

A. Assessment of the Northern Stock of Black Sea Bass

Consensus Assessment Report

SARC 39

SAW Coastal/Pelagic Working Group

National Marine Fisheries Service
Northeast Fisheries Science Center
Woods Hole Laboratory
Woods Hole, MA

May 4, 2004

A meeting of the Coastal/Pelagic working group was held April 27-29th in Woods Hole, MA. The objective was to produce a stock assessment for the northern stock of black sea bass for consideration at the 39th SARC. Participants in the meeting were:

Dr. Liz Brooks - NMFS, Miami Laboratory, Miami, FL
Dr. Steve Cadrin - NMFS, Woods Hole Laboratory, Woods Hole, MA
Jessica Coakley - DE Fish and Wildlife, Dover, DE
Steve Doctor - MD Dept. Natural Resources, Stevensville, MD
Dr. Mary Fabrizio - NMFS, J.J. Howard Laboratory, Sandy Hook NJ
Blanche Jackson – NMFS, Woods Hole Laboratory, Woods Hole, MA
Kohl Kanwit - ME Dept. Natural Resources, W Boothbay HBR, ME
Toni Kerns – Atlantic States Marine Fisheries Commission, Washington, DC
Dr. Rob Latour - Virginia Institute of Marine Science, Gloucester Pt. VA
Dr. Chris Legault - NMFS, Woods Hole Laboratory, Woods Hole, MA
Dr. Chris Moore -Mid-Atlantic Fishery Management Council, Dover DE
Josh Moser - NMFS, Woods Hole Laboratory, Woods Hole, MA
Roy Pemberton - Virginia Institute of Marine Science, Gloucester Pt. VA
Dr. Paul Rago - NMFS, Woods Hole Laboratory, Woods Hole, MA
Gary Shepherd - NMFS, Woods Hole Laboratory, Woods Hole, MA
David Simpson - CT Dept. Environmental Protection, Old Saybrook, CT
Dr. David Smith - USGS, Leetown Laboratory, Leetown, WV
Dr. Mark Terceiro - NMFS, Woods Hole Laboratory, Woods Hole, MA
Dr. William Overholtz - NMFS, Woods Hole Laboratory, Woods Hole, MA
Azure Westwood - NMFS, Woods Hole Laboratory, Woods Hole, MA

Terms of reference were:

- 1) Characterize the commercial and recreational catch data (including length distributions).
- 2) Update NEFSC survey indices and evaluate appropriate state survey indices.
- 3) Summarize tagging program results.
- 4) Develop tag-based estimate(s) of exploitation.
- 5) Evaluate use of index-based methods for estimating relative Fs.
- 6) Evaluate biological reference points.

INTRODUCTION

Black sea bass (*Centropristis striatus*) range from the Gulf of Maine to southern Florida, with the majority of landings from Massachusetts to North Carolina. The population is partitioned into two stocks north and south of Cape Hatteras, NC (Musick and Mercer 1977, Shepherd 1991). The northern stock of black sea bass is jointly managed by the Atlantic States Marine Fisheries Commission (ASMFC) and the Mid-Atlantic Fishery Management Council (MAFMC) under Amendment 9 to the Summer Flounder, Scup, and Black Sea Bass Fishery Management Plan (FMP). The most recent stock assessment, completed in June 1998, indicated that black sea bass were over-exploited and at a low biomass level (NEFSC 1998). The status of the stock was determined using a time series of relative abundance indices from the National Marine Fisheries Service (NMFS) Northeast Fisheries Science Center (NEFSC) spring offshore bottom-trawl survey, beginning in 1968. Amendment 12 to the Summer Flounder, Scup and Black Sea Bass FMP established a biomass threshold based on the maximum value of a three-year moving average of the NEFSC spring offshore survey mean biomass-per-tow. The overfishing definition in the FMP is based on F_{max} as a proxy for F_{msy} . Since there is not a currently accepted value of fishing mortality for black sea bass, the status of the stock relative to the overfishing definition cannot be established. However, a relative measure of exploitation (total landings / exploitable biomass index) can be used to evaluate stock status.

The conclusion of the 27th SARC was that black sea bass were overfished and overfishing was likely occurring. It was recommended that regulatory measures should continue with the objective of increasing total biomass and spawning stock biomass as well as expanding the age distribution within the population. The rebuilding schedule developed in the FMP calls for a reduction in the target exploitation rate for 2001-2002 to 37% with a further reduction in 2003 to the exploitation rate associated with F_{max} (25.6% for $F_{max} = 0.33$).

FISHERIES

Commercial sea bass landings have varied without trend since 1981, ranging from a low of 2.0 million pounds in 1994 to a high of 4.3 million pounds in 1984 (Table 1, Figure 1). The 2003 quota restricted landings of 3.1 million pounds was average for 1981-2000 but slightly lower than 2002 landings of 3.5 million pounds. Recent landings are all substantially below the peak landings of 21.8 million pounds estimated for 1952 (NEFSC 1998).

Commercial black sea bass landings in 2002-2003 were primarily from sea bass pots (42%), otter trawl (40%) and hook and line (12%). Massachusetts, New Jersey, Virginia and Maryland account for the majority (69%) of landings. Minimum size is 11" (28 cm) and landings are restricted by quota. The pot and hook fisheries begin in coastal waters in May and continue until late October in MA to December in southern areas (Shepherd and Terceiro 1994). Otter trawl landings are generally offshore during the winter months in the summer flounder, scup and squid fisheries (Shepherd and Terceiro 1994).

Biological samples collected by NMFS were used to expand length frequencies of commercial landings. Samples from 2002 and 2003 landings were partitioned by quarter, market

category (small, medium, large and jumbo) and gear type (pots, trawls, hand lines and float traps). Large accounted for 33% and 31% of landings in 2002 and 2003, respectively although mediums (28% and 29%) and jumbos (23% and 27%) were a significant part of landings in both years. Expansion of lengths were made from 17 samples in 2002 and 25 in 2003. Length to weight conversions were based on length-weight equations in Wigley et al (2002).

Ln Wt (kg) = ln a + b ln Len (cm)	ln a	b
spring	-11.2205	3.0225
autumn	-11.5992	3.122

Expanded length distributions are shown in Figures 2 and 3. Total estimated landings were 5.7 million fish in 2002 and 4.9 million in 2003. Commercial discards were not estimated.

Recreational fisheries account for roughly half of black sea bass landings. The recreational fishery takes place in coastal areas from May until November and is subject to a 12" (30 cm) minimum size, a 25 fish bag limit and a 2 week closed season. Landings ranged from a low of 1.2 million pounds in 1998 to a high of 12.4 million pounds in 1986 (Table 1, Figure 1). MRFSS estimates of black sea bass recreational landings (A + B1) in 2002 were 2,024 mt (3.38 million fish) and 1,933 mt (3.33 million fish) in 2003. The average for 1981-2001 was 1,772 mt. In 2000-2002, an average of 55% of the recreational landings were from the state of New Jersey. The next highest percentages per state were 9.7% from Delaware and 8.7% from Maryland. Length distributions from the recreational landings are shown in figures 4 and 5. Recreational discards (B2) amounted to 11.7 million and 9.1 million fish in 2002 and 2003, respectively. The previous assessment assumed a 25% discard mortality rate which would result in losses of 2.9 million and 1.8 million sea bass. A published estimate (Bugley and Shepherd 1991) of 5% results in 585,000 and 455,000 sea bass lost due to discarding.

FISHERY INDEPENDENT SURVEY INDICES

NEFSC

The highest abundance index (Log re-transformed mean number per tow) occurred in 1974 and was followed by a period of decline until the mid-1980s (Table 2, Figure 6). A slight rise in abundance was evident in the late 1980s but was followed by a decade of fluctuations around low levels of abundance. Since 1999 there has been a noticeable increase and the index in 2002 (2.175 / tow) was the highest in the time series and three times greater than the series average (0.7 / tow). The preliminary point estimate of the 2004 index (0.86 / tow) remains slightly above average. The NEFSC winter survey, begun in 1992, followed a similar pattern with a large index for 2002 (8.2/tow) followed by a higher index in 2003 (10.4 / tow) (Table 3, Figure 7). The preliminary 2004 index dropped to 2.0 /tow, below the time series average of 3.2 / tow. The autumn survey has also had relatively large indices in recent years (Table 4) but has not been considered reliable as an index of adult abundance due to potential catchability issues during sea bass residency in coastal waters.

Total biomass indices from the spring and winter trawl surveys indicate a significant increase over the past six years. Spring survey log re-transformed mean weight per tow peaked in 2003 at 0.85 kg/tow, well above the long term average of 0.25 kg/tow (Table 5, Figure 8). The preliminary 2004 index declined to 0.39 kg/tow. The winter survey also peaked in 2003 at 1.83 kg/tow, three times greater than the time series average of 0.63 kg/tow (Table 6, Figure 9). The 2004 index decreased to 0.67 kg/tow. A 3-point moving average of an exploitable biomass index provides the basis for biomass determination in the current FMP. During development of the FMP, exploitable biomass from survey results was defined as fish greater or equal to 22 cm. The working group decided to maintain this definition for evaluation of trends over the time series. Exploitable biomass increased substantially beginning in 1998 and reached a peak in 2002 of 0.799 kg/tow that exceeded the 1974 threshold value of 0.509 kg/tow (Table 7, Figure 10). The index has declined in successive years since 2002, reaching 0.320 kg / tow in 2004 (preliminary estimate). The 3-point moving average of the non-transformed biomass indices, as used in the FMP, peaked in 2003 at 1.403 kg/tow compared to the 1978 standard of 0.976 kg/tow (Table 7). The preliminary 2004 index declined to 0.937 kg / tow. Relative exploitation rate (total landings/biomass index) reached its lowest point in 2002 and 2003 (Table 7).

The difference in the pattern between total biomass indices and exploitable biomass appears to be due to the influence of a strong 2002 year class (Table 8, Figure 11). A black sea bass juvenile index has been defined in previous assessments as the log re-transformed stratified mean #/tow for fish ≤ 14 cm. The recruitment index has shown several recent strong year classes with 4 of the past 6 years above the time series average. The 2000 (0.661) and 2002 (0.554) recruitment indices were well above average (0.144) for the period 1968-2003. The 2003 index (0.154) suggests an average year class while the preliminary 2004 juvenile index was below the long term mean.

Massachusetts Division of Marine Fisheries

The Massachusetts spring bottom trawl survey, initiated in 1978, showed a recent increase in sea bass abundance with a peak index of 4.0/tow in 2000 (Table 9, Figure 12). However the indices have declined since and were below the time series average (1.21/tow) in 2003 (0.83/tow). The comparable biomass indices also peaked in 2000 at 1.93 kg/tow and have declined in 2003 to 0.72 kg/tow. The time series of number per tow and weight per tow were not strongly correlated with the NMFS, Connecticut or New Jersey surveys. The MA juvenile sea bass index from the autumn survey indicates strong cohorts in 2000 and 2003.

Connecticut Long Island Sound Trawl survey

The time series of geometric mean number per tow from the CT trawl survey begins in 1984 (Table 9, Figure 12). The survey shows a similar trend as the NMFS surveys with a sharp increase in abundance over the past several years, beginning in 1998. The index peaked in 2002 at 0.67/tow and decreased in 2003 to 0.21/tow, which remains above the series average of 0.14/tow.

New Jersey Coastal Ocean Survey

The New Jersey trawl survey is conducted during January, April, June, August, and October. The survey data from April was used as the index of abundance because it had the

closet relationship with all other survey indices of abundance. Mean number per tow peaked in 2002 (2.7/tow) and remained above average (0.73/tow) in 2003 (1.66/tow). Biomass indices were similar, peaking in 2002 and remaining above average in 2003. Indices of juvenile abundance (≤ 14 cm) varied considerably among bi-monthly surveys (Table 10, Figure 11). However, the 2002 year class was dominant in both June and August surveys.

The state survey indices were well correlated with the NEFSC spring and winter surveys (Table 11), however the NEFSC fall survey did not match either state or federal surveys well. MA indices also were not highly correlated with either NMFS or NJ but were closest to CT with an r value of 0.52.

Maryland Coastal Bays Survey

Maryland Department of Natural Resources has conducted trawl surveys at twenty fixed stations in Maryland coastal bays since 1972. Sampling is done from April to October using a 16 ft. otter trawl and captures primarily juvenile fish. A time series of geometric mean numbers per tow is provided in Table 10.

TAGGING PROGRAM

A tagging program for black sea bass was suggested in the research recommendations of the 27th SARC as a method to determine exploitation rate and examine migration patterns. The project was initiated in 2002 with funding from NOAA's MARFIN program. Estimation of survival, and subsequently exploitation rates, for fish populations using mark-recapture data depends on several assumptions. Among those assumptions are that distribution of tagged fish is equivalent to untagged fish, survival of tagged fish is not influenced by the tags, tag shedding during the recovery period is minimal, fish survive the tagging procedure, the tag recoveries are reported accurately, the rate of tag reporting is known and the tags recoveries represent dead fish. Most of these assumptions can be tested through experimentation and appropriate adjustments made in the estimation of survival rates.

Tag mortality and retention

Three experiments were conducted to determine tag retention and tag induced mortality. In the Woods Hole aquarium, 9 fish (29 to 38 cm) were collected in August 2002 by hook and line and placed in a 250 gallon aquarium tank. After a day of acclimation, the fish were tagged with Floy internal anchor tags with a 3 1/2" tube and a 1/4" x 3/4" anchor tab. A small incision was made with a hook scalpel through the lower left abdominal wall and the tag inserted. Four fish survived until May with no tag losses. The remaining five fish retained the tags but died from diseases related to captivity 4 - 8 months after tagging.

A second experiment was conducted in the NEFSC J.J. Howard Laboratory in Sandy Hook, NJ under the direction of Dr. Mary Fabrizio. Thirty-one sea bass were tagged with internal anchor tags and held for 10 - 12 months. Sizes ranged from 22.5 to 36 cm TL. Within the first week, the tag loss rate was 3.2% (1 loss from 31 fish). Over the remainder of the experiment, the loss rate was 6.9% (2 losses from the remaining 29 fish (1 jumper at day 9 not

included)). Overall, 3 tags were lost among 31 fish for a loss rate of 9.7% and no deaths were attributed to the tagging.

A third experiment was conducted by Brian Murphy of the Rhode Island Division of Fish and Wildlife. The duration of the study was 27 days and involved 30 tagged fish ranging in size from 26 to 41 cm. Tag loss was 13.3% with no tag induced mortalities. Among all three experiments, tag loss was 10.1% (7 of 70) and tag induced mortality was 0% (Figure 13).

Tag Releases

Locations and sample size of tag releases were chosen to disperse the tags throughout the range of the fishery, proportional to annual landings. In addition, the design was to release all the tags coastwide within a two week period, beginning in September 2002. Releases were repeated in May 2003 and September 2003. Appropriate sample size for tag release was estimated by examining the variance of a population estimate from a Petersen model. Using catch estimates from 2000 (N_c) a series of tag release values (M), and recovered tags (M_c) under three recovery rate assumptions (10, 20 and 30%), population size (N) was calculated as:

$$N = M (N_c / M_c)$$

Variance was estimated as (Sullivan et al. 1993, Seber 1970):

$$V(N) = ((M+1) (N_c+1)(M-M_c)(N_c-M_c)) / ((M_c+1)^2 (M_c+2))$$

Under all three recovery rates, approximately 3,000 fish or greater produced relatively little reduction in variance (Figure 14). Therefore, the total number of releases per period was targeted as a minimum of 3,000. The number of high reward tags targeted for release was 10%, and were regularly distributed among regular tags. For budgetary reasons the number of high reward tags in spring releases were reduced because of an anticipated high recapture rate.

Tags were released in September 2002 during 3 trips on sea bass pot boats in Nantucket Sound, MA, 1 trip in Cape Cod Bay, MA, 3 pot trips in Narragansett Bay, RI, 2 trips with recreational hook and line gear in Long Island, NY, 1 trip using lobster pot gear in LI, NY, 1 trip with sea bass pot gear in south/central NJ, 1 trip with recreational hook and line gear from Cape May, NJ, 1 trip with recreational hook and line gear in Ocean City, MD and 2 trips with commercial hook and line gear off Norfolk, VA. In May 2003, tags were released in MA, NJ, DE, MD, and VA all with commercial and recreational hook and line gear, and in September 2003, tags were released in MA, RI, CT, NY, NJ, MD and VA from hook and line and pot gear. A group of tags ($n= 249$) were also released in mid-April 2003 off VA. Tag release locations are summarized in figure 15.

Fish brought onboard a vessel for tagging were examined for evidence of external injuries and measured (total length to nearest ½ cm). A small incision was made in the lower abdominal wall and an anchor tag was inserted into the incision. In cases where there was an inflated air bladder, the bladder was punctured as the tag was inserted. If the bladder remained

inflated, the fish was vented with a syringe needle while being held in a holding tank. Fish were returned to the water as soon as possible, generally in less than 1 minute. If there was some question about the condition, the fish was returned to a tank until it showed signs of recovery, usually within several minutes. If the fish did not recover, the tag was removed and the fish discarded. Occasionally (perhaps 2-3 per trip) a released fish would be unable to return to the bottom. In that event, attempts were made to recover the fish and remove the tag. If unsuccessful, the tag number was noted and excluded from the results. Equipment was sterilized with Betadine during each tagging cruise as time allowed. At each station, depth, surface water temperature, location (lat/lon or loran C) and tagger were recorded. Depths ranged from 6 m to 36.5 m. Locations were also categorized as places well known to the general fishing public or those known only to the captain. Regular tags (orange) were imprinted with tag # and a telephone number on both sides of the tag. Special high reward tags (red) also specified \$100 reward. In total, 8,909 regular tags and 659 high reward tags were released (Table 12). Tagged fish ranged in length from 19 to 61 cm; 3% of tagged fish were below 26 cm. Length frequencies of tagged fish are shown in figure 16 by geographic region and regions combined for each release season. The tagged fish appeared to be comparable to the fishery length frequencies for each release period (Figure 17).

Dispersal

An assumption in tagging models is that tagged fish are homogeneously dispersed among non-tagged fish. The rate of movement of tagged fish among NEFSC statistical areas served as one measure of dispersal rate. For each release season, tagged fish were caught in an adjacent statistical area within 1 to 2 weeks of tagging, suggesting that dispersal was occurring in a relatively short time (Table 13a-13c).

Date and location information from release and recapture data allowed the calculation of linear distance and angle of movement (Sullivan et al. 1993) (Appendix I). Tag release locations were initially grouped into 4 regions: MA-RI, NY-northern NJ, southern NJ- DE, MD-VA. Vectors were created with the mean linear angle and mean distance of all tags released in a given region among five groups of days at liberty: 1-60 days, 61-120 days, 121-225 days, 226-365 days and >365 days. The results suggest that fish dispersed from the original tagging location and were likely to mix in the offshore areas during the winter. The general trend was for fish in the northern end of the range to move south-southwest along the 50 fathom line during winter. Sea bass in the NJ-DE area tended to move east-southeast to the shelf edge during winter. Black sea bass further south had a general tendency of seasonal movement towards the east. The extent of seasonal movement was significantly reduced from New Jersey south, particularly in the Virginia area. Most fish in all areas returned the following spring to the area of release although site fidelity was not 100%.

Based on the distribution of tag recaptures relative to release area, the study area was subdivided into 3 regions: Massachusetts to New York, New Jersey to Delaware, and Maryland to North Carolina (Figure 15). These regions were used for subsequent analyses of reporting and recapture rates. Analysis of recapture matrices by region for fall 2002 and spring 2003 releases indicate 4% - 5% movement among regions within a year at large (4.6% and 4.1%, respectively).

Recaptures

Tags recovered by fishermen, dealers or others were reported to NEFSC via telephone. We asked for information on tag number, date and location of recapture, size of fish, type of fishery (recreational, party/charter, commercial) and gear, port and condition of tagged area on the fish. Tags were not required to be returned unless they were high reward tags or a questionable tag number.

Among the fall 2002 releases were a series in Rhode Island using a local pot fisherman. The fish were tagged and released along the same transect as the pots were set. Within the next several weeks, that same fisherman recaptured and reported over 70 tagged bass. It was evident that the tagged fish did not disperse properly but returned to the pots for shelter (these were unbaited pots typical in New England). Therefore in subsequent analyses we eliminated fish tagged and recaptured by that fisherman within the first two weeks at large.

A total of 1,154 regular tags and 107 high reward tags had been reported as of April 30, 2004 (Figure 18).

The black sea bass commercial and recreational fisheries have different minimum size limits; commercial is 11" (28 cm) and recreational is 12" (30 cm). Estimation of reporting rates and exploitation rates required a definition of the size at which sea bass are to fully vulnerable to exploitation. The working group decision was to use the 28 cm limit because of comparability between size of released fish and fisheries data, the inherent measurement error in the fisheries, the contribution of discards to total catch (unknown sizes and amounts) and the potential growth of fish from 28 to 30 cm during the course of the year.

Reporting Rates

Recapture rates of the high reward tags, relative to regular tags, was used to calculate tag reporting rates. The underlying assumption was that \$100 rewards would elicit 100% compliance from fishermen. Incremental rewards have been used in both bird banding and fish tagging studies and \$100 is generally accepted as a reasonable tag value that would provide full compliance (see Working Group comments).

Reporting rates were calculated as:

$$R_s = (R / M) / (R_h / M_h)$$

where:

R_s = reporting rate for tag recoveries

R = number of regular tags reported

M = number of regular tags released

R_h = number of high reward tags reported

M_h = number of high reward tags released

The Working Group recommended comparison of reporting rate between cells using a log-linear model for categorical data. Stratification into season of release and a smaller geographic cell than region (as previously defined) reduced the sample sizes such that many cells had no reported high reward tags and consequently no reporting rate. Data from fall 2002 and spring 2003 releases were combined to increase sample sizes (fall 2003 releases were not included since time at large was not long enough to include in subsequent exploitation estimates). Tag fate was categorized as either fish killed by the recreational fishery, the commercial fishery or not killed. The working group decided that legal size fish which were caught and re-released, with the tag removed, would constitute a killed fish. The reasoning was that under a quota or bag limited fishery with fish readily available, fishermen would likely replace a tagged fish with a non-tagged fish. Therefore to account for the substituted fish and the fact that the released fish was effectively removed from the population of tagged fish, released fish with tags removed (10.6% of recaptures) were included as kills. Additional restrictions on the data set were: fish greater or equal to 28 cm, fish caught in the same region of release (to avoid migration effects in the recapture rates), same season of release, fish at large greater than 7 days and removal of the first two weeks of recoveries by the RI fisherman as previously noted. Restricted input data are provided in table 14. Expected frequencies of tag type (regular or high reward tags), region (north, middle or south) and tag fate (recreational killed, commercial killed or not removed) were compared in a full log-linear model using SAS CATMOD (2004) (Appendix II). The main effects were significant ($Pr > 0.01$), as well as a significant region*fate interaction term ($PR > 0.001$) (the 3-way interaction could not be estimated). A simplified model was run using only the significant terms with similar results. The significant interaction term is likely the result of different recapture rates between the recreational fishery in the middle region and the commercial fishery in the north. Based on the significance of the main effects in the model, expected recapture rates were calculated using separate reporting rates by region and fishery.

Results of the reporting rate calculations by region and fishery are presented in table 15. There were no reported high reward tags in the NJ-DE commercial fishery, so reporting rate had to be estimated from other fisheries or regions. Reporting rates varied from 49% to 100%. Overall, the recreational fishery had a 68.9% reporting rate and the commercial fishery was 57.1%. Anecdotal reports from commercial fishermen suggest that the assumption of 100% reporting for high reward tags may be incorrect. To evaluate the implications of an incorrect assumption, reporting rates were also calculated assuming only 80% reporting rate of the \$100 tags from commercial fishermen (cells with 0 reported were increased to 1 reported). The change resulted in an overall commercial reporting rate decrease to 44.4 % (Table 16).

Exploitation Rate Estimation

The northern stock of black sea bass is managed as a single unit stock from Massachusetts to Cape Hatteras, NC. Therefore, estimates of exploitation and fishing mortality were provided as a single stock-wide value.

Exploitation rates were calculated using a modification of the Petersen estimate. The number of fish recaptured (R) was adjusted for the reporting rate from the area/fishery cell. The number of tags released was reduced by a tag loss rate of 10%. Therefore, exploitation rate estimate was calculated as:

$$\mu = \sum (R_{rf} / \gamma_{rf}) / \sum (M_{rf} - (M_{rf} * \theta))$$

where:

- μ = exploitation rate
- R_{rf} = tags recaptured by region and fishery
- γ_{rf} = tag reporting rate by region and fishery
- M_{rf} = tags released by region and fishery
- θ = percent of tag loss

Fishing mortality was calculated from the exploitation rate by iteration of F values that would produce the equivalent μ , assuming a natural mortality of 0.2.

The recommendation of the working group was to estimate exploitation rates by region and fishery and weight the final estimate by annual landings or survey abundance indices within each cell. The purpose was to reduce the affect of heterogeneity of tag release and recoveries due to unequal sample sizes. However, there was a difficulty in producing region specific estimates with R/M models when inter-region mixing occurs, due to the confounding of recovery rate, migration and local abundance (Dorazio 1993). For example, suppose an equal number of fish are marked in area A and B. The recaptures in area A would be the sum of fish originating in A plus those originating in B but migrating to A. However, there would be no information available to determine what percent of the unseen marked population also moved into A. Therefore, any exploitation estimate would have an unknown number of marked fish available for recapture. If the assumption can be made that recaptures in different regions is limited (4-5% in this study), local F can be calculated and an overall weighted F produced. Weighting by proportion of tags released in each cell (region, fishery) approximates the estimate based on the sum of all releases. Choice of the weighting factor then presents a problem. Weighting by catch assumes that catch reflects abundance when in fact it also represents exploitation rate which is the objective in solving R/M. Consequently it becomes a circular argument. Survey indices which overlap the inshore fishery are unreliable due to the problems with using trawl gear in sea bass habitat. In each of the options, the effects of migration, abundance and exploitation rate are confounded. With a simple r/m model, it is not possible to find a unique solution for exploitation rate among regions without independent estimates of the other factors. However, a series of weighting schemes and F estimates were produced to examine the sensitivity of different assumptions. The recommended approach remained use of recapture rates, adjusted for regional/fishery specific reporting rates, divided by the total number of tags released.

Estimates were made separately for fall 2002 and spring 2003 releases (using the same reporting rates). Input data were limited to fish ≥ 28 cm that were caught and killed (including caught, tag removed and released) after 7 days following tagging but within 365 days at large

(Tables 17 and 18). High reward tags were included in the estimate assuming 100% reporting. A second estimate was made assuming 80% reporting of commercial high reward tags (Tables 19 and 20).

The overall exploitation rate for October 2002-September 2003 recoveries from September 2002 releases was estimated at 0.148 or $F = 0.18$; May 2003 releases recovered from June 2003-May 2004 had an exploitation rate of 0.197 or $F = 0.24$ (Tables 17 and 18). Alternative exploitation rate estimates, assuming 80% commercial reporting of high reward tags were 0.170 ($F=0.21$) in fall 2002 and 0.207 ($F=0.258$) in spring 2003 (Tables 19 and 20).

Sensitivity of fishing mortality estimates to alternative weighting schemes are provided in table 21. Options included region/fishery specific and region specific estimate assuming no inter-region movement, weighting schemes assuming equal proportions among regions, and proportions skewed to one region (50%, 25%, 25%).

Other Tagging Models

An alternative model was evaluated for calculation of fishing mortality (Rago and Goodyear 1985) Fishing mortality was estimated as the value that produced the expected number of tag recaptures equivalent to the observed number using the equation:

$$E_{(i,j)} = N_{(i)} * S_t * (1 - (\exp(-(F+M))^{(t_j - t_i)})) * (F/(F+M))$$

where:

- $E_{(i,j)}$ = expected number of tags returns at time t_j from releases at t_i
- $N_{(i)}$ = number of marked fish released at time t_i modified for tag loss and reporting rate.
- S_t = fraction of marked fish that survive tagging (100%)
- F = instantaneous rate of fishing mortality
- M = instantaneous rate of natural mortality (0.2)
- t_j = time period of recapture
- t_i = time period of release

Solving for F such that $E_{(i,j)} = R_{(ij)} * \gamma$

where:

- $R_{(ij)}$ = observed tag recaptures
- γ = overall reporting rate of 63.6% (combined regions, fisheries for fall 2002-spring 2003 releases).

Estimates were also made assuming a 10% lower reporting rate.

The estimate of F for the period October 2002 – September 2003 was 0.15, and for June 2003 – May 2004 equaled 0.27 (Table 22). Alternative estimates using an 80% commercial

reporting of high reward tags (overall = 56.4%) produced estimates of 0.18 and 0.31 for the fall and spring, respectively. Assuming an overall reporting rate 10% lower (57.2%) produced estimates of 0.17 and 0.30 for fall 2002 and spring 2003 releases.

REPLACEMENT F

Spring survey biomass indices and landings data were further examined using the program AIM (An Index Method from NOAA Fisheries Toolbox, version 1.4). The model uses a statistical fitting procedure to examine the relationship between indices and landings to calculate a relative F and estimate a replacement ratio necessary to maintain the population. Two models runs were used; one with the longer time series of data involving only commercial landings (1968-2003) and a second with a shorter time series which included recreational landings. The NEFSC spring survey log re-transformed biomass indices provided the relative abundance information.

The analysis using total landings since 1981 produced a significant relationship in the simple regression between relative F and replacement ratio (Table 23). The bootstrap mean relative F value for a ln replacement ratio of 0 was equal to 17.319 with an 80% interval between 14.92 and 21.12 (Figure 19). The relative F in 2003 was 3.91, with a replacement ratio of 2.18. A comparable analysis using the longer time series with only commercial landings produced similar results (Table 24). The relative F value with ln replacement ratio of 0 was equal to 7164.47, with an 80% bootstrap interval of 6472.82 to 7860.93 (Figure 19). The 2003 relative F from this data set was 1638.50 with a replacement ratio of 2.186. In both cases relative F in 2003 suggest the biomass should continue to increase at the current levels of removal (Figures 20 and 21).

BIOLOGICAL REFERENCE POINTS

The present BRP for black sea bass is F_{max} as a proxy for F_{msy} . F_{max} as currently defined is equal to 0.33 based on Thompson-Bell yield per recruit model (Table 25, Figure 22). The working group did not recommend any changes to the estimate. The group also concluded that the use of F from the tagging results as a fully recruited F for comparison to F_{max} was acceptable.

Biomass reference points have been based on exploitable biomass indices from the NEFSC spring survey. No alternative biomass estimates are available and no recommendations were made to change the current biomass threshold reference point.

SUMMARY

Results of the assessment for the northern stock of black sea bass show a level of exploitation at or below the management target and biomass levels comparable to the 1970s. Exploitation rate estimates from fall 2002 releases ranged from 0.14 to 0.17; spring 2003 releases were 0.20 to 0.24. Associated fishing mortality estimates ranged from 0.17 to 0.21 in October 2002 – September 2003 while June 2003 to May 2004 preliminary estimates were 0.24 to 0.30.

Relative exploitation values based on the NEFSC spring survey were the lowest in the time series. Relative F estimates from the AIM model indicate low values and well below the F needed to maintain replacement. Relative biomass indices from state and federal surveys show a stock biomass that increased substantially since 1998, reached highest values between 2000 and 2002 and have begun to decline in 2003. Juvenile recruitment over the past five years, based on survey indices, has included possibly two strong cohorts.

Tag reporting rates varied by geographic region and type of fishery. Coastwide the recreational reporting rate was higher at 69% compared to the commercial rate of 57%. Regional differences occurred in reporting rates and tended to be highest in the MD-NC region (90-100%) but may have been influenced by low sample sizes and the assumption of 100% reporting of high reward tags. A relaxation of that assumption to 80% commercial reporting decreased the southern reporting rate from 90 to 68%.

The conclusion of the working group was that the stock appeared to be below the target exploitation rate and target F. Although biomass has been high over the past several years, recent decreases in biomass indices suggests that caution should be exercised in setting quotas. The current tagging models provided an acceptable measure of exploitation but there remains an unknown degree of uncertainty in the estimates.

WORKING GROUP COMMENTS

The comments could be divided into several general topics:

1. Tag retention: The group felt that further studies should be conducted to examine tag retention. Some issues to consider would be effect of vessel movement while tagging compared to tagging under laboratory conditions, effect of handling fish in the laboratory after tagging; pectoral fin erosion by tags over long term; and possible temperature effects (i.e. temperature contrast in water column when fish are caught or released and differences in tagging mortality rate between areas due to temperature differences). Also include a control group to examine possible affects of gear used to collect fish. The use of double tagging to estimate tag loss should be considered in future releases.
2. Experimental design: the group stressed the importance of continuing releases in the same geographic areas as the past releases. Shifts in locations can create difficulty in comparisons between release cohorts. Effort should continue to be made to distribute tag releases in proportion to expected population abundance.
3. Tag reporting: Tag reporting may be increased with additional outreach efforts and perhaps a 1-800 phone number for reporting tags. Consideration should be given to include sociologists in the project to identify the reasons behind non-reporting. Further efforts should be made to compare reporting rates among specific groups by area, gear types etc.

4. Modeling: The group strongly endorsed the continuation of the tagging program through at least another round of releases. The difficulties involved with use of the simple Peterson estimates may be overcome with more sophisticated models. However, implementation of models such as MARK or SURVIV, require development of recapture matrices involving several release-recapture periods. Although it was suggested that such models should be explored using the current data, the modeling efforts will be strengthened with additional data.
5. General comments: Beyond the sea bass program, the group discussed the future of tagging programs within the states and the NEFSC. It was agreed that a proper experimental design was critical prior to any release of tags. The number of tags released should be estimated based on expected reporting rate and exploitation rate. Tag releases should be made over several years in a consistent fashion and should be done each time over a short release time period (several weeks not months). Degree of tag loss should be examined, tag induced mortality and efforts made to quantify reporting rates. Prior to release, the proper infrastructure should be in place to data collection, outreach to increase likelihood of reporting and funding to pay rewards returned over several years. Although it was noted that compared to many techniques, tagging projects were relatively inexpensive, efforts should be made to coordinate tagging among species to reduce costs (i.e. tag scup and fluke while tagging sea bass).

RESEARCH RECOMMENDATIONS

1. Continue tagging project over another season at the minimum.
2. Conduct double tagging experiment to estimate tag loss over time.
3. Develop non-parametric bootstrap method to estimate variance in R/M model.
4. Develop survival estimates using tagging models such as MARK.
5. Develop age information for possible re-examination of age based analytical models.
6. Evaluate use of a short time series of tag based mortality estimates for conversion of relative index based estimates to absolute values.
7. Increase outreach efforts, possibly with the assistance of sociologists.

LITERATURE CITED

- Bugley, K. and G. Shepherd. 1991. Effect of catch-and-release angling on the survival of black sea bass. *North American Journal of Fisheries Management*. 11:468-471.
- Dorazio, R.M. 1993. The difficulties of interpreting region-specific rates of tag recovery. Report for the Striped Bass Stock Assessment Subcommittee, Atlantic States Marine Fisheries Commission. July 19, 1993.
- Musick, J.A. and L.P. Mercer. 1977. Seasonal distribution of black sea bass, *Centropristis striata*, in the Mid-Atlantic Bight with comments on the ecology and fishery of the species. *Transactions of the American Fisheries Society* 106: 12-25.
- Northeast Fisheries Science Center. 1998. Report of the 27th Northeast Regional Stock Assessment Workshop (27th SAW), Stock Assessment Review Committee (SARC) Consensus Summary of Assessments, NEFSC Ref. Doc. 98-15.
- Rago, P. J. and C.P. Goodyear. 1985. Estimation of mortality rates and population size from tagging studies in Everglades National Park, 1984-1985. Unpubl. Report December 20, 1985.
- Seber, G.A.F. 1970. The effects of trap response on tag-recapture estimates. *Biometrika* 26:13-22.
- Shepherd, G.R. 1991. Meristic and morphometric variation in black sea bass north of Cape Hatteras, North Carolina. *North American Journal of Fisheries Management*. 11:139-148.
- Shepherd, G.R. and M. Terceiro. 1994. The summer flounder, scup and black sea bass fishery of the Middle Atlantic Bight and Southern New England waters. NOAA Tech. Report NMFS 122, 13 pp.
- Sullivan, P.J., T.O. Geernaert, G. St-Pierre, and S.M. Kaimmer. 1993. Mark-recapture methods for the Pacific halibut assessment: a feasibility study conducted off the central coast of Oregon. *International Pacific Halibut Commission Sci. Rpt.* 76. 41 pp.
- Thompson, W.H. and F.H. Bell. 1934. Biological statistics of the Pacific halibut fishery. 2. Effect of changes in intensity upon total yield and yield per unit of gear. *Rep. Int. Fish. (Pacific halibut) Comm.* 8: 49p.
- Wigley, S.E., H.M. McBride, and N.J. McHugh. 2003. Length-weight relationship for 74 fish species collected during NEFSC research vessel bottom trawl surveys, 1992-99. NOAA Tech. Mem. NMFS-NE-171. 26 pp.