B. WHITE HAKE

TERMS OF REFERENCE

(A) Update the status of the white hake stock, providing, to the extent practicable, estimates of fishing mortality and stock size. Characterize uncertainty in estimates.

(B) Provide updated estimates of biological reference points (biomass and fishing mortality targets/thresholds), or appropriate proxies, based on available population data.

(C) Provide projections of biomass in 2002 and 2003 and catch in 2002 under various fishing mortality rate options.

INTRODUCTION

White hake (*Urophycis tenuis*) are distributed from the Gulf of St. Lawrence to North Carolina (Figure B1; Bigelow and Schroeder, 1953). Much confusion on the distribution of this species exists because of the close resemblance to its congener, the red hake (*Urophycis chuss*). Both species occupy much of the same habitat (mud bottom) and have often been described together (Bigelow and Schroeder, 1953; Musick, 1974; Markle et al. 1982). White hake tend to be found in deeper water than red hake, but are also found with red hake in shallow bays and estuaries in the Gulf of Maine. This is especially true for juveniles which are the hardest size classes to distinguish from red hake.

Landings of white hake have been viewed as less important than more desirable species of groundfish such as cod and haddock. In 1993, however, white hake landings exceeded those for Gulf of Maine cod (CUD 1995). Concern arose about the sustainability of such high landings. A preliminary assessment of white hake in 1994 showed that fishing mortality rates based on a Modified DeLury model were higher than any biological reference points (NEFSC 1995). Information from a surplus production model also demonstrated that landings were exceeding MSY. In 1998, a new analysis using a virtual population analysis and a surplus production model was conducted (NEFSC 1999). This analysis showed that fishing mortalities had exceeded 0.6 from 1985 to 1997 and were over 1.0 in 1997. Landings and spawning stock biomass were declining. This paper summarizes all current information on the white hake fishery.

STOCK STRUCTURE

There is no new information about the stock structure of white hake. In light of this, all the white hake found in NAFO subareas 5 and 6 were treated as one stock as in the 1994 and 1998 assessments (Sosebee et al. 1998, NEFSC 1999).

THE FISHERY

Commercial Landings

Total landings of white hake decreased from about 3,000 mt in 1964 to a low of 1,100 mt in 1967 (Table B1, Figure B2). Landings then gradually increased and peaked at 8,300 mt in 1985. Landings fluctuated around 5,000 to 6,000 mt until they peaked again in 1992 at 9,600 tons and declined slightly to 9,100 tons in 1993 (Table B1). Landings fell sharply to a 1997 level of 2500 tons but have since increased moderately to 3,200 tons. The US has accounted for the major portion of landings with small amounts landed by Canada. Landings from other countries have been negligible since 1977.

The primary gear type used to catch white hake is the otter trawl (Table B2, Figure B3). Historically, line trawls were also important, but from 1980 to 1991, this gear accounted for less than 5% of the total. Line trawls again increased in importance and, in 1997, represented 18% of the total landings. However, in recent years they averaged less than 10 percent. Sink gill nets have historically (1960s) accounted for less than 10% of total landings but the share enlarged in the 1970s to between 20 and 40% of the total.

The primary season for landing white hake is summer or quarter 3 (Table B3, Figure B4). The highest percentage of landings occurs in August, with the months of July, September and October each accounting for over 10% of the annual landings.

Maine landings have averaged between 40 and 70% of the total US landings since 1964 (Table B4, Figure B5). Massachusetts landings exceeded those of Maine from 1968 to 1974 but have since accounted for 20 to 40% of the total landings. Other states contributing to landings are New Hampshire, Connecticut, Rhode Island, New York, New Jersey, Delaware, and Virginia.

Undertonnage vessels (less than 5 GRT) traditionally accounted for between 20 and 40% of US landings (Table B5), but have since become less important and, in 1997, were not represented in the total landings. Tonnage classes 2 and 3 (5-50 GRT and 51-150 GRT, respectively) have accounted for the majority of the landings with tonnage class 3 dominating landings for the last ten years. Tonnage class 4 vessels (151-500 GRT) increased in importance in the 1980s and 1990s but have since declined.

Recreational Catches

The amount of white hake recreational catches reported in the Marine Recreational Fishery Statistical Survey since 1979 is insignificant (< 0.1 mt per year).

Discards

Estimates of discards were estimated for three gear types and by half year from the Domestic Sea Sampling Program (DSSP). The discard rate was estimated as the total pounds discarded/total pounds kept for each gear/half cell. The rate was then multiplied by the reported landings for that cell.

The estimates range from less than 200 mt in 1995 to more than 4000 mt in 1990 (Table B6). The three years in which discards accounted for more than 30 per cent of the landings occur in years in which there was at least one dominant year class. To estimate otter trawl discards prior to 1989, an average proportion for 1989-2000 was estimated (25%) and applied to the landings from 1964-1988 (Table B7).

Sampling Intensity

Since the majority of white hake are landed in headed and gutted condition, length measurements have not generally been available from port samples. A regression developed to convert dorsal fin-caudal fin length to total length (Creaser and Lyons, 1985), has allowed measurements obtained from landed catch to be used to evaluate overall length composition since 1985. Age samples are still unavailable from port samples since otoliths are the structures used for ageing and are lost when the head is removed.

Table B8 shows the summary of commercial length samples from the ports by market category. Since medium white hake were poorly sampled at the beginning of the sampling period and since there appeared to be no difference in length composition between small and medium market categories, the two size categories were pooled. The sampling intensity overall has been adequate (< 300 mt/sample), except in 1989 and 1995 when only 13 and 12 samples were taken (one sample taken for every 350 mt and 361 mt landed). The sampling intensity in 1997 was very good (32 mt/sample), but the unclassified market category had only one sample for the entire year. In 1999 and 2000, there were no samples for the unclassified. The landings for this group were small so the landings were added at the end.

Length and Age Composition

Commercial length composition during 1985-2000 was estimated by market category (pooling small and medium size categories together) from length frequency samples, pooled on a semiannual basis. Mean weights were obtained by applying the NEFSC survey length-weight equation,

$$\ln \text{Weight (kg, live)} = -12.58 + 3.2196 * \ln \text{Length (cm)}$$

to the semiannual market category length frequencies. Mean weight values were then divided into semiannual market category landings to derive estimated numbers landed by market category. These numbers were then summed over market categories and half-years to produce annual length compositions.

Age-length keys were derived from NEFSC survey data for 1985-1988 and 1991-1994. Survey data for 1989-1990 and 1995-2000 were combined with data collected from sea sampling trips. Age structures have been collected but not aged for 1991-1994. Commercial landings-at-age were derived by applying these age-length keys to the length composition. The number of ages used in each cell varied from a low of 91 in the spring of 1998 to 844 in the fall of 1990 (Table B9). The landings-at-age are shown in Table B10 and Figure B6.

The length composition of the otter trawl portion of the discards was characterized from the DSSP length samples (Table B11). The sampling of discards from sink gill nets has not been adequate for characterizing that fleet sector. Samples for the otter trawl fishery were pooled by half year. Samples were also pooled for 1997-1999 by half year. The lack of samples in these years, particularly 1998, required pooling. The same age-length keys used for commercial landings were used to derive the age composition shown in Table B12 and Figure B7. The combined age composition is shown in Table B13 and Figure B8.

STOCK ABUNDANCE AND BIOMASS INDICES

Commercial LPUE

Commercial LPUE was not examined for this assessment due to the existence of new regulations (i.e. closed areas) that will impact LPUE.

Research Vessel Abundance and Biomass Indices
The NEFSC autumn bottom trawl survey has been in existence since 1963 (Azarovitz, 1981). Offshore areas from the Gulf of Maine to Southern New England are sampled, and, beginning in 1967, offshore areas in the Mid-Atlantic were sampled as well. The NEFSC spring bottom trawl survey began in 1968. The surveys have been conducted with the same gear and vessel as often as possible. The strata set used for white hake is the Gulf of Maine to Northern Georges Bank (offshore strata 21-30 and 33-40). Indices of abundance and biomass were calculated following the methods of Cochran (1977). Vessel, door, and gear effects were not found to be significant for white hake (NEFSC, 1991).

Spring stratified mean number and weight per tow are variable but have been declining since 1990 (Table B14, Figures B9 and B10). The autumn weight per tow index fluctuated around 5 kg/tow in the early 1960s and increased to approximately 12 kg/tow during the 1970s (Table B15, Figure B11). Excluding the 1982 data point, the autumn mean weight per tow index fluctuated around 10 kg/tow from 1983 to 1993. From 1994-1998 the index declined to a low of 4.55 but has since increased slightly. Over the time period, the autumn abundance index increased relative to the biomass index indicating a gradual shift from larger to smaller fish during the 1970s and 1980s (Figure B12).

The State of Massachusetts has also conducted spring and fall surveys since 1978 (Howe et al., 1981). The survey only covers a portion of the white hake stock area but can still be useful. The spring survey shows a decline over the time series until about 1988 when it dropped to a low level and remained until the present (Figure B13). The autumn series is more variable, particularly for abundance but has shown a similar decline (Figure B14).

The ASMFC conducts a summer shrimp survey in the Gulf of Maine. Finfish are also weighed and measured on these surveys and white hake are often caught. This survey also shows a decline over the time series (Figure B15).

STOCK PARAMETERS

Natural Mortality
Natural mortality (M) for most gadid stocks is assumed to be 0.2. Hoenig (1983) developed an empirical relationship between total mortality (Z) and longevity (T_{max}):

$$\ln Z = 1.46 - 1.01 \ln T_{max}$$

Assuming a maximum age of 20 years for white hake (the oldest fish in the age samples was 15 years and the maximum length is larger than this fish) this relationship estimates a Z of 0.2. In the absence of fishing mortality Z = M = 0.2.

Maturity
Maturity ogives are as in the previous assessment (NEFSC 1999).

ESTIMATES OF STOCK SIZE AND FISHING MORTALITY

Attempts were made to update the previous assessment using virtual population analysis (VPA). Many formulations of the VPA were examined (Table B16). All show a severe retrospective pattern with a tendency to overestimate fishing mortality and to underestimate spawning stock biomass in the terminal year. There were also patterns in the residuals which shifted among ages when indices were removed. The uncertainties associated with the VPA were attributed to mis-identification of species in the catch, poor estimation of discards, low sampling of the commercial landings and low catchability of large fish in the survey. Therefore, the VPA was not accepted at this time.

The possible mis-identification of species is particularly a problem for the discards. The length compositions of both the landings and discards were broken out into fish <= 60 cm and fish > 60 cm (Table B17, Figure B16). This length cutoff ensures that most of the fish > 60 cm are white hake since red hake do not reach this size. For years prior to 1985, an average proportion of fish > 60 cm for 1985-2000 was used to split the landings into two parts (75% > 60 cm). All discards prior to 1989 were assumed to be <= 60 cm. The NEFSC surveys were also split into two parts as in the commercial length compositions (Figure B17, Table B18). The rate of decline for the > 60 cm portion of the stock is apparently greater than that for the stock as a whole. Exploitation (catch/survey biomass) on the 60+ cm component has increased since the 1970s (Figure B18, Table B19). Recruitment estimates from the autumn survey indicate that after some good recruitment in the late 1980s, there were several years of poor recruitment (Figure B19). However, there appears to be an above average year class in 1998.

BIOLOGICAL REFERENCE POINTS

Yield and Spawning Stock Biomass per recruit

Since a VPA was not accepted, updates to the yield-per-recruit and SSB-per-recruit analyses could not be conducted. Estimates of reference points from previous analyses may not be appropriate due to the uncertainties associated with the VPA.

SFA Requirements

A surplus production model incorporating covariates (ASPIC, Prager, 1995) was conducted on the biomass of white hake greater than 60 cm (Table B20). A pattern of residuals from the spring surveys indicated that the gear change in 1973 may have increased the catchability of white hake even though there is currently no significant conversion factor. It was therefore decided that the reference points from this analysis would be considered provisionally acceptable. B_{msy} is estimated to be 14,700 mt and F_{msy} is estimated to be 0.29. The biomass estimates from the model indicate that biomass increased to levels above B_{msy} in the late 1960s through the early 1980s (Figure 20). Biomass has since declined and is estimated to be about 20% of B_{msy}. The estimates of fishing mortality show an increasing trend from a low in 1967 (Figure 21). The current estimate of fishing mortality is at least twice the F_{msy} estimate.

CATCH and STOCK BIOMASS PROJECTIONS

No projections could be completed.

CONCLUSIONS

The Gulf of Maine to Northern Georges Bank stock of white hake is overfished and overfishing is occurring. Fishing mortality should be reduced immediately if the 1998 year class is to be protected.

White Hake SARC Comments

The SARC reviewed the white hake VPA base run and concurred with the Working Group that the VPA was problematic given the persistent retrospective pattern resulting from a catch at age which was not well characterized due to the following issues: possible species mis-identification at small sizes, sparse data to estimate discards, insufficient commercial sampling in recent years, the catchability of older (6+) fish in the survey, and possible mis-identification of stock components. Additionally, the SARC noted that the blending of sea sampling and survey age data may introduce bias if the proportions at age are not similar between the two data sets. The SARC also observed that 1) mean weights at age and mean lengths at age of younger fish, particularly ages 1-3, have a relatively large range within each age group; 2) partial recruitment varied considerably from year to year; and 3) fishing mortality pattern at age varied more than expected.

In an attempt to minimize the species mis-identification and discard issues in the catch at age, the SARC suggested two additional analyses which focused on the older fish in the catch which are believed to be only white hake. Given that red hake, the species often confused with white hake, rarely attain lengths greater than 50 cm, the SARC first suggested that the relative exploitation ratios (catch/survey index) be derived using fish 1) less than or equal to 60 cm (ages 1-3); 2) greater than 60 cm (age 4+ fish); and 3) all fish. The SARC then suggested that a VPA be conducted in which ages 1-3 were removed from the catch at age.

The relative exploitation trend for fish >60 cm indicated that exploitation had increased since the mid-1970's. However, the exploitation pattern for white hake less than or equal to 60 cm revealed a declining trend since 1980. The conflicting trends for the two size groups indicated that the catch may indeed be mis-specified. The exploitation trend for younger fish was consistent with the fishing mortality trend in the base VPA. However, results from the VPA using a catch at age excluding ages 1 to 3 revealed the same persistent retrospective pattern as the VPA base run. The SARC concluded that the VPA formulations were too problematic to accept as the basis for estimating stock size and fishing mortality.

A surplus production model (ASPIC) which utilized catch (> 60 cm) tuned with NEFSC spring (>60 cm) and autumn survey indices (> 60 cm) was reviewed. ASPIC estimates of biomass and fishing mortality were consistent with survey biomass indices and relative exploitation trends. However, there were some problems with residual patterns in the early period; specifically, the SARC noted a cluster of large positive residuals in the spring survey series between 1970 and 1985. These positive residuals may be associated with the gear change which occurred during this time period. The SARC suggested that an intervention analysis may be useful to determine if these years constituted a separate time series or not. The bootstrap analysis which included these large residuals indicated that production parameters have low precision. Resolving the apparent change in the spring survey catchability is likely to reduce uncertainty in the biomass dynamic model. It was the consensus of the SARC that the ASPIC results were illustrative of trends in fishing mortality and biomass but that further investigation would be required to address the diagnostics before the model could be used to provide a definitive update of biological reference points. In the absence of definitive results from either the VPA or the ASPIC, the SARC agreed to use survey biomass indices and relative exploitation ratios as proxies for biomass and fishing mortality estimates.

Sources of Uncertainty

- Catch at age not well characterized due to possible mis-identification of species in the commercial and sea sampling data, low sampling of commercial landings, and sparse discard data.
- Catchability of older ages in the survey.
- Mean weights at age in the catch for ages 5-8 in 1991-1994 may not be well specified due to unaged sea sampling samples.
- Current formulation depends on partially recruited/ younger ages for tuning and estimation of fishing mortality.
- The persistent retrospective pattern indicates the fishing mortality in the terminal year is likely to decrease when the analysis is updated.

RESEARCH RECOMMENDATIONS

- Explore causes of retrospective pattern, if possible.
- Improve species identification in sea sampling.
- Increase sea sampling coverage for improved estimates of discard rates.
- Expand NEFSC survey coverage into deeper water to better define stock distribution.
- Explore the use of 4X landings, 4X samples, and Canadian survey data to define stock area..
- Continue the collection and ageing of samples from the ASMFC Shrimp survey.
- For improved age-based analyses of commercial landings, continue ageing of sea sampling samples from 1991-1994.
- Explore alternative assessment methodology.
- Explore catch curve analysis of survey data.
- Investigate residual patterns observed in ASPIC results, i.e. intervention analysis.

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