means that the tuning is actually only working on the oldest age group. Similarly, the estimated catchabilities increase without reaching an asymptote with increasing age. Also, the SARC observed that $F_{(4\text{-}5)}$ may not be a good estimator of F on the population since a large portion of the catch is age-3

As a result, an alternate ADAPT run which truncated the catch at age to age-5^{+} was considered. Estimation of abundance for the truncated catch at age required that age 3 be considered fully recruited for calculation of F on the oldest true age. The alternate Adapt run reduced the magnitude of the retrospective patterns for fully recruited F and spawning biomass. The results revealed a high sensitivity to the calibration change. The fully recruited F decreased while spawning stock biomass increased.

Including a flat-topped selectivity pattern at age 3+ could mask high F's at true fully recruited ages. The original formulation, which estimated F on age 3, suggested that age 3 yellowtail were partially recruited. A comparison of observed length distribution at age-3 and length selectivity at various mesh sizes indicated only partial retention of age-3 yellowtail. However, mesh selectivity is only one component of fishery selectivity and other factors, such as temporal-spatial elements of the fishery, also influence fishery selectivity. In addition, the mean weights of a plus group at age-5 and older may be difficult to characterize because they continue to grow substantially after age 5.

Age determination does not seem to be a problem with this stock, especially for the young ages in the catch. However, the sampling of catch could be causing a problem, particularly in the Gulf of Maine. The lack of contrast in the VPA time series may lead to imprecise estimate of survey catchability. The time series begins in 1985 due to few commercial samples prior to 1985.

The possibility of contributions from the Georges Bank and/or Southern New England stocks of yellowtail flounder to the Cape Cod-Gulf of Maine stock was discussed in terms of both adult movement and recruitment impacts. Given the relative sizes of the stocks, especially the Georges Bank and Cape Cod stocks, any transfer among stocks could overwhelm the signal from Cape Cod.

The revised ADAPT formulation, which uses average fully recruited F on ages 3 and 4 required re-estimating yield per recruit and biological reference points. Several concerns about including the partially recruited age 3 in the average of fully recruited F were raised. However, the YPR and biological reference points were re-estimated using age 3 as fully recruited in order to be consistent with the revised Adapt configuration.

An examination of stock-recruit observations for Cape Cod-Gulf of Maine yellowtail and fishing mortality rates at various levels of replacement suggests that the stock can replace itself at F greater than $F_{40\%}$ (i.e.$F_{med} > F_{40\%\ MSP}$) and $F_{40\%}$ may be a conservative proxy for $F_{MSY.}$ However, extrapolating recruitment at high stock sizes from the VPA time series may overestimate productivity of the stock at higher SSB. The stock recruitment relationship is similar to the Georges Bank stock prior to recovery, in that most stock recruitment points were above the $F_{40\%}$ replacement line. This suggests that a short-term perspective of the stock recruitment relationship may not represent the potential productivity of the Cape Cod-Gulf of Maine stock. The SARC concluded that there is currently no justification for changing the$F_{40\%}$ reference point.

<u>Sources of Uncertainty</u>

- Very few length samples were available from the relatively small Gulf of Maine catch.
- There was an apparent increase in survey availability in Fall 1999 and Spring 2000 surveys. These recent observations have a large influence on the ADAPT calibration.
- Relative yearclass strengths are not tracked well over time by the surveys, indicating that survey availability has been variable throughout the time series.
- Spawning stock biomass calculations are based on a constant maturity at age assumption. Changes in maturity at age have not been investigated.
- The degree of mixing between Cape Cod-Gulf of Maine yellowtail and adjacent stocks is not precisely known. Substantial mixing may confound population estimates.
- Estimation of the very small 2000 year class may change in future assessments. Previous estimates of recruitment in the most recent year have changed substantially as assessments were updated.
- Lack of contrast in the recruitment time series limits the perception of $SSB_{MSY.}$

<u>Research Recommendations</u>

- Tagging studies should be planned to examine movements and to independently estimate F. Early tagging studies may have been conducted during different temperature regimes.
- Commercial length and age samples from the Gulf of Maine region are needed.
- The use of parametric models to estimate MSY based reference points should be explored.
- Consider using a forward-projection statistical catch at age model.
- Incorporate the State of Maine inshore survey data in the assessment.
- Alternative indices of abundance should be explored, such as industry surveys, study fleets, and a flatfish survey.
- Increase observer sampling on the exempted whiting fishery, particularly to confirm low bycatch observations for the recently required raised footrope.
- Sample inshore NEFSC survey strata more consistently.
- Continue investigation of geographic patterns in sex ratios and maturity at age. Evaluate possible revisions of survey sampling and data processing protocol to obtain abundance indices by sex.
- Evaluate information on dimorphic growth rates.
- Explore stock identification techniques for additional information on stock boundaries and rates of movement among stock areas.
- Unique gear codes for small-mesh fisheries (similar to negear=058 or gearcode='OTS' for shrimp trawls) would greatly benefit estimation of discards.

- Continue processing archived age samples from MADMF surveys to eliminate using NEFSC age keys as noted and process NEFSC observer age samples.
- Revise historical small-mesh discard estimates so that the shrimp and whiting fisheries are treated separately.
- Investigate information available on discard mortality of yellowtail flounder.
- Explore post-stratification of survey data in NEFSC stratum 24 and inshore strata.

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