Stock Assessment Report No. 06-03
of the

# Atlantic States Marine Fisheries Commission

*Terms of Reference & Advisory Report*
*to the American Lobster Stock Assessment Peer Review*

Conducted on
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Boston, Massachusetts

Prepared by the
ASMFC American Lobster Stock Assessment Review Panel

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# Preface

*Summary of the Commission Peer Review Process*

The Atlantic States Marine Fisheries Commission Stock Assessment Peer Review Process, adopted in October 1998 and most recently revised in 2005, was developed to standardize the process of stock assessment reviews and validate the Commission's stock assessments. The purpose of the peer review process is to: (1) ensure that stock assessments for all species managed by the Commission periodically undergo a formal peer review; (2) improve the quality of Commission stock assessments; (3) improve the credibility of the scientific basis for management; and (4) improve public understanding of fisheries stock assessments. The Commission stock assessment review process includes evaluation of input data, model development, model assumptions, scientific advice, and review of broad scientific issues, where appropriate.

The Benchmark Stock Assessments: Data and Assessment Workshop and Peer Review Process report outlines options for conducting an external peer review of Commission managed species. These options are:

1. The Stock Assessment Workshop/Stock Assessment Review Committee (SAW/SARC) conducted by the National Marine Fisheries Service (NMFS), Northeast Fisheries Science Center (NEFSC).

2. The Southeast Data and Assessment Review (SEDAR) conducted by the NMFS, Southeast Fisheries Science Center (SEFSC).

3. The Transboundary Resources Assessment Committee (TRAC) reviews stock assessments for the shared resources across the US-Canada boundary and is conducted jointly through the NMFS and the Canada Department of Fisheries and Oceans (DFO).

4. A Commission stock assessment review panel conducted by 3-4 stock assessment biologists (state, federal, university). The Commission review panel will include scientists from outside the range of the species to improve objectivity.

5. A formal review using the structure of existing organizations (i.e. American Fisheries Society, International Council for Exploration of the Sea, or the National Academy of Sciences).

Up until 1996, American lobster stock assessments were peer reviewed through the SAW/SARC process. The latest stock assessment, completed in 1999, was peer reviewed through the Commission's External Peer Review process in April 2000. The 2004 American lobster stock assessment was initiated in 2003 when the Commission's Inner State Fishery Management Program Policy Board reviewed and approved the lobster stock as a priority for Commission stock assessments. To improve the storage and accessibility of data used in the lobster stock assessment, a comprehensive database of lobster fishery-dependent (landings and biological sampling) and fishery-independent data was developed. Several stock assessment modeling approaches were investigated and developed by the Lobster Technical Committee for use in this stock assessment. Aan independent model review in 2004 provided guidance to the Technical Committee on the preferred modeling approach for this assessment and future stock assessments. Three members of the Lobster Model Technical Review Panel also served on the Lobster Stock Assessment Peer Review Panel.

The American Lobster Stock Assessment Peer Review was held on August 29-31, 2005 in Boston, Massachusetts.

*Purpose of the Terms of Reference and Advisory Report*

The Terms of Reference and Advisory Report provides summary information concerning the American lobster stock assessment and results of the external peer review to evaluate the accuracy of the data and assessment methods for this species. Specific details of the assessment are documented in a supplemental report entitled American Lobster Stock Assessment Report for Peer Review. A copy of the supplemental report can be obtained via the Commission's website at www.asmfc.org under Managed Species/American lobster or by contacting the Commission at (202) 289-6400.

**Acknowledgments**

The Peer Review Panel thanks ASMFC staff Patrick Kilduff and Toni Kerns (ASMFC) for assisting with the Peer Review and preparation of this report.

The Commission thanks all of the individuals who contributed to the development of the American lobster stock assessment and the terms of reference and advisory report. The Commission extends its appreciation to the American Lobster Stock Assessment Peer Review Panel for its efforts in evaluating the stock assessment and developing this Terms of Reference and Advisory Report (Dr. Michael Sigler, Panel Chair, National Marine Fisheries Service; Dr. Rick Deriso, Inter-American Tropical Tuna Commission; Dr. Richard Methot, National Marine Fisheries Service; Mike Murphy, Florida Fish and Wildlife Conservation Commission; Dr. Terrance Quinn, University of Alaska; and Dr. Doug Woodby, Alaska Department of Fish and Game).

The Commission also thanks the ASMFC American Lobster Technical Committee (TC) and Lobster Stock Assessment Committee (SAC) members who developed the consensus stock assessment report, especially Robert Glenn (Massachusetts Division of Marine Fisheries) for his exceptional work as the chair of the SAC and TC. We would also like to thank Dr. Larry Jacobson (NMFS), Penny Howell (Connecticut Marine Fisheries Division), and Dr. Yong Chen (University of Maine) for their presentation of the stock assessment at the peer review. Members of the American Lobster Stock Assessment Committee include Bob Glenn (Chair), Steven Correia (Massachusetts Division of Marine Fisheries), Penny Howell, Dr. Larry Jacobson, and Carl Wilson (Maine Department of Marine Resources). Members of the American Lobster TC include Bob Glenn (Chair), Tom Angell (Rhode Island Department of Environmental Management, Marine Fisheries Section), Don Byrne (New Jersey Department of Environmental Protection, Bureau of Marine Fisheries) Victor Crecco (Connecticut Marine Fisheries Division), Josef Idoine (NMFS), Dr. Clare McBane (New Hampshire Department of Fish and Game), Kim McKown (New York State Department Environmental Conservation, Bureau of Marine Resources), and Carl Wilson.

The Commission appreciates the efforts of former Commission staff former staff Carrie Selberg in development and review of the American Lobster stock assessment.

## Executive Summary

*Status of the Stocks*

The American lobster resource presents a mixed picture, with stable abundance for the Georges Bank (GBK) stock and much of the Gulf of Maine (GOM) stock and decreased abundance and recruitment yet continued high fishing mortality for the Southern New England (SNE) stock and Area 514 of the Gulf of Maine stock.

<u>GOM</u>: Current abundance of the GOM stock overall is relatively high compared to the 20-year time series and recent fishing mortality has been comparable to the past; however, recruitment for the southern GOM (area 514) has declined (three of the last four recruitment values have been near record lows) and post-recruit abundance has declined to the historical low. Further restrictions are warranted for Area 514 given the persistence of low recruitment and its effect on total abundance, and by implication, egg production.

<u>GBK</u>: The GBK stock appears to be stable; current abundance and fishing mortality are similar to their medians for the 20-year time series. However, the number of traps fished is very high and further increases in effort are not advisable.

<u>SNE</u>: The SNE stock abundance is relatively low compared to the 20-year time series and fishing mortality is relatively high; further restrictions are warranted. The Panel believes the declining trend in population abundance is well established and warrants a reduction in fishing mortality.

The lobster fishery is one of the more unusual fisheries in the world in light of the persistence of both the resource and its fishery despite high levels of fishing mortality that higher than most sustainable fisheries and fishing effort that has continued to increase without effective limits. The Panel recognizes that it would only take a sequence of two to three years of poor recruitment to collapse any component of the lobster resource, and the appearance of extremely low recruitments in recent times in some areas is a cause of concern if not alarm.

*Biological Reference Points*

This Panel concurs with the recommendation from the 2000 stock assessment peer review to pursue alternative reference points, including thresholds and targets, and to cast these in a precautionary context with fishery control rules. The Panel believes that a clear rationale for the ($F_{10\%}$) biological reference point (BRP) should have been presented in the stock assessment report.

The Panel recommends that $F_{10\%}$ be estimated for each of the new stock areas as defined in the stock assessment report (GOM, GBK, SNE) and the fishing mortalities from the most recent time-period of 2001-2003 be estimated. These issues should be addressed so that the Commission can determine whether compliance with Amendment 3 and relative addenda are occurring.

*Data*

The most significant improvement for future assessments would be procurement of complete and unbiased catch information. The lack of completely reported catch (landings and discards) data is a serious flaw in the stock assessment and leads to mis-estimates of lobster abundance and fishing mortality. The Panel reiterates the conclusion of the 2004 Panel that the data available are woefully inadequate for the management needs of this fishery, and that the primary limitation on the ability to manage is limited data rather than choice of models. The Panel recommends a mandatory catch reporting system.

*Model*

The Collie-Sissenwine model results regarding absolute fishing mortality and abundance have uncertainty, but they should not be rejected. The current Collie-Sissenwine model does corroborate other information (primarily the highly and increasingly truncated lobster size composition), indicating that fishing mortality rates have been high for all three stocks of American lobster throughout the modeled time period.

The size-structured model is now on par with similar state-of-the-science models worldwide and should be fully developed to provide quantitative management advice for the American lobster fishery.

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## Terms of Reference for the American Lobster Peer Review

**Term of Reference 1. Compile data needed for stock assessment purposes including commercial, recreational, and discards, updating the database to include the most recent information available.**

The assessment team did a thorough job compiling the available data necessary for conducting this stock assessment. The biological and life history information was updated well and included new information on maturity schedules, molt probability, molt increment, and natural mortality. New information about an observed lobster die-off in the SNE stock was provided and used to support model scenarios using a wide range of values of natural mortality (M) for the years 1997-2003. There were areas where the Panel found inadequate data and had recommendations for improving the data in the future. Landings of lobster, by number, are critical for the assessment but have not been collected in a comprehensive and consistent way throughout the fishery. Estimated commercial landings likely are inaccurate in states where landings have been voluntarily reported, where coverage of seafood dealers has been incomplete, or where fishermen provide annual or monthly landings at the end of each year as part of a recall survey or their license renewal. In addition, no Canadian landings were used in the assessment although they are appreciable for the GOM stock area that lies within Canadian waters. No recreational catch statistics are included in the model, though they are minor and likely to equal only a few percent of the commercial landings. The discard mortality rate is apparently low for lobster captured in traps, but no estimate of the mortality rate was presented. If trap encounter rates are high, then even a low discard mortality rate could result in significant numbers of killed lobsters. There was no estimate of the bycatch mortality from other gears that encounter lobsters, although 2% of the total landings are from non-trap gear. **The lack of completely reported catch (landings and discards) data is a serious flaw in the stock assessment and leads to mis-estimates of lobster abundance and fishing mortality.** We reiterate the conclusion of the 2004 Panel (Hilborn et al. 2004) that the data available are woefully inadequate for the management needs of this fishery and that the primary limitation on the ability to manage is limited data rather than choice of models.

While considerable effort is expended to collect size frequency data from caught or landed lobsters there are several areas where coverage appeared inadequate. Length sample sizes from the fishery are often much lower for the offshore portions of the fishery than for the inshore. This is especially problematic for the GBK stock where most of the landings come from offshore waters. It is unclear whether the accuracy of the size frequency data is sufficient for the current model. The Panel recommends a better designed survey that achieves representative coverage of all segments of the fishing fleet. The future use of a length-based statistical model depends on representative size frequency data.

The number of traps fished is used as an indicator of fishing effort in the “traffic light approach”. However, trends in these data may not be directly related to fishing mortality. Data for a more representative unit of fishing effort, for example number of trap hauls is not available throughout the fishery.

Fishery-independent survey data on population size structure and relative abundance appear to be available in all areas except inshore GOM before 2000. No information was presented on the statistical analysis (General Linear Model) for development of standardized abundance indices or their precision. The 2003 index of recruit abundance in the GOM was discounted as biased low, as discussed under Term of Reference 3, but was still used in the Collie-Sissenwine Model. The NEFSC fall trawl survey used in the GOM assessment model does not cover the inshore waters of that area, partly because sampling in areas of intensive lobster fishing is difficult. Historic survey catch and length frequency information presented to the Panel at the meeting (but not given in the stock assessment report) helped put the more recent abundance levels into a historical context.

**Term of Reference 2. Evaluate and revise if necessary the boundaries of the stock assessment areas as outlined in the last peer-reviewed assessment based on objective criteria.**

The U.S. American lobster resource occurs in continental shelf waters from Maine to North Carolina. The U.S. lobster resource is broken into three stock units as defined in this assessment: GOM, GBK, and SNE (Figure 1). These stock boundaries differ from previous assessments, which were the Gulf of Maine (GOM), Georges Bank and Southern New England Outer Shelf (GBS), and South of Cape Cod to Long Island Sound (SCCLIS) stock areas. The stock boundaries for GOM remain unchanged between assessments, while the name change for the other two stock areas reflects a shift in their common boundary. **The revision of stock boundaries appears reasonable based on between-area differences for size at maturity, abundance trajectories, survey size distributions, and features of larval distribution.**

The differences between the GOM and the GBK stocks should be further investigated because the cited maturity differences could be explained by different levels of biological sampling between inshore and offshore waters. The Panel was concerned that movement of small lobsters from settlement areas, inshore in depths less than 10 m and some of the shallow areas of the GBK stock area to deep areas probably confounds the stock assessment of sub-stocks (i.e., inshore and offshore). The GOM assessment should also include the population dynamics of the lobsters in this stock that are found in Canadian waters.

**Term of Reference 3. For each stock assessment area estimate the current levels and historical trends of factors such as egg production, biomass, abundance, and natural and fishing mortality rates. Characterize uncertainty in estimates.**

**Estimates of fishing mortality and abundance in the stock assessment report are reasonable given the available data.** However**,** absolute levels of fishing mortality and abundance were affected by input parameters in the Collie-Sissenwine model (see model discussion under Term of Reference 5) and the value for some of these parameters, such as relative catchability of pre-recruits and recruits, cannot be independently validated. **Trends in relative quantities are more robust, so they are emphasized in our discussion below regarding status of the population. The Panel agrees with conclusions of the stock assessment report regarding recent trends in the status of the stocks (restated below) and the finding that the level of fishing mortality is high in all areas.**

*Gulf of Maine*

The stock assessment report concluded that "The good conditions in the GOM (Gulf of Maine) stock indicate that recent mortality rates are sustainable. However, effort indicators are negative (i.e. the number of traps fished is very high). This high effort is concurrent with high stock abundance, and is not likely to be supportable if abundance returns to median levels. Conditions are poor in southern GOM (Area 514). The mortality rates are above the threshold and abundance is below the threshold in Area 514. Managers should consider alternate approaches to reducing fishing mortality and rebuilding stock abundance in this portion of the Gulf of Maine."

The Panel concluded that current abundance of the GOM stock overall has been relatively high compared to the 20-year time series and recent fishing mortality has been comparable to the past. Therefore, the Panel does not recommend additional management measures for the entire GOM at this time. However, the Panel believes further restrictions are warranted for Area 514 given the persistence of low recruitment and its effect on total abundance (and by implication egg production).

<u>Gulf of Maine overall</u>: A long-term trend of increasing recruitment and spawning stock egg production continued through 2002. Abundance and recruitment estimates for GOM during 2003 were strongly influenced by very low catches of recruit lobster in the Massachusetts and NEFSC surveys during 2003.

Some factors suggest the low recruit abundance observed in the 2003 survey may have been affected by anomalous conditions. Post-recruitment abundance in 2004 did not decline drastically as might be expected if recruitment had been low in 2003. The summer fishery was delayed, which could indicate that environmental conditions may have been atypical during 2003 when fall surveys took place. The Maine inshore trawl survey did not show a dramatic drop from 2002 to 2003. On the other hand, other factors suggest that recruitment in fact was low during 2003. In particular, recruitment was low for both the NEFSC and Massachusetts surveys during 2003. Cool water is thought to reduce lobster catchability, but bottom temperatures were normal to high during the NEFSC survey in 2003. Recruit and post-recruit indices normally tend to track together due to common environmental effects on survey catchability. In the 2003 NEFSC survey, however, recruit abundance declined independently of post-recruit abundance. Finally, larval settlement data collected in coastal areas off Massachusetts were low during 1996-1998. Links between settlement and recruitment to the fishery have not been clearly established, but low settlement during 1996-1998 might cause low recruitment to the fishery 5-7 years later.

Recruitment estimates for 2003 had little effect on perceived stock status, which is based on average abundance and fishing mortality during the most recent three years (2001-2003). The Panel is concerned with low recruitment in 2003 and urges vigilance in monitoring recruitment in the near future.

<u>NEFSC survey area</u>: Trends in the GOM as a whole and in the NEFSC survey area within the GOM are very similar because abundance in the area surveyed by Massachusetts represents only a small proportion of the total stock. NEFSC recruit indices for male and female lobster combined increased during 1982-2000 and then declined to a low level in 2003. Trends in estimated abundance of females were similar to trends for males during 1982-1997. After 1997, female abundance increased more rapidly than male abundance. As described above, recruit abundance estimates for 2003 are low but possibly suspect. Landings in the GOM were stable between 1981 and 1987, then increased steadily from 1988 to 1999, and have remained at record high levels since.

Abundance estimates for male and female recruits from the Collie-Sissenwine model generally increased over time but declined abruptly in 2003 in response to the 2003 survey observation. Post-recruit abundance increased steadily during 1982-2003. Total estimated abundance increased over time but declined in 2003. The proportion of the fishable stock composed of recruits in the GOM as a whole varied without trend and averaged about 60%. High exploitation rates occurring in years of reduced recruitment are indicative of the fishery's dependence on recruits and lagged adjustment to changing abundance.

Fishing and total mortality for males and females combined varied without trend between 1982 and 1993, then declined steadily until 2002 before increasing abruptly during 2003. Fishing mortality rates for females only declined after 1995, but varied without trend for males. Annual exploitation rates declined steadily during 1982-2002, but increased abruptly in 2003. Landings, recruits, post-recruits, and the stock as a whole are roughly 50% female.

Massachusetts survey area (Statistical Area 514): Trends in the Massachusetts survey area within the GOM were distinctly different from trends in the NEFSC survey area and in the GOM as a whole. Recruitment for the southern GOM (area 514) has declined (three of the last four recruitment values have been near record lows) and led to post-recruit abundance declining to the historical low. Fishing mortality rates were high, but varied without trend from 1982 to 1998, then increased in 1999 and remained above the median since that time. Lobsters in Area 514 were mostly new recruits (75% on average). Landings increased from 1981 to 1990, remained high between 1991 and 2000, and have declined to a time series low in 2003. Landings, recruits, post-recruits, and the stock as a whole are roughly 50% female.

*Georges Bank*

The stock assessment report concluded that "The good conditions in the Georges Bank stock indicate that recent mortality rates are sustainable. However, effort indicators are negative for the stock and further increases in effort are not advisable."

The Panel concluded that the GBK stock appears to be stable; current abundance and fishing mortality are similar to their medians for the 20-year time series.

Abundance of male and female recruits and male post-recruits in GBK during 1982-2003 varied without trend with 2000-2003 estimates of recruitment all above the median value for 1982-2003. Estimates of female post-recruits and egg production increased and are above the 1982-2003 median values in the last five years. The proportion of the fishable stock composed of recruits varied without trend and averaged about 40%.

Landings in GBK were stable and varied without trend. Fishing mortality for the whole stock (sexes combined) varied without trend during 1982-1995 and declined thereafter. Male fishing mortality rates varied without trend, but were higher than female fishing mortality rates. Female fishing mortality rates varied without trend until 1999 and were at or near time series lows in recent years. Annual exploitation rates (total landings over total abundance) varied without trend during 1982-1995 and declined slightly thereafter.

Overall, females comprised 48% of landings, 60% of recruits, 79% of post recruits, and 71% of the stock. There was a slight increasing trend over time in the proportion of female post-recruits and total stock. Higher proportions of post-recruit females may be due to higher mortality in males and management measures that protect females on GBK (protection of ovigerous females and v-notching).

*Southern New England*

The stock assessment report concluded that "In light of the poor stock conditions observed in SNE, the SAC recommends reducing fishing mortality to the target level and rebuilding stock abundance to the target level. The response of the population will also depend on recruitment strength and magnitude of natural mortality."

The Panel concluded that the Southern New England stock is relatively low compared to the 20-year time series and fishing mortality is relatively high; further restrictions are warranted. The Panel believes the declining trend in population abundance is well established so a reduction in fishing mortality is necessary; however because we do not know the cause of the decline or in fact what natural mortality was in recent years, we cannot estimate how much of a reduction in fishing mortality is needed to allow a stock recovery.

<u>Sensitivity testing with M=0.15-0.9 during 1997-2003</u>: Recent empirical evidence suggests natural mortality (M) increased after 1996 for the SNE stock, although the magnitude of the change is unknown. In order to test the sensitivity of the Collie-Sissenwine model to changes in natural mortality, natural mortality from 1997 to 2003 was set to a range of values: 0.15 (no change), 0.40, 0.65, and 0.90. As expected, with higher levels of natural mortality the model produces higher levels of recruits after 1997, but trends in abundance and fishing mortality were relatively robust to changes in natural mortality after 1997.

The most important stock assessment variables (recruit abundance, post-recruit abundance, total abundance, fishing mortality, total mortality, and exploitation rates) from each of the alternative natural mortality runs were converted to trends. Recruit abundance estimates in all runs varied without trend until 1994 and then increased to a peak level during 1995-1998. All runs show recruitment declining to low levels during 2001 to 2003. Post-recruit abundance estimates in all runs varied without trend until 1996, then increased to a peak in 1997, and declined thereafter to a time series low in 2003. Total abundance estimates increased from 1996 to 1998 in all runs and declined afterwards. Recruits were 61-72% of the fishable stock. Egg production estimates for the run with M=0.65 (the only run with egg production shown to the Panel) declined continuously from 1999 to 2003.

Exploitation rates are difficult to interpret when natural mortality changes because they depend on both natural and fishing mortality. In particular, exploitation rates do not measure fishing pressure in a consistent fashion when natural mortality rates change over time. In model runs with natural mortality greater than 0.15 during recent years, exploitation rates varied without trend prior to 1996 and were below average after 2000. In contrast, exploitation rates from the run with constant natural mortality during recent years were near average after 2000.

*Characterize uncertainty in estimates*

Bootstrap estimates of the coefficient of variation of abundance and fishing mortality estimates are produced for each of the management regions. They generally show that estimates have a roughly 20% coefficient of variation. However, the coefficient of variation underestimates true uncertainty because some uncertainties were not included in the bootstrap procedure, such as limitations to the data discussed under Term of Reference 1, parameters held constant in the model, and model structure limitations discussed under Term of Reference 5.

**Term of Reference 4: Address and incorporate as applicable recommendations from the 2000 American Lobster Peer Review.**

The 2005 stock assessment addressed many of the issues identified in the 2000 American Lobster Stock Assessment Peer Review Report. While some significant improvements were made to the assessment in response to those recommendations, some of the recommendations remain as priority issues. Those recommendations are reiterated and expanded here using the same hierarchy of categories as in the 2000 Peer Review Report.

2000 Term of Reference 1. Review and evaluate assessment methods used to assess American lobster stocks, including, but not limited to the following:

*Quantity and quality of input data for models (in particular, trawl survey abundance indices and catch in numbers for DeLury models).*

As in 2000, one of the most critical issues pertains to the survey and catch data used as input for the Collie-Sissenwine model (modified DeLury model). The 2005 Panel notes that it appears from the data presented that the size composition data and landings data may not be representative of the lobster populations and catches. **The Panel recommends a mandatory catch reporting system. The Panel also recommends that size composition data be collected using statistically efficient methods, with sampling allocated to areas based on a sampling plan that identifies variability within and between areas.**

Tables of catch and survey data by area should show sample sizes and coefficients of variation, or comparable measures of variability. Tabular data showing relative sampling intensity (e.g., Table 5.1.1.2.1 of the 2005 ASMFC Lobster Stock Assessment Report) should show the actual number of lengths and landings, and not just the quotient. As in the 2000 report, the Panel asks that future stock assessments provide maps showing the spatial relationships between survey sampling stratification and landings. Tabular landings data should be of sufficiently fine spatial resolution to allow for evaluation of changes through time of the relationships between inshore and offshore landings.

The 2000 Panel requested an evaluation of potential differences in night and day survey samples due to the nocturnal behavior of lobsters, with separate evaluations of nearshore and offshore stations. This was not provided in the 2005 assessment.

*Validity and utility of length cohort analysis and modified DeLury model, including model assumptions and parameter estimation techniques.*

The 2005 stock assessment followed on the heels of a review of models conducted in 2004; hence, some of the concerns raised by the review Panel in 2000 have been addressed in the 2005 assessment or were obviated by the 2004 model review. Additional issues are identified under the present Term of Reference 5.

As of yet unresolved are concerns with the estimated q-ratios, which relate catchability of recruits to that of post-recruits. The 2000 Panel identified empirical estimates of the q-ratios as a critical need and suggested tag recapture approaches, comparisons of spring and fall survey data, and sensitivity analyses, none of which were provided in the 2005 assessment for the Collie-Sissenwine model (modified DeLury model).

*Methods used to blend multiple modified DeLury model results into unit stock estimates of fishing mortality.*

The algorithms for blending the Collie-Sissenwine model results were well described in the 2005 assessment report. Missing was a recommended evaluation of potential sensitivity or bias with respect to movement of lobsters, for example, of small lobsters to inshore areas or of adults to offshore areas.

*Characterization of uncertainty associated with model results, reference point estimation, and sensitivity to model parameters.*

The 2000 peer review gave clear recommendations to conduct sensitivity analyses to determine how potential changes in the catch matrix and uncertainty in natural mortality might affect model results. To this end, only potential uncertainty in natural mortality in the SNE area was addressed, but changes in goodness of fit with varied natural mortality were not presented. The recommendation to provide simple plots of the frequencies of outcomes to illustrate the uncertainty in the measures was not followed; however, coefficients of variation were provided for estimates of abundance and of fishing mortality by area and by year.

*Potential validity and utility of new assessment model (Mark model) developed for this assessment.*

Modeling approaches were reviewed in 2004 and recommendations were made in that review regarding the Collie-Sissenwine model and continued development of a size-structured model. The 2004 recommendations largely supercede this 2000 term of reference item, with the exception of a recommendation to include a yield-per-recruit analysis for male lobsters in future assessments, and a recommendation to develop a predictive capability using trawl survey catches of small (pre-recruit) lobsters.

2000 Term of Reference 2. Evaluate the current status of American lobster stocks, and trends in abundance and fishing mortality, by examining model based indices and alternative indices derived from fishery dependent and independent data.

The 2000 Panel recommended a precautionary approach, highlighting the dependence of the current fishery on recruitment and the potential decline in egg production should recruitment fall off. Citing the potential dependence of inshore areas on offshore egg production, the 2000 Panel recommended a more precise definition and description of traditional and emerging fishing grounds, particularly the nearshore federal waters where catch reporting is not adequate. An improved definition and description of fishing grounds is still needed.

In regards to alternative indices, the 2005 assessment presented a traffic light approach and a target/threshold approach, discussed in some detail below.

2000 Term of Reference 3. Comment on explanations for stable and increasing abundance despite the low estimates of recent egg production per recruit.

The 2000 Panel made no recommendations on this term of reference.

2000 Term of Reference 4. Evaluate methods used to estimate the overfishing definition ($F_{10\%}$) for American lobster, and if appropriate, suggest additional reference points or analyses which could be used to define overfishing.

The 2000 Panel felt it essential to have biological reference targets that are distinct from thresholds, to have reference points that are biomass-based, and to cast these in a precautionary context with fishery control rules. **This would be a major change for the American lobster fishery, yet this Panel is in complete agreement.** The 2005 assessment presented two approaches. One identified thresholds equal to the recent median values for fishing mortality and abundance in each area and targets that were one standard deviation away from the recent medians. This approach, coupled with the graphical "quadrant" analysis, is a reasonable step in the right direction; however, the use of the recent median values as thresholds requires further consideration, as this approach institutionalizes high fishing mortality as normal and institutes a shifting baseline and a baseline without sufficient theoretical support. The second was a "traffic light" approach, which is a good step towards a more easily understood compilation of an otherwise confusing suite of indicators. While this is a sensible approach, the traffic light indicators are relative to recent levels and trends, and a more theoretically sound basis for evaluating status of the stock is needed. Further, the traffic light baseline presumes that the median is an acceptable target level, which is contrary to the proposed threshold approach. The size-structured modeling approach (under development) is expected to offer more reliable estimates of abundance and fishing mortality for comparison to reference points. Further discussion of medians as reference points is provided under the present Term of Reference 6.

2000 Term of Reference 5. Review management and research recommendations and identify any additional research necessary to improve future stock assessments for American lobster.

The 2000 Panel recommendations included short-term research needs that could have been met by the 2005 assessment timeline, as well as longer-term needs. Several of the short-term research recommendations were met. Those not met that are still applicable:

- Variance estimates should be presented for landings and survey data, where possible. All zero-catch survey hauls should also be included.

- Spatial mapping of survey abundance indices by size and sex should be conducted.

- Diurnal variation in survey catch rates should be evaluated.

- Early indicators of trends in smaller molt groups should be developed using existing trawl survey data. For maximum utility, analysis and review of pre- recruit indices should be conducted on an annual basis, not on an intermittent basis in the principal stock assessment cycle.

- Predictions of egg-per-recruit models with respect to data from fishery-dependent and fishery-independent sources should be validated. This includes projected growth trajectory, size frequency, size specific sex ratios, fraction egg-bearing, fraction soft shell and fraction v-notched.

- Changes in egg production and yield associated with various changes in minimum legal size and fishing effort should be explored.

- Yield-per-recruit analyses for male lobsters should be included in future assessments for evaluation of growth overfishing.

The 2000 Panel also made recommendations on coordination issues. These were largely unmet:

- Environmental and ecosystem factors, and evaluation of these factors, should be included in the assessment process.

- Collaboration with Canadian stock assessment biologists should be expanded from the existing structure of largely informal links between specific individuals and assessment groups to a more formalized and ongoing program of exchange of technical information on assessment approaches and stock status.

**Term of Reference 5. Use new models and input parameter estimates developed as appropriate, as well as any input parameter estimates and models used in the last stock assessment.**

*Collie-Sissenwine Model*

The primary approach to assess the abundance and mortality of American lobster is application of the Collie-Sissenwine model. The Collie-Sissenwine model is a simple model with limited data requirements. Given suitable data and model configuration, the Collie-Sissenwine model will provide reliable estimates of a time series of fishing mortality, stock abundance, and recruitment. One goal has been to provide management advice on overfishing by comparing the Collie-Sissenwine model estimates of fishing mortality (F) to the level of fishing mortality that would reduce the production of eggs per recruit to 10% of the level that is expected if there was no fishing ($F_{10\%}$). This is a standard approach worldwide and in the U.S. for providing quantitative management advice; the primary differences being in the data and models used to estimate fishing mortality, and in the level and basis for the selected management targets and limits.

Application of the Collie-Sissenwine model to American lobster is hampered by several technical factors discussed below. These factors are not new. They have been discussed by previous review Panels and evaluated by the stock assessment team to the extent possible, but resolution is not straightforward due to the details of lobster life history and spatial distribution, limited relevant data, and limited flexibility of the Collie-Sissenwine model. The Collie-Sissenwine model will provide its most robust estimates in terms of trends in fishing mortality and stock abundance over the time period modeled. Results in terms of absolute fishing mortality and abundance are more sensitive to model configuration issues and assumptions and various biases may remain in the current configuration. However, all models are approximations of nature and have some degree of imprecision and inaccuracy. **The Collie-Sissenwine model results regarding absolute fishing mortality and abundance have uncertainty, but they should not be rejected. The current Collie-Sissenwine model does corroborate other information (primarily the highly and increasingly truncated lobster size composition) indicating that fishing mortality rates have been high for all three stocks of American lobster throughout the modeled time period.**

*Size-Structured Model*

The best way to move forward and improve the modeling of American lobster is to transition in the next assessment cycle to the new size-structured model. Although some of these improvements could be made to the Collie-Sissenwine model, the new model provides a better foundation to implement these changes. For example, the previously recommended linkage of male and female recruitment levels in Collie-Sissenwine model would be naturally implemented in the new model. Major advantages of the new model include the ability to: (1) obtain information from size composition data and from multiple surveys simultaneously, (2) match the seasonality of the fishery and of the lobster life history, (3) provide completely comparable estimates of fishing mortality (F) and F-based reference points (including $F_{10\%}$), (4) estimate parameters that are equivalent to the troublesome pre-recruit to recruit catchability ratio in the Collie-Sissenwine model, and (5) provide confidence intervals that include nearly all major sources of variability. **The size-structured model is now on par with similar state-of-the-science models worldwide and in the U.S. to provide quantitative management advice for valuable fisheries.** An explicit new review is not attempted here. One area for additional refinement is in the relative weighting of information from various sources.

*Estimation of changes in natural mortality*

Additional modeling efforts were directed towards estimating changes in natural mortality (Appendix 4, Howell and Crecco, stock assessment report), whereas a counter-argument was raised in a subsequent section (Appendix 4, Correia). The estimability of natural mortality (M) has been a key issue in stock assessment science for decades (Quinn and Deriso 1999). Natural mortality is usually treated as a fixed constant from auxiliary information for which a variety of approaches can be used (Vetter 1988, Quinn and Deriso 1999, section 8.3). In the past, direct estimation of natural mortality in stock assessment models has been attempted with varying success. Frequently, there is not enough contrast in the data to provide precise estimation of natural mortality; the model fits the data equally well with different values of natural mortality. Recently, there have been several stock assessments in which natural mortality does seem to be reliably estimated. In a simulation study of estimability of natural mortality, Fu and Quinn (2000) found that natural mortality is estimable when there is a precise index of population abundance (say CV < 0.25). Their study assumed that the underlying model structure is correct. So, estimation of natural mortality may be problematic when variability in the abundance index (or indices) is high or when the model is incorrectly specified. With the Collie-Sissenwine model appearing to fit the annual survey at least as well as one would expect given the ~30-40% variability in each survey estimate, there is no additional information in the residuals to provide inference about changes in natural mortality. Therefore, the estimability of natural mortality for American lobster is highly uncertain. We concur with Correia's conclusion (Appendix 4, stock assessment report) that estimation of natural mortality is confounded with survey catchability and survey error.

We strongly recommend that any future model-based investigation of natural mortality occur within the assessment model, not independently of it. We discourage further investigation of natural mortality independently of the assessment model like that completed by Howell and Crecco in Appendix 4. Our recommendation reiterates the 2004 Panel conclusion: "this concept (time-varying natural mortality) is best incorporated by modifying the Collie-Sissenwine model and that further development of FIZ should be discontinued". We also warn that definitive results, even for modeling within the assessment model, are not likely.

Progress in estimating changes in natural mortality will depend on providing additional data to the assessment model. For example, shell disease and increasing water temperature are invoked as causes of increasing natural mortality in the SNE lobster stock; changes in predatory fish abundance is mentioned as a factor that could change natural mortality and the possibility of density-dependent natural mortality and growth changes also is mentioned. Further research on the causes of changes in natural mortality (and catchability) also may help quantify the relation between these variables.

*Improvements to the Collie-Sissenwine model*

The Collie-Sissenwine model was improved by replacing the approximate method for calculating fishing mortality with the exact method. However, even this approach only approximately models the true nature of fishing mortality because fishing intensity varies seasonally. The quarterly configuration of the new size-structured model is a further improvement in this regard.

*Factors Influencing Model Performance*

<u>Spatial Patterns</u>: The realignment of the three major stock areas is an improvement that more closely matches available information on stock structure

of lobster. However, within each stock area there is a pronounced inshore-offshore pattern with small lobster dominating inshore and large lobster offshore. This is probably due to a combination of settlement occurring predominately nearshore, longer history of high fishing mortality nearshore, and slow rates of inshore-offshore mixing with net movement of lobster towards the offshore as they grow/age. There is not sufficient information to disentangle these various processes and the current practice of analyzing the population in survey sub-areas and blending model results is acceptable. However, such an approach assumes that inshore-offshore movement is negligible and alternatives should continue to be considered in the future. This is especially true in the GOM where the NEFSC offshore trawl survey is used as the abundance index in an assessment area where most of the catch occurs in the Maine nearshore zone. This inshore-offshore issue is not unique to the Collie-Sissenwine model. The new size-structured model's ability to incorporate multiple surveys, each with its own unique selectivity pattern relative to the stock-wide abundance, will provide an alternative, but will not explicitly address the inshore-offshore movement issue as currently configured.

<u>Calculation of pre-recruit index</u>: Calculation of Collie-Sissenwine model's pre-recruit index from the abundance of pre-recruits in the fall survey is complicated due to the seasonal timing of the survey, molting, and major fishery. This calculation cannot be done in a way that provides an input that exactly matches the assumptions of the Collie-Sissenwine model's annual time step. Further, the result is probably confounded with the pre-recruit to recruit catchability ratio (q-ratio or $\phi$) used in the model. It is not clear how the seasonality approximations caused the bias identified in the 2004 model review, or why an adjustment could not be made in the current Collie-Sissenwine model. This appears to be one of the major issues hindering exact interpretation of the fishing mortality estimates from the current Collie-Sissenwine model. The proposed size-structured model does not require calculation of a separate pre-recruit index, and the quarterly time steps of the size-structured model would provide a more flexible approach to dealing with the fundamental factors that confound calculation of the current pre-recruit index.

<u>Catchability ratio</u>: The recruit to post-recruit catchability ratio in the surveys has been identified previously as a factor influencing the Collie-Sissenwine model results. There was no new information with which to guide adjustments of these ratios, which are partly related to the inshore-offshore distribution pattern noted above and partly due to the different nets used by the nearshore and offshore surveys. Given the uncertainty in the exact value of this ratio and the sensitivity of the model result to the ratio, a more complete assessment would incorporate the uncertainty in the catchability ratio into the uncertainty in model outputs.

<u>Variance calculations</u>: A bootstrap approach is used to calculate the variance in output quantities such as fishing mortality and abundance. As noted in the 2000

review, such an approach only incorporates variability due to deviations between survey data observations and the model's predicted values for these observations. Variability in catch data and uncertainty in fixed model inputs (such as natural mortality and pre-recruit catchability ratio (q-ratio or $\phi$)) do not contribute to the variance calculation. A more complete portrayal of variability should be a goal of future model developments.

Cross-correlated error for recruit and post-recruit surveys: For most years of the surveys, the recruit and post-recruit indices fluctuate in synchrony. The recruit index does not appear to act as a leading indicator for future changes in post-recruit abundance. Annual fluctuations in survey catchability appear to affect recruit and post-recruits similarly. Speculatively, this is partly due to high fishing mortality, which leads to little persistence in the post-recruit stage, and partly due to the variability in growth which causes annual recruitment fluctuations to be spread across the recruit and post-recruit size ranges. Previous work with simulated data showed no degradation in Collie-Sissenwine model performance due to such a correlated pattern in survey data, but it would be desirable to incorporate such a pattern into future Collie-Sissenwine model implementations, particularly the bootstrap estimation of variance.

**Term of Reference 6. Update the current biological reference point ($F_{10\%}$) and develop additional biological reference points including limits, thresholds and targets for F and biomass if feasible. Characterize uncertainty in stock status.**

*Current biological reference point ($F_{10\%}$)*

Amendment 3 defines overfishing for the American lobster resource as a fishing mortality rate that corresponds to a long-term reduction in egg-production per recruit to 10% of that of an unfished population ($F_{10\%}$). The management measures approach does not involve the specification of a total allowable catch limit, but rather uses minimum size limits, protection of egg bearing females, and trap limits to attempt to achieve this goal. **A clear rationale for this biological reference point (BRP) should have been presented in the Stock Assessment Report.** The Panel notes that previous stock assessments have shown that recent fishing mortality is generally higher than this biological reference point. The Panel also notes that there is no evidence to suggest that this biological reference point, even if achieved, would lead to a stable population capable of producing sufficient egg production to sustain the resource. The Panel also recommends that the management goals for this resource from the fishery management plan be clearly stated in the introduction of the Stock Assessment Report.

The 2005 Stock Assessment Report updated the $F_{10\%}$ threshold values for stocks of American lobster. The update is a "turn-of-the-crank" assessment flowing from the previous 2000 stock assessment. The previous stock areas are used

(Gulf of Maine (GOM), Georges Bank and southern New England offshore [GBS], south of Cape Cod to Long Island Sound [SCCLIS]), and the updated values are compared with recent fishing mortality in Table 7.7.1 of the current stock assessment report. Changes in $F_{10\%}$ occurred because of use of an updated life history model, new growth parameters, and changes in management measures. The changes to the thresholds by area are from 0.34 to 0.31 for GOM, from 0.29 to 0.21 in GBS, and from 0.84 to 0.35 for SCCLIS. Table 7.7.1 further shows that average fishing mortality from 1995 to 1997 is well above these values (0.65 GOM, 0.45 GBS, and 1.16 SCCLIS).

Table 7.7.1 displays results of the 2005 Stock Assessment Report, which does not include the new stock areas (GOM, GBK, SNE) used in the current assessment, nor does it include fishing mortalities from the most recent time-period 2001-2003. **This should be remedied so that Atlantic States Marine Fisheries Commission can determine whether compliance with Amendment 3 and relevant addenda is occurring (see appendix A for LSAC submitted results for fishing mortalities for the most recent time period 2001-2003).**

*Additional biological reference points*

The current (2005) stock assessment report proposes new biological reference points as targets and limits for both fishing mortality and abundance (not total biomass or egg production). The limit biological reference point is the median value estimated from the Collie-Sissenwine model over the time-period of the assessment and is a proposed management threshold (to stay away from). The target biological point is derived from the limit biological reference point by creating a buffer equal to one standard deviation. For precaution, the fishing mortality buffer would be subtracted from the median, and the abundance buffer would be added to the median.

The analysts' motivation for developing this alternative was guidance from the 2004 panel review of American lobster models, which suggested that biological reference points based on trends in fishing mortality and abundance would be more robust than biological reference points based on absolute values of fishing mortality and abundance. This suggestion was based on simulation studies using older versions of the Collie-Sissenwine model. The stock assessment report also follows the recommendation from the 2000 review for a separation of targets from thresholds. Such a separation is advisable given the uncertainty in the model results, the time lag between settlement and entry to the survey and fishery, and the lack of direct controls on fishing mortality. As an aside, these standard errors are underestimated due, at least, to the lack of inclusion of uncertainty in catch, natural mortality, and recruit catchability.

Values of alternative biological reference points for fishing mortality and abundance are given in Table 9.2.1 of the 2005 report. The targets and limits for fishing mortality are 0.67 and 0.76 for GOM, 0.31 and 0.34 for GBK, and 0.74 and 0.82 for SNE. In contrast, recent fishing mortalities (average) are 0.54 for GOM, 0.29 for GBK, and 0.84 for SNE. A cursory glance at the time series suggests that the median fishing mortality for years that produce median recruitment is similar to median fishing mortality for the entire series, suggesting that recruitment overfishing has not taken place as of yet.

The Panel notes that the sensitivity of model results to varying natural mortality, the pre-recruit catchability ratio (q-ratio or $\phi$), and other factors was not reanalyzed with the new Collie-Sissenwine model configuration. **The Panel was not convinced that sufficient evidence is available to conclude that absolute values of fishing mortality and abundance are so substantially biased as to be useless comparisons with biological reference points**. The Panel does support the consideration of alternatives that are based on relative trends in fishing mortality and abundance. Therefore, the Panel believes that the magnitude of current fishing mortalities is high, which is consistent with the narrow size distribution of the lobster resource near its legal minimum size and it being far lower than the growth capacity of the species.

The alternative biological reference points cannot be viewed as proxies for measuring compliance with Amendment 3. Instead, the approach sets a new objective to be achieved that deserves further consideration by the Atlantic States Marine Fisheries Commission. Biologically, the objective appears to be to determine interim biological reference points for a short transitional period. After the transitional period, a length-based stock assessment model will replace the Collie-Sissenwine model (and better use the data at hand), and a new management strategy evaluation will take place to recommend a replacement for $F_{10\%.}$ The proposed objective essentially states that the median fishing mortality in the past should be viewed as a limit to be avoided in the future, with a reduction based on the variability in past estimates of fishing mortality. The Panel fully endorses the transition to a length-based model and management strategy evaluation to determine long-term objectives, but it has some concerns about the interim biological reference points based on median performance.

The choice of a management objective is the business of managers and not scientists. What scientists can comment on is the logic of the objective and the ability to achieve long-term stability of the resource. In the present case, results of current stock assessments show that fishing mortalities on the order of the median have generally not reduced the abundance of the lobster population, although there are some current uncertainties about this in Area 514 of the GOM stock area and the entire SNE stock area (and generally low abundance of large lobster). However, there is no formal analysis of projections of future abundance (rebuilding analysis), so that no strong statements can be made about whether the alternative biological reference points will achieve its objective. The Panel recommends that future assessments investigate spawner-recruit relationships for use in forecasting future recruitment and abundance. These forecasts will then substantiate whether a recommended fishing mortality rate will achieve the set objective to maintain or rebuild a stock.

Furthermore, using the median as a limit explicitly implies that median fishing mortality is too high. The rationale for this supposition is consistent with the old $F_{10\%}$ approach which indicates that reductions in fishing mortality are needed throughout the stock areas. It cannot be reiterated too strongly that the baseline period is a time in which the lobster stocks are experiencing high fishing mortality, truncated size distribution and near disappearance of large lobsters, and persistence due to sufficiently high recruitment levels. The various factors in the trend analysis do not and cannot place the recent trends in a longer historical context that includes periods of low fishing mortality. Evidence against the implication that fishing mortality is too high is that median fishing mortality has not caused persistent recruitment failure.

In conclusion, there are both pros and cons in the alternative approach of using medians for biological reference points. Pros include using empirical and relative trends in fishing mortality and abundance in developing the biological reference points. Cons include lack of evidence that the Amendment 3 objective can be achieved and the possibly incorrect implication that fishing at median values of fishing mortality has been detrimental.

*Panel recommendation for choice of reference points*

The $F_{epr\%}$-type approach is preferred in the long run because this approach has strong theoretical support in the fisheries literature and is commonly used to guide fisheries management. The Panel recommends a transition to a length-based model with an integrated $F_{epr\%}$ calculation and a management strategy evaluation to determine long-term objectives and evaluate the optimal value of $F_{epr\%}$.

In the interim, a median F approach is technically acceptable (although the Panel has several concerns). The Panel supports the consideration of alternatives that are based on relative trends in fishing mortality and abundance. However the alternative biological reference points cannot be viewed as proxies for measuring compliance with Amendment 3.

*Uncertainty*

While there are substantial sources of uncertainty in the assessment, the overall approach of applying the Collie-Sissenwine model to lobster data is reasonable. Bootstrapping provides estimation of uncertainty (albeit understating it to an unknown degree). Having a 20-year track record of historical abundance and fishing mortality presents a clear picture of trends in stock status.

However, it is the future that leads to the greatest peril for the lobster resource. In the mid-1980s, respected scientist Vaughn Anthony of Woods Hole (in personal communication with Panel member Quinn) was astounded that the lobster fishery had persisted to that time due to continuously high fishing mortality in excess of what is viewed to be sustainable around the world. He just shook his head at the approach of fishing on the edge and gambling on continued recruitment. Even 20 years later, the lobster resource has not collapsed and has even increased in some areas. **Nevertheless, it would only take a sequence of two to three years of poor recruitment to collapse any component of the lobster resource, and the appearance of extremely low recruitments in recent times in some areas is a cause of concern if not alarm.** Until the harvest strategy is revised to provide a buffer of mature adult spawners to cover the bad times, lobster fishery management is a time bomb waiting to explode, its fuse lit by recruitment failure.

*Additional comments*

Management Strategy Evaluation: "Management Strategy Evaluation (MSE) is an approach that assesses the performance of a range of management strategies (e.g., how much harvest is appropriate) against a set of management objectives (e.g., maintaining biomass or a certain fishing rate), and allows the evaluation of the tradeoffs among different management strategies. They evaluate how sensitive these strategies are to uncertainty (e.g., uncertainty about climate regime, how stocks are distributed spatially, and sampling effectiveness) and are also used to evaluate an implemented strategy against the predictions of the MSE" (from Marasco et al. 2005; see also Goodman et al. 2002).

Median values as biological reference points: There are problems with using median fishing mortality and median abundance as the limits of a new harvest policy. As mentioned above, a critical problem is the implication that median fishing mortality is the appropriate point for expressing concern about the stock's ability to maintain itself. There is no clear evidence that this is the appropriate point. A MSE is needed to determine the appropriate point. The continual use of median fishing mortality creates a moving target that cannot be achieved. Each year, the median changes, so if fishing mortality goes up, so does median fishing mortality, and vice versa. If median fishing mortality is a limit, then roughly half the time it will be exceeded, even when the stock dynamics are stable. One potential fix for this problem is to establish a fixed period for its calculation. The time period could be a set of years in which fishing mortality was at a level producing favorable recruitment.

Other biological reference points for consideration: MSE should be used to determine which harvest policies are robust to the uncertainties in stock dynamics and stock assessment inputs. The classic biological reference point based on maximum sustainable yield should be one candidate under consideration in developing new biological reference points. All population models with feedback between spawning populations and recruitment (including constant recruitment) have maximum sustainable yield parameters implicitly (Quinn and Deriso 1999). Stock assessment authors should perform spawner-recruit analysis (possibly including environmental variables) to investigate this feedback and to attempt to understand factors affecting recruitment. This information may aid development and justification for a reference point based on egg production (such as $F_{10\%}$ or some other level). One advantage of the length-based model is its ease of use for management strategy evaluation. Its more explicit treatment of size composition leads to internal calculation of biological reference points in a consistent manner.

Links between assessment and management: The current management system uses indirect measures to attempt to reduce fishing mortality, including v-notching of berried females, minimum and maximum size limits, area-specific measures, etc. An open question remains: How do these measures translate into reductions in fishing mortality? Studies should be conducted to determine these linkages between management actions and desired fishing mortality.

Traffic light summary: The stock assessment authors use the traffic light approach to summarize and visualize assessment results. The main advantage is the ability to summarize results from multiple variables on a single page. But there are several problems with its current implementation.

1. The authors use the 25th and 75th percentiles to distinguish between poor, neutral, and good values for a variable. This can be misleading, because 25 percent of the values are designated as poor and 25% are designated as good, while additional consideration might show that all values are poor or good. The authors should consider different binning criteria than the use of percentiles to avoid forcing some data points to be poor, when they really are not. Criteria based on absolute magnitudes are necessary to avoid the over or understatement of such quality designations. This same criticism also applies to the median-based limit and target approach.
2. The choice of categories to present can induce subtle and subjective conclusions. For example, the presentation of exploitation rate and/or total mortality instead of fishing mortality can create a designation of adverse fishing mortality effects when natural mortality increases. Secondly, the presentation of data and model results simultaneously can give undue weighting to data, which influence both categories. Traffic light tables should minimize presentation of data inputs, especially data inputs that have already been used in model results. In addition, model results should be given primary focus in traffic light tables through careful presentation. The inclusion of other information not used in the model should not dominate the traffic light presentation.

Forecasting: Stock assessment authors should consider two lines of inquiry to improve forecasting of future abundance. First, a projection system should be set up for short-term projections to evaluate the efficacy of management measures. Recruitment is forecast from spawning stock and environmental information (including the possibility of constant recruitment from a time period of conditions thought comparable to what would occur in the future), then other size or age classes are computed through propagation in the population dynamics model. Secondly, there should be an investigation of whether an index of recruitment can be used to foretell bad recruitment events. It is possible that the settlement index or an index based on young pre-recruits would be useful to forecast recruitment. Even if one does not know why bad recruitment events occur, they can be anticipated or explicitly considered in management strategy formulation and evaluation. No matter what the cause, reductions in fishing mortality should take place when reductions in abundance are anticipated.

**Term of Reference 7. Identify research recommendations to improve future assessments.**

**The most significant improvement for future assessments would be procurement of complete and unbiased catch information.** The 2000 Panel made a similar recommendation calling for a standardized mandatory reporting system for American lobster fishermen. The lack of complete landings is a serious flaw in the stock assessment. This flaw in the data collection cannot be corrected through modeling improvements, such as a size-structured assessment. Additionally, Canadian landings data should be incorporated into the current Collie-Sissenwine model and the size-structured model under development.

Recent efforts to use lipofuscin methods to age lobsters appear promising and should be continued for the New England stocks. Similarly, efforts to develop a settlement index based on directed surveys should be continued and expanded to cover additional areas if the method proves feasible and useful.

Of great concern to the Panel is the uncertainty that current recruitment levels will continue. The Panel recommends that hypotheses be developed for the mechanisms that continue to sustain the fishery despite high fishing mortality, and that these hypotheses be tested with appropriate research efforts.

The Panel also recommends that an evaluation be made of the risk associated with management recommendations. In particular, there is an unknown but substantial risk that management measures intended to limit effort or to make minor changes to legal sizes, may be ineffective in addressing stock collapse should recruitment decrease. This evaluation needs to seriously consider the long time lag between the beginning of a persistent recruitment decrease and initiation of an effective management action.

## Advisory Report

### Status of Stocks

The American lobster resource is one of the most important natural resources in the northeastern United States and has provided an important component of the region's economy for hundreds of years. In addition, **the lobster fishery is one of the more unusual fisheries in the world in light of the persistence of both the resource and its fishery despite high levels of fishing mortality, which are larger than most sustainable fisheries in the world, and fishing effort, which has continued to increase without effective limits.** The resilience of this population to harvesting may be due to unusual factors in its life history or environment. One hypothesis is that throughout the lobster population, unknown refugia exist, which produce the recruits that sustain the resource. Another hypothesis is that the high level of effort in the pot fishery has created an "artificial feeding" program for younger lobsters to enhance their growth and survival. Whatever the true factors are, the key point is that they are largely unknown. Therefore our ability to predict the sustainability of the lobster resource is limited at best. Further research and analytical efforts to identify the key factors affecting lobster recruitment and growth will aid greatly in rational management of the lobster population.

**The American lobster resource presents a mixed picture, with stable abundance for the GBK stock and much of the GOM stock and decreased abundance and recruitment yet continued high fishing mortality for the SNE stock and Area 514 of the GOM stock.**

*Gulf of Maine*

Current abundance of the GOM stock overall is relatively high compared to the 20-year time series and recent fishing mortality has been comparable to the past; however, recruitment for the southern GOM (area 514) has declined (three of the last four recruitment values have been near record lows) and post-recruit abundance has declined to the historical low. Further restrictions are warranted for Area 514 given the persistence of low recruitment and its effect on total abundance, and by implication, egg production.

*Georges Bank*

The GBK stock appears to be stable; current abundance and fishing mortality are similar to their medians for the 20-year time series.

*Southern New England*

The SNE stock is relatively low compared to the 20-year time series and fishing mortality is relatively high; further restrictions are warranted. The Panel believes the declining trend in population abundance is well established and warrants a reduction in fishing mortality. However, because we do not know the cause of the decline or in fact what natural mortality was in recent years, we cannot estimate how much of a reduction in fishing mortality is needed to allow a stock recovery.

**Stock Identification and Distribution**

The U.S. American lobster resource occurs in continental shelf waters from Maine to North Carolina. The U.S. lobster resource is broken into three stock units as defined in this assessment: GOM, GBK, and SNE (Figure 1). These stock boundaries differ from previous assessments, which were the GOM, Georges Bank and Southern New England Outer Shelf (GBS), and South of Cape Cod to Long Island Sound (SCCLIS) stock areas. The stock boundaries for GOM remain unchanged between assessments, while the name change for the other two stock areas reflects a shift in their common boundary.

**Management Unit**

The management unit for American lobster is the entire Northwest Atlantic Ocean and its adjacent inshore waters where lobsters are found, from Maine through North Carolina. The Atlantic States Marine Fisheries Commission (ASFMC) manages the lobster fishery in state waters (0-3 miles from shore) and the NMFS manages the lobster fishery in federal waters (3-200 miles from shore), both under the authority of the Atlantic Coastal Fisheries Cooperative Management Act. The fishery management plan provides for management of lobster throughout their range.

For management purposes, the management unit is subdivided into seven areas: Area 1 - Inshore GOM; Area 2 - Inshore SNE; Area 3 - Offshore waters; Area 4 - Inshore Northern Mid-Atlantic; Area 5 - Inshore Southern Mid-Atlantic; Area 6 - New York and Connecticut State Waters (primarily Long Island Sound); and Outer Cape Lobster Management Area.

**Landings**

The U.S. lobster fishery is conducted in each of the three stock units: the GOM, Georges GBK, and SNE. Each area has an inshore and offshore component to the fishery, with the inshore fishery dominating in the GOM and SNE, and the offshore fishery dominating in the GBK. Total landings were relatively constant at 14,000 mt through the late 1970s. Since then, landings have doubled, reaching 37-38,000 mt in 1997-98 and dropping to 33,000 mt in 2003.

*Gulf of Maine*

The GOM supports the largest fishery, constituting 74% of the U.S. landings between 1981 and 2003, and 85% between 2001 and 2003. Landings in the GOM were stable between 1981 and 1989, averaging 14,700 mt, then increased dramatically from 1990 (19,200 mt) to 1999 (30,000 mt), remaining at record levels since (2000-2003 average of 30,300 mt) (Table 1).

*Georges Bank*

GBK constitutes the smallest portion of the U.S. fishery, averaging 5% of the landings from 1981 to 2003. During this time period, landings from the GBK fishery have remained stable, varying between 1,100 and 1,700 mt (1981-2003 average of 1,400 mt) (Table 1).

*Southern New England*

SNE has the second largest fishery, accounting for 21% of the U.S. landings between 1981 and 2003. This fishery recently has experienced dramatic declines in landings and has accounted for only 12% of the U.S. landings from 2000 to 2003, reaching a time series low of 8% in 2003. Landings increased sharply from the early 1980s to the late 1990s, reaching a time series high of 10,054 mt in 1997. Landings remained near the time series high until 1999, then declined dramatically back to levels observed in the early 1980s (Table 1).

**Data and Assessment**

Fishery-dependent and fishery-independent data collected by NMFS and the states from Maine to New Jersey were used in the American lobster stock assessment. Fishery-dependent data included commercial landings collected by NMFS, Maine, Massachusetts, and Connecticut; and port and sea sampling data collected by NMFS, Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, and New York. Fishery independent data included trawl surveys conducted by NMFS, Maine, New Hampshire, Massachusetts, Rhode Island, Connecticut, and New Jersey.

Trends in abundance and fishing mortality for male and female lobsters in individual stock areas were derived from the Collie-Sissenwine model. The life history (egg-per-recruit) model was used to estimate egg production and yield-per-recruit as a function of fishing mortality for female lobsters in the three previously-defined stock areas, but not the revised stock areas. In addition to the results derived from assessment models, “common sense” indicators of stock and fishery status were evaluated by examining trends in 12 different fishery-dependent and fisher- independent indices. Finally, a revised size structured assessment model that responded to recommendations by the 2004 Atlantic States Marine Fisheries Commission Lobster Model Peer Review was presented.

**Biological Reference Points / Fishing mortality**

The status of the lobster stocks was compared to two overfishing definitions/standards: the Commission's overfishing definition and new approaches based on abundance and fishing mortality trends. The Commission's overfishing definition is the basis for management actions as established by Amendment 3 in order to protect lobster stocks and provide for sustained harvest over the long-term. The overfishing definition is a fishing mortality rate that results in egg production per recruit equal to 10% of that value in an unfished stock. The Commission's overfishing definition applies to the resource throughout its range, but is applied on a stock by stock basis to lobsters in three stock units as defined above.

The 2004 Stock Assessment Report updated the $F_{10\%}$ threshold values for stocks of American lobster with revised life history model, growth parameters, and management measures. The previous stock areas are used (GOM, GBS, SCCLIS). The updated $F_{10\%}$ values are 0.31 (GOM), 0.21 (GBS), and 0.36 (SSCLIS) (2005 report, Table 7.7.1). **Average fishing mortality from 1995 to 1997 is well above these values (0.65 GOM, 0.45 GBS, and 1.16 SCCLIS) and therefore the three stocks were overfished according to the Commission overfishing definition.**

The 2005 Stock Assessment Report did not present $F_{10\%}$ values for the new stock areas (GOM, GBK, SNE) used in the current assessment nor a comparison to fishing mortalities from the most recent time-period 2001-2003. **This should be remedied so that Atlantic States Marine Fisheries Commission can determine whether compliance with Amendment 3 is occurring. (see appendix A for LSAC submitted results for fishing mortalities for the most recent time period 2001-2003)**

The 2005 stock assessment report proposes new biological reference points as targets and limits for both fishing mortality and abundance (not total biomass or egg production). The limit biological reference point is the median value estimated from the Collie-Sissenwine model over the time-period of the assessment. The target biological reference point is one standard deviation away from the median. The targets and limits for fishing mortality are 0.67 and 0.76 for GOM, 0.31 and 0.34 for GBK, and 0.74 and 0.82 for SNE (2005 report, Table 9.2.1). In contrast, recent fishing mortalities (average) are 0.54 for GOM, 0.29 for GBK, and 0.84 for SNE. Fishing mortality is below the threshold for GOM and GBK and above the threshold for SNE.

### Recruitment / Spawning Stock Biomass

Current abundance of the GOM stock overall has been relatively high compared to the 20-year time series and recent fishing mortality has been comparable to the past. The Panel is concerned with low recruitment in 2003 and urges vigilance in monitoring recruitment during the near future. In particular, recruitment for the southern GOM (area 514) has declined (three of the last four recruitment values have been near record lows) and led to post-recruit abundance declining to the historical low. The GBK stock appears to be stable; current abundance and fishing mortality are similar to their medians for the 20-year time series. The SNE stock is relatively low compared to the 20-year time series and fishing mortality is relatively high.

### Bycatch

All indications are that the bycatch of other species in the lobster trap fishery is minor though this is not documented in the assessment report. The discarded bycatch of lobster in gear deployed to catch other species is unknown, although 1% of the commercial landings originate from fishing gears besides traps in the time series mean (1981-2003).

### Sources of Information


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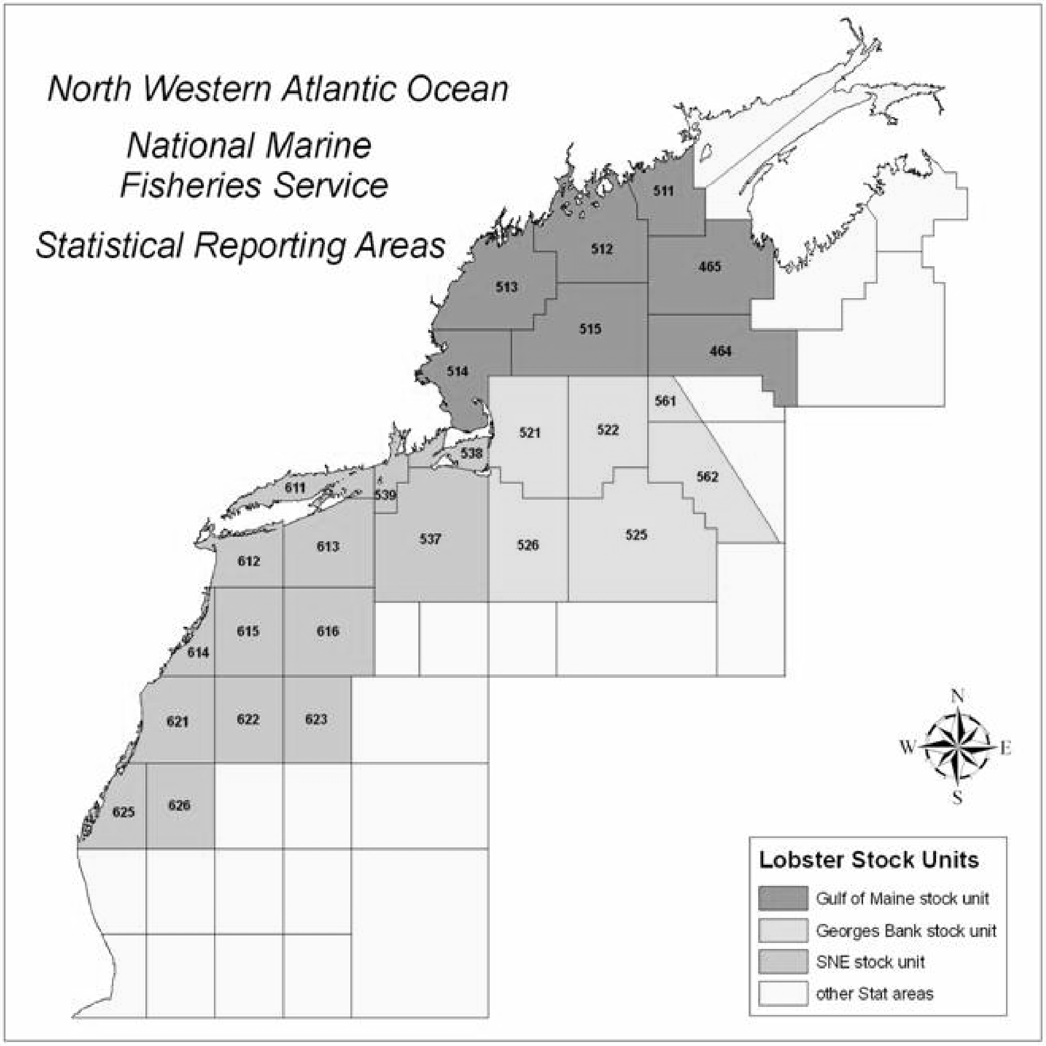
Table 1. Landings by stock area for American lobster in metric tons from 1981 to 2003.

| Year | Gulf of Maine | Georges Bank and South | Southern New England |
|---|---|---|---|
| 1981 | 14,777 | 1,143 | 1,828 |
| 1982 | 14,669 | 1,273 | 2,649 |
| 1983 | 15,069 | 1,447 | 3,788 |
| 1984 | 13,797 | 1,496 | 4,254 |
| 1985 | 14,558 | 1,489 | 3,960 |
| 1986 | 13,816 | 1,243 | 4,383 |
| 1987 | 13,952 | 1,316 | 4,457 |
| 1988 | 14,696 | 1,417 | 4,752 |
| 1989 | 16,708 | 1,326 | 5,940 |
| 1990 | 19,244 | 1,430 | 7,620 |
| 1991 | 20,215 | 1,580 | 7,086 |
| 1992 | 17,738 | 1,703 | 6,233 |
| 1993 | 18,802 | 1,545 | 6,008 |
| 1994 | 23,869 | 1,443 | 6,757 |
| 1995 | 23,001 | 1,215 | 8,070 |
| 1996 | 22,155 | 1,134 | 9,130 |
| 1997 | 26,726 | 1,229 | 10,054 |
| 1998 | 25,836 | 1,212 | 9,757 |
| 1999 | 30,038 | 1,472 | 9,492 |
| 2000 | 31,845 | 1,214 | 6,207 |
| 2001 | 26,517 | 1,422 | 4,430 |
| 2002 | 33,806 | 1,568 | 3,636 |
| 2003 | 29,198 | 1,427 | 2,754 |
| Mean | 20,914 | 1,380 | 5,793 |

Figure 1. Stock areas for American lobster: Gulf of Maine, Georges Bank, and southern New England.



## Appendix A
## Response submitted by ASMFC Lobster Stock Assessment Subcommittee in response to peer review panel's request for fishing mortality estimates from the most recent time-period 2001-2003

**The 2005 peer review of the ASMFC stock assessment suggested** including in the assessment fishing mortalities from the most recent time-period 2001-2003. The ASMFC Lobster Stock Assessment Committee completed model runs to estimate $F_{10\%}$ values for stocks of American lobster with revised life history model, growth parameters, and management measures. The previous stock areas are used (Gulf of Maine - GOM, Georges Bank South - GBS, and Southern Cape Cod/Long Island Sound - SCCLIS). The threshold values are 0.31 (GOM), 0.21 (GBS), and 0.36 (SSCLIS). **Average fishing mortality from 2001 to 2003 is well above these values for two stock areas (GOM and SCCLIS (0.65 GOM and 1.06 SCCLIS) and on target for GBS (0.21 GBS); therefore, overfishing is occurring in the GOM and SCCLIS stocks according to the Commission's overfishing definition and is not occurring in the GBS stock (see table below).**

| | GOM | GBS | SCCLIS |
|---|---|---|---|
| **2001 –2003 Average** | ***0.65*** | **0.21** | ***1.06*** |
| **$F_{10\%}$ Threshold** | **0.31** | **0.21** | **0.36** |