A. Goosefish (Monkfish)

Southern Demersal Working Group (WG) Meeting

The Southern Demersal Working Group met during October 25 - 27, 2004 at the Northeast Fisheries Science Center, Woods Hole. MA, USA, with the following participants:

Jay Burnett	NEFSC
Jon Brodziak	NEFSC
Matt Cieri	MEDMR
Allison Ferreira	NERO
Phil Haring	NEFMC
Jay Hermsen	NERO
Kathy Lang	NEFSC
Chris Legault	NEFSC
Paul Nitschke	NEFSC
Anne Richards	NEFSC (lead)
Kathy Sosebee	NEFSC
Mark Terceiro	NEFSC (chair)
Michele Traver	NEFSC

Goosefish / Monkfish Terms of Reference

1. Review results of the 2004 Cooperative Monkfish Survey; make comparison to the results of the 2001 survey.

WG Response: Given the late finish of the 2004 cooperative survey, and the time required for processing the survey data, analysis of the 2004 cooperative survey data is not complete. However, preliminary stock biomass and exploitation rate estimates from the 2004 survey were made and compared to 2001 survey results.

2. Characterize the commercial catch including landings and discards.

WG Response: This TOR was completed. The WG notes that discard estimates for 2001 and later may be subject to further revision.

3. Update other monkfish survey indices *(i.e.,* NEFSC and MADMF indices) and analyses based on those indices.

WG Response: This TOR was completed. The MADMF indices were not updated, as MADMF staff indicated that their indices were of little utility for monkfish due to low catch rates. Therefore the MADMF indices have been dropped from the assessment.

4. Evaluate the current status of the stock assessment units relative to existing reference points.

WG Response: This TOR was completed for the biomass reference point (neither management unit is overfished). The WG noted that the lack of reliable estimates of instantaneous fishing mortality rates precludes evaluation with respect to fishing mortality reference points.

5. Review, evaluate, and report on the status of the SARC/Working Group Research Recommendations offered in the previous SARC-reviewed assessment (i.e., SAW 34 in November 2001).

WG Response: This TOR was completed.

Introduction

Goosefish fisheries are managed in the Exclusive Economic Zone (EEZ) through a joint New England Fishery Management Council - Mid-Atlantic Fishery Management Council Monkfish Fishery Management Plan (FMP). The FMP defines two management areas for monkfish (northern and southern), divided roughly by a line bisecting Georges Bank.

The FMP and its subsequent modifications define monkfish biological reference points as follows:

> Monkfish in the northern and southern management areas are defined as being overfished (below $B_{threshold}$) when the three-year moving average autumn survey weight per tow falls below one half of $B_{target..}$ $B_{target.}$ is defined as the median of the three-year moving average autumn survey weight per tow during 1965-1981. Thus $B_{threshold}$ = 1.25 for the northern management region and =0.93 for the southern management region. For both management areas, $F_{threshold}$ is set equal to F_{max}, currently estimated as F=0.2 (NEFSC 2002). The overfishing definition does not include an F_{target} reference point. Optimum yield is addressed by adjusting annual TACs and trip limits based on how biomass indices compared to annual biomass targets.

Table A1 provides a summary of recent regulatory measures affecting monkfish.

The two assessment and management areas for goosefish (northern and southern) were defined based on differences in temporal patterns of recruitment (NEFSC survey indices for 10-20 cm goosefish), the spatial and temporal distribution of all sizes of goosefish in NEFSC surveys, perceived differences in growth patterns, and differences in the contribution of fishing gear types (mainly trawl, gill net, and dredge) to the landings. NEFSC surveys continue to indicate different recruitment patterns in the two units in the most recent years. The perceived differences in growth were based on studies about 10 years apart and under different stock conditions (Armstrong (1987): Georges Bank to Mid-Atlantic Bight, 1982-1985; Hartley (1995): Gulf of Maine, 1992-1993). Age, growth, and maturity information later available from the NEFSC surveys and the 2001 cooperative monkfish survey indicated only minor differences in age, growth, and maturity between the areas. A genetics study (Chickarmane et al. 2000) indicated no differences among goosefish collected from North Carolina to Maine in depths up to 300 m. There continue to be significant differences in the contribution of different gear types to the landings in the two areas.

The recent biological evidence (growth, maturity, and genetic information) suggests that use of a single stock hypothesis in the assessment might be appropriate. However, substantial differences in the fisheries exist, and current management maintains separate management areas to accommodate these differences.

The research survey strata and statistical areas used to define the northern and southern management regions are as follows:

Survey	Northern Area	Southern Area
NEFSC Offshore bottom trawl	20-30, 34-40	1-19, 61-76
ASMFC Shrimp	1 -12	
Shellfish	49-54, 65-68, 71-72, 651,661	1-48, 55-64, 69-70 73-74, 621, 631
Statistical areas	511-515, 521-523 561	525-526, 562, 537-543, 611-636

The southern deepwater extent of the range of American goosefish (*Lophius americanus*) overlaps with the northern extent of the range of blackfin goosefish (*Lophius gastrophysus*) (Caruso, 1983). These two species are very similar morphologically, and this may create a problem in identification of survey catches and landings from the southern extent of the range of goosefish. The potential for a problem however is believed to be small. The NEFSC closely examined winter and spring 2000 survey catches for the presence of blackfin goosefish and found none. The cooperative goosefish survey conducted in 2001 caught only 8 blackfin goosefish of a total of 6,364 goosefish captured in the southern management region.

The spatial distribution of goosefish catches in winter, spring, and autumn bottom trawl surveys and the summer scallop survey is shown in Figure A1. The winter and scallop surveys do not sample in the Gulf of Maine.

Larval distributions have been inferred from collections by the NEFSC Marine Resources Monitoring, Assessment and Prediction (MARMAP) ichthyoplankton survey (Steimle et al. 1999). Larvae were collected during March-April over deeper (< 300 m) offshore waters of the Mid-Atlantic Bight. Later in the year, they were most abundant across the continental shelf at 30 to 90 m. Larvae were most abundant at integrated water column temperatures between 10-16^{o} C, and peak catches were at 11-15^{o} C regardless of month or area. Relatively few larvae were caught in the northern stock area.

Fishery Data

U.S. Landings

Landings statistics for goosefish are sensitive to conversion from landed weight to live weight, because a substantial fraction of the landings occur as tails only (or other parts). The conversion of landed weight of tails to live weight of goosefish in the NEFSC weigh-out database is made by multiplying landed tail weight by a factor of 3.32.

For 1964 through 1989, there are two potential sources of landings information for goosefish; the NEFSC "weigh-out" database, which consists of fish dealer reports of landings, and the "general canvass" database, which contains landings data collected by NMFS port agents (for ports not included in the weigh-out system) or reported by states not included in the weigh-out system (Table A2). All landings of goosefish are reported in the general canvass data as "unclassified tails." Consequently, some landed weight attributable to livers or whole fish in the canvass data may be inappropriately converted to live weight. This is not an issue for years 1964 through 1981 when only tails were recorded in both databases. However, for years 1982 through 1989, the weigh-out database contains market category information which allows for improved conversions from landed to live weight. The two data sources produce the same trends in landings, with general canvass landings slightly greater than the weigh-out system. It is not known which of the two measures more accurately reflects landings, but the additional data sources argue for use of the general canvass landings for years 1964 through 1981 while market category details available in the weigh-out system argue for use of this database for years 1982 through 1989. Until the mid-1970's, many of the goosefish caught were sold outside of dealers or used for personal consumption, introducing further uncertainty into the early estimates of landings.

Beginning in 1990, most of the extra sources of landings in the general canvass database were incorporated into the NEFSC weigh-out database. However, North Carolina reported landings of goosefish to the Southeast Fisheries Science Center and until 1997 these landings were not added to the NEFSC general canvass database. Since these landings most likely come from the southern management region, they have been added to the weigh-out data for the southern management region for 1977-1997 (TableA2).

Beginning in July 1994, the NEFSC commercial landings data collection system was redesigned to consist of vessel trip reports (VTR data) and dealer weigh-out records. The VTRs include area fished for each trip which is used to apportion dealer-reported landings to statistical areas. Each VTR trip should have a direct match in the dealer data base; however, this is not always true. For data with no matches, we dropped the record if there was a VTR with no dealer landings and retained the record if there were dealer landings but no VTR. For dealer landings with no matching VTR, we apportioned the landings to area using proportions calculated from successfully matched trips pooled over gear, state and quarter.

Total landings (live weight) remained at low levels until the middle 1970s, increasing from hundreds of metric tons to around 6,000 mt in 1978 (Table A2, Figure A2). Landings remained stable at between 8,000-10,000 mt until the late 1980s. Landings increased steadily from the late 1980s to a peak of 28,500 mt in 1997. Landings declined slightly from 1997 through 2000, but have increased since then, to over 26,000 mt in 2003. By region, landings began to increase in the north in the mid-1970s, and began to increase in the south in the late 1970s. Most of the increase in landings during the late 1980s through mid-1990s was from the southern region. Since 1998, landings in the south have declined while landings in the north have increased.

Trawls, scallop dredges and gill nets are the primary gear types that land goosefish (Table A3, Figure A3). During 1998-2000, trawls accounted for 54% of the total landings, scallop dredges about 17%, and gill nets 29%, but during the most recent 3-year period (2001-2003), gillnets increased to 36% and scallop dredges dropped to 8%, while trawls remained essentially constant at 55% of the landings. In recent years trawl landings have been greater in the northern than the southern area, while more scallop dredge and gill net landings have come from the south than from the north.

Until the late 1990s, total landings were dominated by landings of goosefish tails. From 1964 to 1980 landings of tails rose from 19 mt to 2,302 mt, and peaked at 7,191 mt in 1997 (Table A4). Landings of tails declined after 1997, but are still an important component of the landings. Landings of gutted whole fish have increased steadily since the early 1990s and are now the largest market category on a landed-weight basis. On a regional basis, more tails were landed from the northern area than the southern area prior to the late 1970s (Tables A5, A6). From 1979 to 1989, landings of tails were about equal from both regions. In the 1990's, landings of tails from the south predominated, but since 2000, landings of tails have been greater in the north.

Beginning in 1982, several market categories were added to the system (Table A4). Tails were broken down into large (> 2.0 lbs), small (0.5 to 2.0 lbs), and unclassified categories and the liver market category was added. In 1989, unclassified round fish were added, in 1991 peewee tails (<0.5 lbs) and cheeks, in 1992 belly flaps, and in 1993 whole gutted fish were added.

Goosefish livers have become a very valuable product. Landings of livers increased from 10 mt in 1982 to an average of over 600 mt during 1998 - 2000. During 1982-1994, ex-vessel prices for livers rose from an average of $0.97/lb to over $5.00/lb, with seasonal variations as high as $19.00/lb. Landings of unclassified round (whole) or gutted whole fish jumped in 1994 to 2,045 mt and 1,454 mt, respectively; landings of gutted fish continued to increase through 2000. The tonnage of peewee tails landed increased through 1995 to 364 mt and then declined to 153 mt in 1999 and 4 mt in 2000 when the category was essentially eliminated by regulations.

Foreign Landings

Landings (live wt) from NAFO areas 5 and 6 by countries other than the US are shown in Table A2 and Figure A2. Reported landings were high but variable in the 1960s and 1970s with a peak in 1973 of 6,818 mt. Landings were low but variable in the 1980s, declined in the early 1990s, and have generally been below 300 mt in recent years.

Size Composition of U.S. Landings and Catch

Table A7 shows the number of commercial samples taken through the port sampling program for 1996-2003. Length frequencies of the samples taken during 2001-2003 are shown in Figures A4-A6. Tail lengths were converted to total lengths using relations developed by Almeida et. al. (1995).

Length composition data collected by the NEFSC fishery observer program (sea sampling data) were summarized for 1996-2000. Sea sampling data for goosefish were collected aboard trawls, scallop dredges and gill nets (drift and sink). Figures A7 and A8 show length frequency distributions from sea sampling data by major gear type, stock region and year. Discards were generally between 20-40 cm, while kept fish were greater than 40 cm.

Discard Estimates

Catch data from the fishery observer and VTR databases were used to investigate discarding frequencies and rates. The number of tows or trips with goosefish discards available for analysis varied widely among stocks and gear types (Tables A8 and A9). Discard ratios (kg discarded / kg kept) from the two data sources showed similar patterns even though the estimates based on observer data were generally higher than reported in VTRs (Figures A9, A10). Gill nets consistently have had the lowest discard ratios. Discarding has increased in the trawl fishery in recent years, particularly in the south. This may reflect imposition of size limits starting in 2000 and decreased trip limits in the south starting in 2002. In addition, the WG noted a potential bias in discard estimates due to increased observer sampling in the multispecies groundfish fishery. Monkfish discard rates may differ between the directed monkfish fisheries and bycatch fisheries. In the first half of 2001, the high discard ratio stems largely from estimates from the multispecies fishery. The most frequent discard reasons were that fish were too small for regulations or the market, and this may reflect the appearance of a relatively strong 1999 year class in the north. The WG group recommends that in the future, attempts be made to stratify by component of the trawl fishery when estimating discards.

The total amount of goosefish discarded was derived by calculating discard ratios from the observer program on a management region, gear type and half-year basis. We applied the discard ratios to reported landings (live weight, by stock, gear type and half-year cells) to derive metric tons discarded and total catch (Tables A10 and A11, Figure A11). If no sampling data were available for a cell, we applied the overall mean discard ratio for all gears and years. The overall annual discard ratio (Table A11) ranged from 0.07 - 0.96 mt discarded per mt kept. The percentage of the catch discarded has ranged from 6-50%, with the highest rates occurring in 2001.

Catch per Unit Effort by Gear and Depth

Commercial catch per unit effort (CPUE) from the VTR database was examined by gear type in order to determine if a depth effect was present, especially in the deepest waters. Scallop dredge, large and small mesh gill net, and otter trawls were examined separately. Depth zones were categorized in 20 fathom increments starting with 0-20 fathoms (zone 1) and ending with zone

10 (greater than 180 fathoms). Obvious outliers were removed before analysis based on examination of the actual logbooks.

Table A12 presents the number of observations, median CPUE by depth zone and the estimated depth effect from a generalized linear model incorporating year, quarter, vessel ton class and depth zone. Dredge gear does not fish in deep waters and does not show changes in CPUE with depth. Large and small mesh gill nets fish in deeper waters, but do not show a trend in CPUE with depth. In contrast, trawls fish in deep waters and show an increasing trend in CPUE with depth. However, this apparent trend is due to a loss of low CPUE values at greater depths; maximum catch rate is consistent over all depths. Examining only directed trips (trips in which at least half of the catch (kg) was goosefish) removes the apparent trend with depth by removing most of the low catch rates in shallow water (Table A13). Thus catch per unit effort does not appear to have a depth effect associated with any gear. However, the low sample sizes in the deepest water do not allow definite conclusions to be reached.

During the examination of catch rates by depth, it was observed that few trawl trips fall into the directed category, as defined above. Table A14 shows the number of directed and total trips by gear and stock area and the associated landings. Although trawl trips are infrequently directed in both the north and south (6% and 7% of trips respectively) the proportion of catch associated with these trips is much higher in the south (30% north, 74% south). This difference between north and south was not apparent in either gill net fishery.

Research Survey Abundance and Biomass Indices

NEFSC Survey Indices

NEFSC spring and autumn bottom trawl survey indices were standardized to adjust for statistically significant effects of trawl type and vessel on catch rates as noted below. The trawl conversion coefficients apply only to the spring survey during 1973-1981.

Effect	Coefficient	Source
Trawl	Weight: 0.2985	
	Number: 0.4082	Sissenwine and Bowman, 1977
Vessel	Weight: Not significant	NEFSC, 1991
	Number: 0.83	

Northern Region

Indices from NEFSC autumn research trawl surveys indicate that biomass fluctuated without trend between 1963-1975, appears to have increased briefly in the late 1970's, but declined thereafter to near historic lows during the 1990's. In 2000 the index increased to its highest level since 1984 (Table A15, Figure A12). The three year moving average of the biomass index has remained above Bthreshold since 2000 and is currently at 81% of Btarget (Table A35).

Abundance (Table A15, Figure A13) declined during the early 1960s, and then fluctuated without trend until the late 1980s. Abundance increased steadily from the late 1980s to a peak in 1994, declined during the late 1990s, then increased sharply in 2000, reflecting a relatively strong 1999 yearclass (Figure A14). Abundance has declined steadily since 2000, but remains high relative to the earlier part of the time series.

Indices from the NEFSC spring research trawl surveys reflect similar trends of relatively high biomass levels in the mid 1970s (but with possible declines in the late 1970s), a declining trend from the early 1980s to the lowest values in the time series in 1998 and an increasing trend since then (Table A16, Figure A15). As in the autumn survey series, abundance in numbers fluctuated until the early 1980s (Table A16, Figure A16). Since 1996, numbers have trended upwards and reached the highest levels in the time series in 2001-2003.

Length distributions have become increasingly truncated over time (Figure A17). By 1990, fish greater than 60 cm long were uncommon in length frequency distributions. The minimum, mean and maximum lengths in the trawl surveys declined steadily from the early 1980s until around 2000, when they began to increase again (Figure A18).

Several modes potentially representing strong year classes have appeared consistently in survey distributions in recent years. Abundance indices were estimated for goosefish of lengths corresponding to ages 1 and 2 to help identify potential recruitment patterns (Figure A14, Table A17). To the extent that these indices reflect recruitment, recruitment in the northern area has increased in the past decade. Relatively strong year-classes were produced in 1993 and 1999. Survey abundance at age data (available since the mid-1990s) corroborate the suggestion of relatively strong 1993 and 1999 year-classes (Table A18) in the northern area.

Survey age data are available for 1993-2003 from the autumn trawl survey and for 1995-2004 for the spring trawl survey (Table A18). The mean length at age is shown in Table A19 and Figures A19 and A20. Within the range of ages observed in the surveys, growth is essentially linear and there are no obvious differences with gender or stock..

Southern Region

Biomass indices from the NEFSC autumn research survey were high during the mid-1960s, fluctuated around an intermediate level during the 1970s-mid 1980s, then declined to consistently low levels since the late 1980s (Table A20, Figure A21). A slight upward trend has been evident since 2000. The three year moving average of the index exceeded Bthreshold in 2003, and is currently at 50% of Btarget (Table A35). Abundance in numbers shows similar trends, with a spike in 1972, fluctuations around a relatively low level since the mid-1970s and a slight increase in 2002 and 2003 (Figure A22).

NEFSC spring surveys reflect similar trends as the autumn series: biomass remained fairly high during the mid 1970s - early 1980s, but fluctuated around lower levels thereafter (Table A21, Figures A23 and A24). A spike was observed in 2003, but the 2004 index was low again.

Biomass indices based on the NEFSC winter flatfish survey fluctuated without trend during the 1990s, but have remained relatively high since 2001, consistent with autumn survey indices (Table A22, Figure A25). Abundance indices have fluctuated without trend (Table A22, Figure A26). Although the winter survey series has a short duration, the gear used in the winter survey is more effective for capturing monkfish than the gear used in autumn or spring surveys. Age data are available for the winter survey for 1997-2004 (Table A23). The mean length at age for the winter survey samples is similar to mean length at age from NEFSC spring surveys (Figure A20).

Abundance indices based on the NEFSC sea scallop survey show an increasing trend during 1984-1994 followed by a rapid decline from 1994-1998 and fluctuations at a somewhat higher level since then (Table A24, Figure A28). Length distributions from the southern region show increasing truncation over time (Figure A29), which is reflected in declines in minimum, mean and maximum length over time (Figures A30 and A31). Maximum lengths declined by approximately 20 cm or more over the time series.

As in the northern region, fish greater than 60 cm have been rare since the 1980s, especially when compared to the 1960s. Any recent strong recruitment does not appear to survive long enough to contribute substantially to increased stock biomass.

ME-NH Survey Indices

Since 1999, the ME Department of Marine Resources, in conjunction with the state of New Hampshire, has been conducting an inshore trawl survey for groundfish. Surveys are performed each autumn and spring. A total of 5 regional areas are sampled; from the ME Canadian border to the MA/NH border. Each region is then further divided into 5 depth strata: 5-20 fathoms, 20-35 fathoms, 35-55 fathoms, and > 55 fathoms. Surveys utilize a modified shrimp bottom trawl that has 2" mesh with a ½ inch mesh liner in the cod end. The net has a sweep of 4" cookies, 70' footrope, and 59' headrope. A NetMind system is deployed for each tow. Normal protocol is to tow for 20 minutes at ~ 2.5 knots.

Figure A32 shows the distribution of catches for all survey years combined. Length frequency distributions suggest differences between autumn and spring surveys. The spring surveys seem to sample smaller monkfish, a difference which probably reflects growth from spring to fall (Figure A33). The modal size in both seasons approximates age two monkfish. These surveys (particularly the fall) may become useful indicators of recruitment as the time series develop (Figure A34).

Cooperative Goosefish Surveys

Summary of 2001 Cooperative Goosefish Survey

An industry-based survey for goosefish was conducted during Feb 27 - April 6, 2001 using two commercial trawlers fishing concurrently in the northern and southern management regions. The survey used a stratified random design with sampling effort proportional to reported fishing effort during 1995-1999. Additional station locations were assigned by fishermen. The stratum boundaries were those used in NEFSC bottom trawl surveys (defined by depth), with an additional set of strata from Georges Bank south in 100 to 500 fathoms. Standard protocols for tow speed, tow time, scope ratios and biological sampling were followed by each vessel. Experimental tows were made with each of the 3 nets (2 flat nets, 1 rockhopper) to estimate net efficiency and wingspread at a range of depths. Video footage from cameras attached to the net provided no evidence of herding of goosefish by the gear, nor of strong escape responses. Area swept estimates of population size and biomass were derived using tow duration, vessel speed (as recorded by GPS) and wingspread under a range of assumptions regarding net efficiencies.

A total of 284 survey tows were used to estimate goosefish abundance. Swept area biomass and population size were estimated using nominal tow distances for the F/V Mary K and inclinometer distances for the F/V Drake, and assuming intermediate net efficiencies. The resulting estimates were 135 thousand metric tons (69,000 in the north, 66,000 in the south) and 91 million goosefish (53 million in the north, 38 million in the south). Minimum estimates (assuming 100% efficiency of nets and the same tow distance assumptions) were 72 thousand metric tons (33,000 north, 39,000 south) and 48 million goosefish (25 million north, 23 million south). Bootstrapped estimates of the coefficient of variation for these estimates ranged 4-7%.

Biological results included the following:
- growth rates are similar in the northern and southern areas, and between males and females
- sex ratios are length- and age-dependent. Most fish larger than 70 cm and age 7 are females. In the southern area, sex ratios are skewed towards males in the 40-60 cm size range.
-Female maturity (L_{50}) is 40 cm (4.7 years) in the north and 46 cm (5.1 years) in the south (43 cm or 4.8 years, regions combined). Male maturity (L_{50}) is 35 cm (4.1 years) in the north and 37 cm (4.3 years) in the south (36 cm or 4.2 years, regions combined).

2004 Cooperative Goosefish Survey

Methods

The 2004 cooperative monkfish survey was conducted during March 1 - June 20, 2004 using one fishing vessel (F/V Mary K). All survey tows were completed by June 16, 2004. The Mary K was equipped with two nets (flat net and rockhopper) (Figure A35, Tables A25, A26). These were different nets than were used on the 2001 survey; however, they had the same codend mesh size (6 inch stretch mesh) as used in the 2001 survey. The survey stations were the same locations where successful tows were completed during the 2001 cooperative monkfish survey (Figure A36). However, not all stations could be occupied either because of problems with fixed gear or because of severe weather conditions, particularly during March and April. A total of 304 tows were made; 255 of these were successful survey tows (105 north, 150 south). A NetMind gear mensuration system was used to measure wingspread on all tows (only about 15% of tows successfully collected wingspread data). Bottom contact time was recorded using an inclinometer, GPS data were captured from the ship's GPS, and bottom temperature was recorded using a SeaBird SBE temperature and pressure recorder. Survey catches were processed using standard procedures for NEFSC surveys. Biological data were collected electronically using the NEFSC FSCS (Fisheries Scientific Computer System) package.

Gear experiments included depletion experiments and comparative (side-by-side) tows with the two nets. The depletion experiments were used to estimate efficiency of the nets. For each depletion experiment, standard 30 minute tows were repeated along a given tow path until catch rates dropped to near zero or until no further reduction in catches was observed. Four experiments were done with the flat net, one experiment was completed with the rock hopper. Approximately 10 comparison tows were completed.

Provisional area-swept estimates of total biomass and abundance were developed using estimates of net efficiency from the 2001 survey, wingspread estimates from 2004 survey NetMind data, and nominal tow duration for each of the 2004 survey tows. Wingspread for each tow was estimated from relationships between wingspread and depth developed from tows with valid wingspread readings. Inclinometer data were not analyzed in time for the WG meeting; inclinometer data were used in 2001 to refine the estimates of tow duration.

Results – 2004 Cooperative Goosefish Survey

Due to severe weather during the spring, use of only one survey vessel, and the length of time needed for data loading and auditing, survey data were not available for analysis until approximately 2 weeks before the working group meeting. Therefore, only a limited set of results is available at this time, and all results should be considered preliminary as internal data checking (beyond standard audits) and refinement was limited.

Table A27 summarizes the general accomplishments of the survey and compares them to the 2001 cooperative survey.

Biology

Length-weight relationships are similar for males and females and between management regions (Figure A37). In 2001, mature females in the south were heavier at length than males, probably because of the weight of developing egg veils. That pattern was not seen in 2004, possibly because the sampling occurred later in the year in 2004, and many females may have already spawned.

Age-length relationships are similar to those observed in 2001, with growth nearly identical between males and females until age 7, when male growth slows and females continue a linear increase in length up to age 10, the oldest age observed in the surveys (Figure A38). No males older than age 8 were observed in 2001, and no males older than age 7 were observed in 2004. No differences were detectable in mean length at age between management areas (Figure A39).

Goosefish weight at age increases exponentially up through the oldest ages observed in the survey, and does not differ between management areas (Figure A40).

Sex ratio patterns are similar to those observed in 2001, with a roughly 50:50 male:female sex ratio in the north until approximately 60 cm, a rapid decline in the proportion of males greater than 60 cm, and no males greater than about 70 cm. In the south, male:female sex ratios are approximately 50:50 in the 20-40 cm size range, become skewed towards males in the 40-60 cm size range, then decline to zero (100% females) by around 70 cm. The WG examined sex ratios and their spatial distribution in the NEFSC winter surveys during 1999-2004 (southern region) for comparison. The same pattern in sex ratio with length was observed (Figure A41). The spatial distribution of sex ratios for monkfish 50-65 cm showed a preponderance of males in the southern most strata, but no area where females dominated (Figure A42).

Population Estimates

Reliable wingspread measurements were available for 41 tows for the flat net and 6 tows for the rockhopper. A polynomial relation between wingspread and tow depth (Figure A43) was used to estimate wingspread for tows for which the mensuration gear did not operate properly. No wingspread measurements were obtained for the rockhopper net for tows shallower than about 200 m. To derive an estimate of the intercept for the rockhopper, we calculated expected wingspread for each net based on net geometry (expected wingspread=1/2[(headrope+footrope)/2]; H. Milliken, NEFSC personal communication) and added the difference to the intercept for the flat net. We assumed a polynomial relationship would apply to the rockhopper wingspread vs. depth relation, and fit the curve through the observed points and the estimated intercept. The resulting relation (Figure A43) was used to estimate wingspread for the rockhopper tows.

Swept area biomass and population size estimates are given in Table A28. Minimum biomass estimates (assuming 100% efficiency of nets) are 28.5 thousand mt (kt) in the north and 65.9 kt in the south (94.4 kt total). This compares with an estimated total of 71.8 kt in 2001, divided roughly equally between the areas (NEFSC 2002). Minimum population numbers are 14.4 million in the north and 36.6 million in the south (total 51 million). This compares with an estimated minimum number of 47.7 million in 2001 (25 million in the north, 22.6 million in the south). Assuming the ‘intermediate’ net efficiencies estimated for the 2001 survey (flat net = 0.60, rockhopper=0.432) and using nominal tow distances, the biomass estimates are 51.8 kt (north), 109.8 kt (south), and 161.6 kt total. The corresponding population number estimates are 25.7 million fish (north), 61.0 million (south), and 90.9 (areas combined).

The length composition of the population estimated from the cooperative survey (based on minimum population size and proportion at length within stratum) is shown in Figure A44. In the south, most of the population is below the minimum landing size required under the FMP (equivalent to 53 cm total length). Length frequencies from the NEFSC winter survey for 2004 are very similar to the length frequencies derived from the cooperative survey (Figure A45).

Egg Production Indices From NEFSC Survey Length Composition Data

NEFSC survey indices were used to develop indices of egg production. Composite length frequencies, based on a five year summation of catch per tow at length, $\bar{I}(L,t)$ were multiplied by predicted eggs at length Egg(L) and the fraction mature (PMAT(L)). The computational formula is:

$$SSB(t) = \sum_L SSB(L,t) = \sum PMAT(L) * Eggs(L) * \bar{I}(L,t)$$

where
$$PMAT(L) = \frac{1}{1 + e^{13.9568 - 0.03862325L}}$$

L = length(mm)

Parameters for PMAT(L) were derived by fitting the logistic function to derived percentiles of fraction mature described in Hartley (1995). The fecundity-length relationship was obtained from Armstrong (1987).

$$Eggs(L) = 0.0683L^{3.74}$$

Results for the indices of egg production (Figures A46 and A47, Table A29) mirror the progressive decline in mean length. The egg production indices declined steadily from the late 1970s until the late 1990s, when they began to increase slightly. Currently, about 14% of egg production is by fish less than L_{99}. This compares with 1-5% in the first decade of the time series.

Estimation of Mortality and Stock Size

Natural Mortality Rate

The instantaneous natural mortality rate for monkfish is assumed to be 0.2, based on an expected maximum age of 15-20 years given previous studies of age and growth (Armstrong 1987, Armstrong et al. 1992, Hartley 1995).

Mortality estimates from NEFSC Surveys

Mortality rates were estimated from NEFSC survey abundance at age data using cohort-based catch curves (Table A30, Figures A48-A56) and Heinke's method (Table A31). The annual estimates from both methods are highly variable and the Heinke method results in many unreasonable estimates. This is likely due to inter-annual variations in catchability coupled with the overall low catch rates of goosefish in the NEFSC surveys.

Exploitation ratios were calculated from the cooperative survey using the same methods as used for SARC 34. The estimates were produced using two methods: using landings and exploitable biomass from the cooperative survey (> 40 cm north, > 52 cm south), and using catch (landings plus discards) and total biomass from the cooperative survey. In each case, landings (catch) were added to the cooperative survey estimate of biomass to derive a proxy for biomass at the beginning of 2003, and the cooperative survey biomass was taken as biomass at the beginning of 2004. The exploitation ratio was calculated using the average between 2003 and 2004 biomass estimates. The estimates were produced under assumptions of 100% and 'intermediate' net efficiencies (from 2001 cooperative survey) and using nominal tow distances. This produced the exploitation ratios shown in Table A32. The results from the catch and biomass method were very similar to the results from landings and exploitable biomass (Table A32).

An additional set of exploitation ratios was generated using survey biomass estimates and fishing year 2003 (May 2003-April 2004) landings and catch (Table A33). The results were very similar to the estimates derived above, with exploitation ratios somewhat lower in the north using fishing year landings.

For comparison with yield per recruit -based reference points adopted in Framework 2 of the Monkfish FMP, exploitation ratios were converted to F assuming M=0.2.

Bayesian Surplus Production Model

The Southern Demersal Working Group updated the Bayesian surplus production models developed for SARCs 31 and 34. SARC 34 felt the approach had value, but that data limitations were a significant impediment to its application at that time. The WG extended the SARC34 analyses (NEFSC 2002) using the same basic model structure, but with the following modifications (see Appendix I for documentation):

- A beta function prior was implemented for the distribution of r, the intrinsic rate of increase (mean = 0.5, CV = 20%)
- 2001 and 2004 estimates of biomass from the cooperative monkfish surveys were included as inputs

Estimates of the mean and quantiles of the posterior distributions of key model parameters and important outputs are listed in Table A34. There the variable BRATIO is the ratio of stock biomass in year 2003 to the biomass that would produce maximum surplus production. The variable HRATIO is the ratio of the harvest rate in year 2003 to the harvest rate that would produce maximum surplus production. The parameter K is the carrying capacity. The parameter M is the shape parameter for the production curve in the Pella-Thomlinson model. The variable B2004 is population biomass at the start of year 2004. The variable BMSP is the population biomass that would produce maximum surplus production (MSP). The variables qFALL and qSCALLOP are the catchability coefficients for the fall groundfish and the scallop survey biomass time series. The parameter r is the intrinsic growth rate of the stock. The parameter sigma2 is the process error variance, while the parameters tau2FALL and tau2SCALLOP are the observation error variances for the fall groundfish and the scallop survey biomass time series.

Model results indicated that fishing mortality has increased and stock biomass has decreased during the assessment time series of 1964-2003. When 2001 and 2004 biomass estimates were used as inputs for surplus production modeling, the median (50th percentile) model results for the northern area indicated that F_{msy} = 0.18, B_{msy} = 60,100 mt, F_{2003} = 0.25, and B_{2003} = 72,100 mt. The median model results for the southern area indicated that F_{msy} = 0.20, B_{msy} = 82,300 mt, F_{2003} = 0.13, and B_{2003} = 107,300 mt. Given the provisional nature of the 2004 cooperative survey biomass estimates and potential for subsequent revision, the 2004 WG considers the surplus production model results to be preliminary and not yet sufficient for evaluation of the status of the stock with respect to reference points.

Evaluation of Stock Status with Respect to Reference Points

Monkfish in the northern and southern management areas are defined as being overfished (below $B_{threshold}$) when the three-year moving average autumn survey weight per tow falls below one half of $B_{target..}$ $B_{target.}$ is defined as the median of the three-year moving average autumn survey weight per tow during 1965-1981. Thus $B_{threshold}$ = 1.25 for the northern management region and 0.93 for the southern management region. For both management areas, $F_{threshold}$ is set equal to F_{max}, currently estimated as F=0.2 (NEFSC 2002). The overfishing definition does not include an Ftarget reference point. Optimum yield is addressed by adjusting annual TACs and trip limits based on how biomass indices compare to annual biomass targets.

Northern Region

The current three-year moving average catch per tow (kg/tow from NEFSC offshore autumn research vessel survey) of 2.025 kg/tow is above Bthreshold (=1.25) (Table A35). The three-year running average has been above Bthreshold since 2000. The moving average remains below the biomass target of 2.496 kg/tow (median of three-year moving average during 1965-1981). Re-sampling from the error distribution of the indices used in calculating the biomass threshold and the current 3-year running average indicates that the probability the current 3-year average is at or above the biomass threshold is equal to 0.98 (Figure A56). The WG concluded that current F estimates are too uncertain to be used for evaluation of stock status relative to fishing mortality reference points.

Southern Region

The current three-year moving average catch per tow (kg/tow from NEFSC offshore autumn research vessel survey) of 0.93 is equal to Bthreshold (=0.93) (Table A35). The moving average was below Bthreshold from1986-2002. Re-sampling from the error distribution of the indices used in calculating the biomass threshold and the current 3-year running average indicates that the probability the current 3-year average is at or above the biomass threshold is equal to 0.56 (Figure A57). The three-year average remains well below the biomass target of 1.848 kg/tow (median of three-year moving average during 1965-1981). The WG concluded that current F estimates are too uncertain to be used for evaluation of stock status relative to fishing mortality reference points.

Trends in Stock Biomass, Recruitment, and Mortality

For the northern component, NEFSC autumn and spring research survey indices show an overall decline in biomass between 1975 and 1999 and a somewhat higher level since then (Tables A15 and A16, Figures A12 and A13). The increases since 2000 reflect increases in both spring and autumn survey abundance indices since 1998 (numbers per tow, Figures A13 and A16). The improved recruitment during the 1990s reflects contributions from several year classes (particularly 1993 and 1999). The maximum and mean lengths of goosefish caught in NEFSC surveys have increased in the past 3-4 years, but remain low relative to the entire time series (Figure A18).

For the southern component, biomass and abundance indices from the NEFSC spring and autumn surveys have fluctuated around the time series low since the mid-1980s, but have increased slightly since 2000 (Tables A20 and A21, Figures A21-A24). The 2002 yearclass appears to be relatively strong (Figure A14). The NEFSC winter flatfish survey shows an increasing trend in biomass since 1999 (Table A22, Figure A25); however, the survey has only been conducted since 1992. The maximum and mean lengths of goosefish in NEFSC surveys have stabilized during the past decade, but remain low relative to the time series (Figures A30 and C31).

For both stock components, indices of egg production (Figures A46-A47) mirror the progressive decline in abundance of larger fish in survey catches and the slight recovery of biomass in the northern region especially.

The WG did not consider available mortality estimates sufficiently precise for evaluating trends in mortality.

Working Group Comments

The Working Group discussed the increase in discards in 2000 through 2003. Minimum size limits and trip limits went into effect in May 2000, after the FMP was implemented. This appears to have increased regulatory discards. The recent discard estimates in the trawl fishery also could be biased by relative sampling effort in the multispecies fisheries (monkfish taken as bycatch) and directed monkfish trips if there are differences in discard patterns between vessels fishing under a groundfish day-at-sea or a monkfish day-at-sea. In the southern management area, both the trip limit and the minimum size limit are more constraining than in the northern management area. A recommendation was made to stratify the observer data by type of trip (monkfish vs. groundfish) to better characterize the discards. A preliminary examination done by stratifying discard rates by mesh size (>6.5 in. and <= 6.5 in) as a proxy for fishery type revealed higher discard rates on trips with mesh <= 6.5 inches. A more complete investigation is needed; however, the WG anticipates that this will be hampered by difficulties associated with linking the various databases (observer, dealer, etc.).

The Working Group noted the disparity between apparent longevity of males and females as well as the shape of the sex ratio curve for the Southern Region. A J-shaped curve usually represents cases where one sex stops growing and accumulates numbers at a certain length while the other sex continues to grow and becomes the only sex at larger lengths. In the case of monkfish, no males have been found to be older than 7 years which should not result in a J-shaped sex ratio curve. A recommendation was made to implement a tagging study, to determine where males go after age 7 or where females are from age 5 to 7. Also a recommendation was made for a program which would pay fishermen for bringing in any monkfish over 120 cm for biological sampling.

Selection of appropriate models for the depth-wingspread relationships was discussed by the Working Group. A polynomial function gave a good fit and conformed to expectations that wingspread should show a convex relationship with depth. The lack of wingspread data for the rockhopper net at shallow depths was addressed by examining several assumed values for the intercept. The WG decided to use an intercept for the rockhopper equal to the intercept of the flatnet relationship plus the difference in expected wingspread between the two gears, and assumed the same shape curve applied to the rockhopper as the flat net. The resulting relationship was used to assign wingspread to the rockhopper tows.

The Working Group decided to use nominal tow distances and intermediate net efficiency estimates for comparison of the 2001 and 2004 biomass estimates. Net efficiency estimates for the 2004 cooperative survey were not yet available, so efficiency estimates from the 2001 survey were used to calculate biomass for the 2004 survey. The 2004 estimates are provisional and are likely to change when the net efficiency estimates for 2004 become available.

Bayesian surplus production analyses from SARC 34 were updated with three additional years of catch and NEFSC survey data plus the biomass estimates from the 2004 cooperative research survey. A run starting with 1980 (SARC 34 recommendation) and assuming a uniform prior for r (intrinsic rate of increase) gave unrealistic results. Using the entire time series (1964-2003) and use of a beta-distribution prior with mean=0.5 and CV=20% for r gave more realistic results. The Working Group, however, considered these results preliminary given the provisional nature of the 2004 cooperative survey biomass estimates.

Research Recommendations

SARC 34 Recommendations and Actions Taken

1) Research should be continued to define stock structure, including genetic studies, reproductive behavior analyses, morphometric studies, parasite studies, elemental analyses, and studies of egg and larvae transport.

WG Response: An elemental analysis project is underway by Jonathan Grabowski at the University of Maine. Samples for the study were collected during the 2004 cooperative monkfish survey and analysis is expected to be completed by 2006. A study on reproductive behavior has been completed by Chris Chambers of NEFSC Sandy Hook Lab.

2) The SARC recommends changing the overfishing definitions for goosefish. Research on yield per recruit for goosefish should examine the effect and possible causes of differential natural mortality rates by sex, methods to estimate gear selectivity, and the incorporation of discards.

WG Response: The recommendations of SARC 34 were implemented in Framework 2 of the FMP in May 2003. The WG plans to update the estimation of selectivity patterns and the yield per recruit analysis for the next assessment review, tentatively scheduled for 2007. The WG will also explore the feasibility of estimating discards by trawl fishery strata (multispecies bycatch, directed monkfish).

3) Surplus production modeling should continue with special emphasis placed on uncertainty in under-reported catches and population size prior to 1980.

WG Response: The Bayesian surplus production model for goosefish was updated for this assessment by including 2001-2003 fishery catch, trawl survey indices, and the 2004 cooperative survey biomass estimates. As noted above concerning the current uncertainty of the 2004 cooperative survey biomass estimates and potential for subsequent revision, the Southern Demersal WG considers the surplus production results to be preliminary and not yet sufficient for evaluation of the status of the stock with respect to reference points. The WG plans to continue development of the model in the next assessment, since it appears to have potential to serve as a valuable tool for integration of the estimation of population biomass and mortality rates and reference points.

4) Size selectivity studies should be conducted in the trawl fishery to investigate the potential effectiveness of minimum mesh size and shape regulations to reduce discards of undersize monkfish. Additionally, comparative studies of the size selectivity and catchability of trawls and gill nets should be undertaken in order to understand the differences in the numbers of large fish captured in the two gear types.

WG Response: A cooperative research project is underway to investigate fishery selectivity patterns in the trawl fishery the Gulf of Maine (6.5 inch vs. 10 inch square mesh; M. Raymond of Associate Fisheries of Maine and C. Glass of Manomet CCS).

5) Another cooperative survey for monkfish should be conducted in 2004.

WG Response: The 2004 cooperative survey has been conducted, but analytical results are not yet complete.

6) Improved sampling rates (as observed in 2000-2001) for commercial landings should be maintained, which should eventually lead to an age-based assessment approach for this species.

WG Response: The overall commercial fishery landings sampling intensity (samples per mt) was 171 mt per length sample in 2000 and 149 mt per sample in 2001. Sampling intensity improved to 121 mt per sample in both 2002 and 2003.

7) Tagging studies should be considered as a basis to evaluate adult movement and rates of growth.

WG Response: A limited number goosefish (46 individuals) were tagged as part of the Rutgers/SMART/MADMF gillnets fishery project. No returns have yet been reported from this project.

8) Spatial distribution of mature and immature fish and the potential effects of size limits on fishing behavior should be evaluated as a basis for advising on strategies to minimize catch and discard of immature fish.

WG Response: Elimination of minimum size regulations were considered, but not adopted, in the development of Amendment 2 to the FMP as a means to reduce discards. Instead, the minimum size regulation was reduced in the southern area to be consistent with the northern area.

9) Indices of abundance should be developed from industry "study fleets,@ including coverage from outside the depth and spatial range of the NEFSC research surveys.

WG Response: A Study Fleet-NMFS cooperative research project has been implemented in several New England ports. Information on patterns of monkfish landings and cpue are expected to result from this project; no results are available at present.

Recommendations of Southern Demersal Working Group

1) Explore the feasibility of estimating trawl fishery discards separately for monkfish caught as bycatch on multispecies DAS and on directed monkfish trips, since possession limits are different and annually variable for these components of the fishery.

2) Update the SARC 34 selectivity analysis and yield-per-recruit calculations for the next assessment review, tentatively scheduled for 2007.

3) Implement a reward program for large monkfish specimens (> 120 cm total length). The goal of this program would be to gain information on longevity and natural mortality rate of monkfish, and extend age and growth studies.

4) Tagging studies should be considered as a basis to evaluate adult movement, spatial segregation by sex, and growth rates.

5) Given the time needed for thorough analysis of data from the cooperative surveys, the WG recommends that if a cooperative survey is conducted in winter/spring 2007, review of the survey should not be scheduled until at least the SARC in Spring 2009.

6) The cooperative monkfish surveys have greatly increased knowledge of monkfish biology, and have helped improve the reliability and accuracy of the stock assessment. An additional benefit has been increased industry acceptance of assessment results. However, the Northeast Region=s management and science agencies should carefully weigh the benefit:cost of the

cooperative monkfish surveys in considering whether to undertake a survey for 2007. If a survey is conducted in 2007, it is critical that sampling protocols (e.g. net and ground gear designs, survey timing, vessels) be examined and standardized to the extent possible to maximize the value of annual cooperative survey estimates. Sampling intensity should be evaluated to determine optimal levels and allocation of sampling effort.

Literature Cited

Almeida, F. P., D.-L. Hartley, and J. Burnett. 1995. Length-weight relationships and sexual maturity of goosefish off the northeast coast of the United States. N. Am. J. Fish. Manage. 15:14-25.

Armstrong, M. P. 1987. Life history of the goosefish, *Lophius americanus*. M. Sc. Thesis, College of William and Mary in Virginia. 80 pp.

Armstrong, M. P., J. A. Musick, and J. A. Colvocoresses. 1992. Age, growth and reproduction of the goosefish, *Lophius americanus* (Pisces: Lophiiformes) U. S. Fishery Bulletin. 90:217-230.

Beverton, R. J. H. and S. J. Holt. A review of methods for estimating mortality rates in exploited fish populations, with special reference to sources of bias in catch sampling. Rapprts et Proces-Verbaux des Reunions 140: 67-83.

Caruso, J. H. 1983. The systematics and distribution of the lophiid angler fisher: II. Revision of the genera *Lophiomus* and *Lophius*. Copeia 1:11-30.

Chikarmane, H.M. , Kuzirian, A.M, Kozlowksi, R, Kuzirian, M. and Lee, T. 2000. Population genetic structure of the goosefish, *Lophius americanus.* Biol. Bull. 199: 227-228.

Cleveland, W. S. 1979. Robust locally weighted regression and smoothing scatterplots. J. Am. Stat. Assoc. 74(368): 829-836.

Cochran, W. G. 1977. Sampling techniques. Wiley. NY.

Conan, G. Y. and E. Wade. 1989. Geostatistical mapping and global estimation of harvestable resources in a fishery of northern shrimp (Pandalus borealis). Int. Coun. Explor. Sea C.M. 1989/D:1, 11p.

Hartley, D. 1995. The population biology of the goosefish, *Lophius americanus*, in the Gulf of Maine. M. Sc. Thesis, University of Massachusetts, Amherst. 142 p.

Martinez, C.M. 1999. The reproductive biology of the goosefish, *Lophius americanus*. M.S. Thesis, University of Rhode Island.

Myers R. A. and P. Pepin. 1990. The robustness of lognormal-based estimators of abundance. Biometrics 46:1185-1192.

NEFSC. 1991. Report of the twelfth northeast regional stock assessment workshop (12th SAW). NEFSC Ref. Doc. 91-03.

NEFSC. 1997. Report of 23rd Northeast Regional Stock Assessment Workshop(23rdSAW). NEFSC Reference Document 97-05.

NEFSC. 2000. 31st Northeast Regional Stock Assessment Workshop(31st SAW). NEFSC Reference Document 00-15.

NEFSC. 2002. 34th Northeast Regional Stock Assessment Workshop(34th SAW). NEFSC Reference Document 02-06.

Pennington, M. 1983. Efficient estimators of abundance, for fish and plankton surveys. Biometrics 39:281-286.

Pennington, M. 1986. Some statistical techniques for estimating abundance indices from trawl surveys. Fishery Bulletin US 84:519-525.

Rao J. N. K. and C. F. J. Wu. 1988. Resampling inference with complex survey data. J. Amer. Stat. Assoc. 83:231-241.

Sissenwine, M. P. and E. W. Bowman. 1977. Fishing power of two bottom trawls towed by research vessels off the northeast coast of the USA during day and night. ICES C.M. 1977:B30.

Sitter R. R. 1992. A resampling procedure for complex survey data. J. Amer. Stat. Assoc. 97:755-765.

Smith S. J. 1990. Use of statistical models for the estimation of abundance from groundfish trawl surveys. Can. J. Fish. Aquat. Sci. 47:894-903.

Smith S. J. 1996. Analysis of data from bottom trawl surveys, in H. Lassen, ed., "Assessment of groundfish stocks based on bottom trawl surveys" NAFO Scientific Council Studies, 28, pp 25-53.

Smith S. J. 1997. Bootstrap confidence limits for groundfish trawl survey estimates of mean abundance. Can. J. Fish. Aquat. Sci. 54:616-630.

Smith S. J. 2000. Notes for National Graduate School Fish Biology and Fisheries Course on: Design and analysis of trawl/dredge surveys for abundance. Sep. 20-25 1998, Tvarminne, Finland.

Smith S. J. and S. Gavaris. 1993. Improving the precision of fish abundance estimates of Eastern Scotian Shelf cod from bottom trawl surveys. N. Amer. J. Fish. Manage. 13:35-47.

Steimle, F.W., W.W. Morse, and D.L. Johnson. 1999. Essential fish habitat source document: goosefish, Lophius americanus, life history and habitat characteristics. NOAA Technical Memorandum NMFS-NE-127.