**Stock Assessment Report No. 09-01**
**of the**

# Atlantic States Marine Fisheries Commission

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

***Healthy, self-sustaining populations for all Atlantic coast fish species or successful restoration well in progress by the year 2015***

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# Atlantic States Marine Fisheries Commission

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

Conducted on
March 17-20, 2009
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 is designed 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) validate the credibility of the scientific basis for management; (2) ensure the quality of Commission stock assessments; (3) periodically conduct formal peer reviews of stock assessments for all species managed by the Commission; 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.

In March 2009, the Commission convened a Stock Assessment Peer Review Panel comprised of members with expertise in stock assessment methods and/or crustacean species and their life histories. The review for the American Lobster Stock Assessment was conducted in Boston, Massachusetts from March 17-20, 2009. Prior to the Review Panel meeting, the Commission provided the Review Panel members with electronic copies of the 2009 American Lobster Stock Assessment Report and background materials.

The review process consisted of presentations describing the completed 2009 stock assessment. Each presentation was followed by general questions from the Review Panel. The final two days involved a closed-door meeting of the Review Panel during which the documents and presentations were reviewed, conclusions drawn, and a report prepared.

The report of the Review Panel, hereafter referred to as the Panel, is structured to follow the terms of reference provided to the stock assessment team.

*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 data and assessment methods. 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 on the American Lobster page or by contacting the Commission at (202) 289-6400.

## Acknowledgments

The Peer Review Panel thanks Patrick Campfield (ASMFC) for assisting with the Peer Review and preparation of this report. The Panel appreciated the Atlantic States Marine Fisheries Commission's efforts to provide the documents and supplemental material to the members three weeks before the review meeting, which facilitated a thorough review. The Panel also thanks the scientists who presented the stock assessment and answered our questions including Kim McKown (New York State Department Environmental Conservation, Bureau of Marine Resources), Dr. Genevieve Nesslage (ASMFC), Dr. Larry Jacobson (National Marine Fisheries Service), Robert Glenn (Massachusetts Division of Marine Fisheries), Carl Wilson (Maine Department of Marine Resources), Penny Howell (Connecticut Marine Fisheries Division) and Dr. Yong Chen (University of Maine).

# I. Introduction

The American lobster fishery has been an important component of the region's economy and culture for hundreds of years. The U.S. lobster fishery is conducted in the Gulf of Maine (GOM), Georges Bank (GBK), and Southern New England (SNE). Each area has an inshore and offshore component to the fishery, with the inshore fishery dominating in the Gulf of Maine and Southern New England, and the offshore fishery dominating in Georges Bank. The lobster fishery has persisted despite high exploitation. Total landings were relatively constant through the late 1970s, but since then they have more than doubled.

The Panel and the assessment team recommended the use of trend-based reference points to manage the lobster fishery. Inherent in such an approach is the assumption that the productivity currently supporting the different fisheries will be maintained. Simply stated, we are assuming trends will continue unaltered. However, we lack any credible scientific foundation to support this assumption. We caution that productivity has been lower in the past. For instance, landings in the GOM, which comprises the bulk of the coast wide fishery, oscillated without trend around a value of approximately 20 million lbs from 1930-1990. Those levels were substantially lower than current levels, possibly due to low recruitment and production. The current levels of fishing effort and harvest will not be sustainable if the stock returns to lower recruitment and production. **Thus, the Panel recommends that managers be particularly vigilant of recruitment patterns in these stocks and stand ready to impose substantial restrictions should recruitments decline.** Of particular concern to the Panel is the difference between the level of exploitation calculated for a reasonable biological reference point to maintain 10% of the virgin spawning potential, which would suggest limiting exploitation to about 30% of the available lobster annually, and the observed and apparently stable removal of approximately 50% of the available lobster annually. This discrepancy is the central conundrum facing managers. How are the higher exploitation rates that characterize the fishery sustained, and how much risk is assumed by continuing exploitation at these levels?

The American Lobster Stock Assessment Peer Review of the 2009 Atlantic Lobster Assessment was held on March 17-20, 2009 in Boston, Massachusetts. The previous assessment was completed in 2005 and reviewed through the Atlantic States Marine Fisheries Commission's (Commission) External Peer Review process in August 2005.

This report is organized into two sections. In the first section, the Panel addresses the Terms of Reference recommended by the American Lobster Stock Assessment Subcommittee. In the second section, the Panel provides an advisory report on the status of the American lobster fishery.

## II. Terms of Reference

**Term of Reference 1. Compile data needed for stock assessment purposes, including commercial, recreational, discard, and fishery-independent data. Update the lobster database to include the most recent information available.**

The assessment team did a thorough job clearly summarizing all of the major data types necessary for conducting this stock assessment. The team completed the task of adding the most recent information available to the lobster database, fulfilling the need to gather all model input data from the states and other sources, and submitted the data in a consistent usable format. However, a number of issues remain that bear on the reliability of this and future lobster assessments.

Most importantly, commercial data - both landings and particularly fishing effort - continue to be recorded piecemeal rather than universally. Stock assessments require a complete and accurate accounting of all sources of removals from the stock. While concerned with the continuation of upward expansion of total landings estimates, the Panel recognized that improvements in landings reporting systems are being made. Continued uncertainties over catch and effort directly limit inferences in this and future assessments. States should be strongly encouraged to standardize collection of fishery-dependent data and work toward universal coverage (see 2006 Panel's recommendations regarding data: item 1). The Panel was presented with alternative estimates of Maine landings for 1997-2003. The 2009 Panel does not feel they're so different that the alternate estimates of Maine landings should be used in place of reported landings. The possibility of unreported landings in the GOM during 1997–2003 is discussed in Term of Reference 2. Information on other sources of removals was also lacking. The Panel noted Canadian landings were not mentioned although they are likely to be appreciable for the part of Gulf of Maine that lies within Canadian waters. Removals from this portion of the stock may affect lobster stock dynamics in US waters. Recreational catches were noted as minor and were not included in subsequent modeling. Discards from conservation practices were briefly presented but not considered further. The Panel believes the level of discard mortality could be high, even if lobster are not directly killed in the pot. An exploration of conservation discards through programs such as sea sampling and V-notching is necessary. This effort could provide a basis for estimating discard mortality based on mark-recapture analysis and for evaluating reproductive contribution of the conservation discarded females.

The Panel also reviewed information on the biological characteristics of the catch. The spatial coverage of biological sampling from commercial landings has improved since the last stock assessment although it is heavily dependent on funding availability. **The Panel stresses the need to continue this port and sea sampling so as to achieve representative coverage of all segments of the fishing fleet, because the length-based model depends on statistically representative length frequency data.**

Data on population size structure and relative abundance were available from fishery-independent bottom trawl surveys. Offshore waters are surveyed by the Northeast Fisheries Science Center (NEFSC) and inshore waters by the states of Maine, New Hampshire, Massachusetts, Rhode Island, and Connecticut. In particular, the Maine inshore trawl survey,

conducted since 2000, has added abundance information and biological characteristics for the area where much of the landings occur. The principal weakness of the application of survey data in the lobster assessment is that the spatial perspective of the data was neither clearly presented nor adequately addressed in the report. A simple exercise to present spatial aspects would be to plot catch rate data from all surveys on one map. The assessment report mentioned survey abundance indices were calculated as stratified delta mean number per tow. However, no details were given with regard to how the calculation was done. The Panel recommends assessing the utility of statistical analyses (e.g., Generalized Linear/Additive Model) to develop standardized abundance indices to improve their precision for each region. To account for spatial heterogeneity, other factors, particularly lobster length and depth that might affect survey catchability, should also be considered in addition to the types of survey, sex, and season.

Biological and ecological information on lobster growth, maturity, and natural mortality was used in the assessment model and to develop potential reference points. Growth is at the core of the assessment model projecting the current size structure forward in time. The team did the best they could with the data at hand. However, the assessment report would benefit from a clearer presentation of the fits of the growth functions for molt increment and frequency to existing data. The Panel recommends using the extensive Canadian tag database to refine the estimates of growth, especially molt frequency.

The maturity at length data appeared complete. However, more detail on how the maturity at length data were pooled within areas would be helpful. The value of natural mortality, *M,* of $0.15 \cdot yr^{-1}$ was justified based on internal consistency with prior assessments. While *M* value might range from $0.10\text{-}0.25 \cdot yr^{-1}$, more information should be presented for justifying the choice of $M = 0.15 \cdot yr^{-1}$. As mentioned above, programs such as the Rhode Island V-notching program may provide data to estimate *M*. Further, there seemed to be inconsistency in the assessment report between the *M* values used in developing the growth transition matrix and the *M* values used in the length-based model.

**Term of Reference 2. For each stock assessment area estimate the current levels and historical trends of factors such as biomass, abundance, and natural and fishing mortality rates. Characterize uncertainty in estimates.**

Two assessment models were presented to the reviewers: the University of Maine model (a statistical catch-at-length model described in Term of Reference 4) which we refer to as the length-based model, and the Collie-Sissenwine model which had been used in the 2006 assessment. Base case runs from both models were developed for each of the three areas - GOM, GBK, and SNE - and used a constant natural mortality rate of $0.15 \cdot yr^{-1}$ (0.0375 per quarter).

**Gulf of Maine**

***Length-based Model***

The base case run of the length-based model for the GOM was fit to three fishery-independent trawl abundance surveys (NEFSC fall, ME-NH, and MA DMF), the commercial landings, and

survey and commercial lengths by sex, year, and season. For the base case, none of the components received any additional weights or emphasis in the fitting process.

The length-based model fit the abundance surveys and landings reasonably well, although, the abundance trends were more damped than the variation demonstrated by the surveys or landings. The length frequency distributions also had reasonable fits but there was a tendency to underestimate the number of larger sized lobster.

The relative abundance from the model predicted increasing trends for males and females until 2005 with lower values afterwards. The spawning biomass trend showed a dip in 1984-1987 and then increased afterward to a peak in 2005. Consistent with the increases in abundance and biomass, recruitment began to increase in 1988 and reached a plateau in 1997 and then varied without trend since 1997 with the recruitment in 2007 being the highest value in the time series. Approximately 12% of the female lobster in the GOM are mature at the minimum legal size (~81-83 mm CL), indicating that the majority of female lobster recruit to the fishery before reaching sexual maturity.

The effective exploitation (catch/abundance on January 1 for lobster ≥78 mm CL) has been stable over the entire time series averaging 0.49. This value indicates fisheries in the GOM harvest approximately half of all lobster available at the beginning of the year.

The lack of fit to declining survey trends in recent years may be explained by the conflict between data sources used in the assessment. Observed length frequencies and landings increased over time while relative abundance trends from surveys have decreased. NEFSC survey length data and to a lesser extent commercial data both indicate an increase in abundance of large lobster in recent years that may be a response to record high recruitment. In addition, the model was challenged by the fact that no single survey represented the entire stock unit, yet the model assumes each survey is proportional to total abundance of the stock.

### *Collie-Sissenwine Model*

According to the Collie-Sissenwine model (CSM), the abundance of post-recruit lobster increased in the GOM reaching a peak in 2003 and then has been variable with 2006 and 2007 markedly lower. The overall patterns are similar when comparing this trend with that from the length-based model. The CSM indicates the stock reached an abundance peak in 2003 while the length-based model predicted that abundances continued to increase until 2005. However, both models show a decrease in the last two years. In contrast to results from the length-based model, the CSM predicted that exploitation decreased slightly over the time series until 2005 when there was an increase in exploitation.

## Georges Bank

### *Length-based Model*

The length-based model for Georges Bank was fit to the NEFSC spring and fall trawl surveys, the commercial landings in weight instead of numbers, and the survey and commercial lengths

by year and season without “gap filling”. The landings were separated by sex; the other components were fit to sexes combined data. As with the Gulf of Maine model, none of the components received any additional weights or emphasis in the fitting process.

The model estimated the landings in weight, spring survey abundance index, spring survey length, fall survey length and commercial length data well but at the expense of the fall survey abundance after 2003. In particular, the model was able to mimic the female landings that peaked during 2006 and the male landings that peaked during 1993.

The model predicted that the reference abundance increased gradually from 1982-2002 and then increased quickly to record levels during 2004 and then declined. The estimated female spawning biomass was stable until 1997 when it began to increase reaching a peak in 2005, a year later than the reference abundance, and then also declined. Recruitment varied widely without trend across the whole time series. Approximately 7% of the female lobster in GBK are mature at the minimum legal size (~81-83 mm CL), indicating that the majority of female lobster recruit to the fishery before reaching sexual maturity.

Effective exploitation declined steadily from 1984-2002 from about 0.65 to about 0.22 and then increased to about 0.31 during 2007.

***Collie-Sissenwine Model***

The CSM results are not strictly comparable because the length-based model was run with the sexes combined while individual CSM runs were completed by sex. The post-recruit abundance increased for females and was flat for males but the combined abundance estimates show a pattern similar to that from the length-based model with a peak in 2004 followed by a decline. Female recruitment was variable but increasing overall until 2004 while male recruitment was variable and slightly decreasing with an upturn in 2006.

The exploitation estimated by the CSM was either stable or slightly declining until the final year while exploitation estimated by the length-based model was declining until the last three years.

**Southern New England**

***Length-based Model***

The base case run of the length-based model for Southern New England was fit to three fishery-independent abundance surveys (NEFSC fall, CT DEP, and RI DEM), the commercial landings, and survey and commercial lengths by sex, year, and season. As with the other areas, none of the components in the base case received any additional weights or emphasis in the fitting process.

The abundance trends for SNE for both sexes were higher from 1990 to 2000 with an upturn in 2006 and fit the NEFSC fall survey well for both sexes. The CT DEP survey was similar for both sexes and did not show an increase after 2000, while the recent upturn was pronounced in the RI DEM survey. This illustrates a common problem in stock assessments in interpreting index data with conflicting signals. The model cannot agree with the recent increases shown by the NEFSC

fall survey and RI DEM and also predict a decline to fit the CT DEP survey. Landings trends (in numbers) fit well, although summer fits and female fall fits were not exact. Trends in spawning biomass followed a similar pattern to reference abundance. Recruitment increased to a peak in 1995 and then declined to historical lows after 1999 and then increased slightly since 2004. In contrast to the other two areas, approximately 85% of the female lobster in the SNE are mature at the minimum legal size (~81-83 mm CL), indicating that the majority of female lobster in the fishery are sexually mature.

Effective exploitation was relatively stable in the first decade, increased until 2002, then declined to historical lows thereafter.

***Collie-Sissenwine Model***

Abundance of post-recruits estimated by the CSM, reached a peak in 1997 and then declined afterwards which is the same pattern estimated by the length-based model. The CSM estimated a stable pattern for exploitation while the length-based model predicted a drop in exploitation after 2000. Recruitment in SNE was similar for both the CSM model and the length-based model, with increases until 1996 and then decreases with only a slight increase in 2007 with the CSM model and increasing after 2005 with the length-based model.

**Uncertainty**

Uncertainty was addressed in the assessment through additional model runs. The additional runs included using higher values in the growth matrix, using increased landings when reported landings may be low, emphasizing the surveys as compared to the landings, using the NEFSC spring survey instead of the fall survey, using both spring and fall NEFSC surveys, and using alternative natural mortality values.

As mentioned above, there is some concern over the amount of reported landings from the NMFS weigh-out and canvass database from 1997-2003. The State of Maine has conducted a dealer sampling program since 1966 and those daily landings from Maine sampling are multiplied by the number of fishing days per month and the number of dealers that buy from five or more boats per day. The ratio between this dealer based sampling program and the reported landings was consistent until 1997. The ratio between the two estimates diverged from 1997-2003. When a mandatory reporting system was implemented in 2004, the ratio returned to its former levels. Changes to the landings input would change the numbers of lobster landed and their length frequencies which, in turn, would change the abundance, exploitation, biomass, and recruitment estimates from both models. **The Panel recommends serious effort be made to resolve this question before the next assessment.** Additional concerns regarding the reported landings stem from trawling in the Georges Bank area and the incidental bycatch of lobster that may have gone unreported. Also, the assessment did not include discards from any source nor did it include recreational landings.

Underlying the dynamics in the length-based model is the growth transition matrix. This matrix was based on an analysis of growth per molt and inter-molt periods from a diverse array of data. The assessment team was careful in their work. However, as currently implemented the length-

based model uses a fixed, constant growth matrix. This approach suffers from two concerns. If the molt probabilities are incorrect, then all of the subsequent, estimated rates will be incorrect. Second, even if the average rates are correct, variation is a widely recognized feature of crustacean growth. **It is imperative to investigate the uncertainty in the growth model through simulation.** The simulation results could be used to establish a prior for the length-based model and inject some variability into the model.

A conundrum with this species is the apparent resilience of lobster in the face of high exploitation rates (e.g. around 0.50 in the case of the GOM) and still the landings have tracked abundance for more than 25 years. When spawner-per-recruit (SPR) based reference points were calculated, the reference points were substantially lower than current exploitation rates. The Panel recommends model runs be completed that include a stock-recruit relationship so that recruitment becomes coupled to the spawning biomass instead of having the same levels of recruitment without regard to spawning biomass. The Panel expects such scenarios will more appropriately reflect uncertainty in our ability to forecast future lobster stock abundance and evaluate management reference points.

The base case length-based model for the GOM exhibited retrospective bias that underestimated abundance and overestimated exploitation rate across the time period examined. Bias became progressively worse as the number of years of data in the ME-NH survey decreased (2007-2000), but terminal year estimates improved after no ME-NH survey data remained in the analysis (1999-1998). However, removing the ME-NH survey altogether worsened retrospective bias, indicating the ME-NH survey may be providing information that helps the model balance conflicting trends in the two declining surveys (MA DMF & NEFSC) and increasing length compositions (commercial and survey). The overall magnitude of the retrospective pattern in the GOM was moderate. Results for GBK indicated little or no retrospective bias with the base case because differences between the base case and retrospective run were both positive and negative and lacked any trend. The base case model produced moderate retrospective pattern for SNE that was slightly biased such that effective exploitation was underestimated and reference abundance was overestimated.

The CSM showed little retrospective pattern in the GOM, a slight underestimate of the post-recruits, and a slight overestimate in exploitation on GBK. The retrospective bias with CSM in SNE was similar to that from the length-based model: the post-recruits were underestimated and the exploitation was overestimated.

**Term of Reference 3. Address and incorporate, as applicable, recommendations from the 2006 American Lobster Peer Review.**

The 2009 stock assessment addressed many of the issues identified in the 2006 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 2006 Peer Review Report.

2006 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.

Although the lack of completely reported catch (landings and discards) data was a serious flaw in the 2006 stock assessment, it is less of an issue with the length-based model. Commercial landing information from the states has been compiled. Mandatory reporting has been implemented since the last assessment, although not yet in all states. Mandatory dealer reporting in Maine and 10% harvester reporting is a big step forward. Such information would allow incorporation of changes in allocation of effort among stock units. The Panel recommends that mandatory reporting should be consistently and universally applied across all regions.

2006 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 2009 Review Panel was not asked to comment on this Term of Reference.

2006 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.

This Term of Reference is addressed in the 2009 Term of Reference 2.

2006 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.

The 2006 Review Panel concluded, *"The Collie-Sissenwine model results regarding absolute fishing mortality and abundance have uncertainty, but they should not be rejected. 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. One area for additional refinement is in the relative weighting of information from various sources."*

We agree the CSM should continue to be applied as a model check on the length-based model (size-structured model). Relative weighting of information was done in some alternative runs in this assessment and we suggest the next assessment provide more scenarios with regard to information weighting.

The 2006 Review Panel further concluded, "*We strongly recommend that any future model-based investigation of natural mortality occur within the assessment model, not independently of it. Progress in estimating changes in natural mortality will depend on providing additional data to the assessment model. Further research on the causes of changes in natural mortality (and catchability) also may help quantify the relation between these variables."*

We agree *M* can be explored in a meaningful way in the length-based model through estimating posterior distribution, which will further benefit from additional data being provided to the

assessment model, such as water temperature. There were model runs incorporating alternative natural mortality rates for GBK and SNE but the assessment report does not state whether the growth transition matrix was recalculated with the different *M* values.

Finally, the 2006 Review Panel stated, "*A bootstrap approach is used to calculate the variance in output quantities such as fishing mortality (F) and abundance. A more complete portrayal of variability should be a goal of future model developments."*

We agree a more complete portrayal of variability should still be a goal of future model developments. We discourage the use of a bootstrap approach based on the fact that standard deviation values produced by the length-based model were very narrow. We recommend that Monte Carlo Markov Chain (MCMC) simulations be conducted to obtain realistic posterior distributions for important parameters, such as natural mortality, as well as output quantities such as exploitation and abundance.

2006 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.

These reference points were amended in Addendum VIII.

The 2006 Review Panel noted, "*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 ($F_{10\%}$). A clear rationale for this biological reference point (BRP) should have been presented in the Stock Assessment Report."*

The current management definition specifies the biological reference points as the median relative exploitation rate and relative abundance, which are obviously not thresholds but may be considered as target values. Overall, the biological reference points were the weakest part of this assessment, and the panel recommends alternate reference points (see below Term of Reference 5).

The 2006 Review Panel also noted that, "*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."*

In this assessment, neither spawner-recruit relationships nor forecasts were presented. We agree with the 2006 Panel that spawner-recruit relationships should be investigated before doing population projections in the management strategy evaluation (MSE) procedure. In this lobster case, continued high recruitment has provided the foundation for sustainability. Other recruitment scenarios should be explored in MSE.

The 2006 Review Panel concluded, "*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 this assessment, the length-based model and exploitation rate calculations were integrated as recommended, but a MSE was not completed.

The 2006 Review Panel also stated that, *"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. 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. Second, there should be an investigation of whether an index of recruitment can be used to foretell bad recruitment events."*

The question raised by the 2006 Panel has not been addressed in the current assessment. We echo the recommendations by the 2006 Panel, which we also mentioned above, that various recruitment scenarios should be modeled and some index that foretells bad recruitment events should be investigated. An MSE also should be implemented for short-term projections to evaluate the efficacy of management measures.

2006 Term of Reference 7. Identify research recommendations to improve future assessments.

The 2006 Review Panel stated that, *"The most significant improvement for future assessments would be procurement of complete and unbiased catch information."*

Some progress has been made in that fisheries-independent sampling (ventless trap survey) and port and sea sampling have substantially increased. Both programs substantially improved the stock assessment and should be continued. For example, the additional reporting program provided consistent information for Georges Bank that previously was woefully inadequate. Nevertheless, the recommendation regarding implementing mandatory standardized reporting of catch information remains.

The 2006 Review Panel also noted that, "*Recent efforts to use lipofuscin methods to age lobster appear promising and should be continued for the New England stocks."*

Lipofuscin provides some information for estimating growth but does not provide absolute age and thus mortality. In order for lipofuscin methods to be applicable, large sample sizes are needed to overcome the uncertainty in lipofuscin-based ages. The Panel recommends using biochemical, rather than histological, assessment of lipofuscin content to maximize sample processing rates.

A central concern of the 2006 Review Panel was that "*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."*

We reiterate the recommendation of the 2006 Panel that hypotheses be developed for the mechanisms of continued fishery sustainability. Research into larval mortality and distributions should be very useful. The biophysical coupled modeling approach published by Xue et al. (2008) that simulates the patterns of egg production (abundance, distribution, and timing of hatch), temperature-dependent larval growth, stage-explicit vertical distributions of larvae, and mortality in a realistically simulated physical environment (current and temperature) should be extended to other areas to understand recruitment sources for U.S. lobster stocks. This approach may help us understand how the source location varies between good and bad recruitment years/eras and to identify a potential index that can be used to foretell recruitment dynamics.

In 2006 the Review Panel also recommended 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."*

We reiterate the recommendations by the 2006 Panel and point out that all these investigations can be accomplished through MSE (see above).

**Term of Reference 4. Use Chen-Kanaiwa-Wilson model (CKWM) to develop estimates of fishing mortality and abundance for all stock areas. Use Collie-Sissenwine model (CSM) to compare current stock status to prior assessment. Compare performance of the CKWM and CSM.**

Two assessment models were used in the 2009 lobster stock assessment: a statistical catch-at-length model developed by Chen, Kanaiwa and Wilson, (length-based model), and a standard Collie-Sissenwine model (CSM). The length-based model has been developed over the last decade by scientists at the University of Maine (Chen et al. 2005, Kanaiwa et al. 2008) and was further modified for the specific needs of this assessment. The CSM has been used in assessments of numerous fisheries, including assessments for several other crustaceans (e.g., Miller et al. 2005) since it was first developed (Collie and Sissenwine 1983).

***Length-based Model***

The Panel concluded the length-based model provided a reliable, scientifically-sound foundation for lobster assessment work. This model uses a rigorous statistical approach to integrate different data streams and yields reliable estimates of the previous history and current status of a lobster stock. The model uses size-based population dynamics to predict commercial catch, commercial size composition, survey indices, and survey length frequencies. Central to this representation is a growth matrix which projects the size distribution forward in time. The model uses statistical maximum likelihood optimization methods to optimize the fit to each data stream simultaneously. The model is sufficiently flexible to be able to include multiple surveys

conducted at different times of the year, and with differing catchabilities. The assessment team made appropriate use of effective sample size calculations for the different data streams to reflect the uncertainty in the information content in each data type. The ability of the model to effectively represent a wide range of selectivity patterns in the fishery with only 2-4 parameters per curve, including conservation policies such as V-notching and maximum size limits, was a particularly attractive feature. The assessment authors purposefully chose selectivity functions that were biologically realistic and used few parameters, which the Panel commends.

The model has the potential to be configured in numerous ways. The assessment team chose a simplified version, which was appropriate for the initial application of the model, but needs to be justified better. In most cases, the assessment team interpolated the raw data to "fill" temporal or spatial gaps in the levels and biological characteristics of the catch prior to use of the data in the model. While this approach is necessary for former assessment models (e.g., CSM), it is not required in the length-based model. The assessment teams' approach of interpolating data outside of the model and then applying the model to further integrate patterns in the data, risks over-smoothing of variability in the catch data streams. The review panel thought explorations of model performance on "un-filled" data streams would be helpful. Additionally, the assessment team did not examine the implications of systematically varying the weightings on components of the overall likelihood on model fits. Such exploration is considered good practice in assessment modeling. The review panel also would liked to have seen the actual likelihood values for the baseline and alternative model runs, rather than just relative differences. Finally, the current application of the model assumes a constant growth transition matrix. The consequences of stochastic variability in this matrix should be explored. Furthermore, a more detailed evaluation of the reliability of the elements of this matrix is required as systematic errors in the growth projection matrix have direct consequences on the estimates of abundance and exploitation. **The Panel recommends that the deficiencies noted above should be evaluated before the next assessment**.

***Collie-Sissenwine Model***

The CSM is a simple difference equation approach that estimates changes in abundance of a population in two life stages, pre-recruits and fully recruited animals, in response to recruitment, natural mortality and fishery removals. Its simple structure and few assumptions suggest it might be a resilient, reliable assessment model. The Panel thought the Collie-Sissenwine model continues to provide a useful, aggregate summary of patterns in lobster stocks. The Panel recommends continued dual use of both models, with the length-based model as the primary assessment tool for stock status determination and the CSM as a check on the estimates from the more complex length-based model.

The Panel recognized a potential weakness in the CSM, as currently employed, in that it requires the data filling approach criticized above and requires an external estimate of the ratio of catchabilities between the two life history stages. The Panel recommends the use and exploration of more recent implementations of the CSM, such as that used by Miller et al. (2005) in their assessment of blue crab in the Chesapeake Bay. This updated version of the CSM allows gaps in the data stream, estimates the catchability ratio internally, and permits the use of multiple surveys. Additionally, the Panel recommends the assessment team evaluate whether the length-

based model could be modified to operate at a more aggregated level. For example, could the length-based model be configured to emulate the CSM by aggregating the numbers of lobster in the length classes into the two length stages before model fitting is attempted?

*Compare performance of size-structured and Collie-Sissenwine models*

The review panel thought both the length-based model and the CSM provide information of use to managers. The CSM provides an aggregate picture of abundance trends. However, the CSM does not allow complete representation of the characteristics of different lobster fisheries or of lobster life histories which are more fully incorporated in the length-based approach. Accordingly, we recommend use of both models be continued. We do not see the CSM as a bridge model, the use of which is to be discontinued when the more sophisticated model is understood better. Our analogy for this recommendation is one of estimating a company's financial health. The CSM provides simple summaries rather like that provided by an account balance. In contrast, the length-based model is analogous to a detailed set of accounts describing income and expenses. Both provide useful information to assess the health of a company. For example, the bank balance can be low, but incomes exceed expenses such that the company is on a healthy trajectory. Alternatively, even with a healthy balance, if expenses exceed income, financial health will not be maintained indefinitely. Similarly, the review panel feels that both models continue to provide useful information on the status of lobster stocks.

The ability of the length-based model to fit length composition data was thought by the Panel to be an important gauge of the reliability of its predictions. However, uncertainty over the growth dynamics inherent in the length-based approach raises concerns that the length compositions are well described, but for possibly the wrong reasons. The CSM, which is largely independent of the full growth matrix is less sensitive to these concerns.

**Term of Reference 5. Update the current fishing mortality and abundance biological reference points. Investigate additional biological reference points. Characterize uncertainty in stock status.**

The assessment notes the SPR-based reference points are substantially lower than the current exploitation rates, yet the stock has sustained these levels for more than 25 years in the case of the GOM. This mismatch argues for more exploration into recruitment processes and the methods used to determine the SPR values. The SPR-based rates appear to be reasonable in that they produce values similar to the assumed value of natural mortality. The disparity between calculated exploitation fractions and the calculated SPR-based reference points could be reconciled by understanding whether there is some feature of the lobster population that promotes resilience (spatial stock structure, V-notch program, minimum size limit, oceanographic feature). Understanding the source of larvae and recruits and why they are so consistent given the lack of an apparent stock-recruitment relationship would also be useful contributions to resolving the disparity. Maybe nursery areas are not limiting and only density-dependent effects control population size (e.g., cannibalism of juveniles by adults). A MSE is needed to explore the risk of continuing a constant, high exploitation rate in the fisheries that are higher than usual SPR-based rates.

*Current biological reference point*

The current thresholds used to evaluate the condition of the lobster stock are the median values for abundance and fishing mortality for 1982-2003 for GOM and GBK and 1984-2003 for SNE. A stock would be considered 'depleted' if the average abundance for the three most recent years fell below the median threshold level. Similarly, 'overfishing' would occur if the average fishing mortality rate for the three most recent years were higher than the median threshold. The targets are a minimum of one estimated standard error from the threshold. This standard error corresponds to the measurement error typical of a three-year average fishing mortality rate or abundance value used in status determination. These targets are designed to reduce the risk associated with exceeding the thresholds due to uncertainty in the three-year average estimates.

*Panel recommendation for choice of reference point*

The Panel agreed with the assessment team that these reference points were empirically determined only using the years of data that were included in the 2005 stock assessment and these high harvests may not be sustainable. However, the Panel concluded that the median exploitation rate was inappropriate for a threshold because the stock would be declared 'depleted' half of the time even if well managed. The Panel rejected the use of a median reference point strategy as a threshold.

The Panel recommends using the median as the target instead of a threshold. The median values for abundance and exploitation are values that have been maintained in the fishery for several years, apparently sustainably. Thus, median values represent something that managers could target. **However, the Panel notes these targets are empirically derived and should not be taken to indicate a stock managed for the target levels is in any way at an optimal level, or that such levels can be maintained indefinitely**.

For thresholds, the Panel proposes to use half of the median abundance and the $90^{th}$ percentile for exploitation rate. This approach to defining thresholds is in line with the ½ $B_{MSY}$ standard used in other assessments, if one assumes the stock is currently at a sustainable level. The SNE area is problematic because of the recent decline in abundance. It must be emphasized these are interim measures while life history-based reference points (e.g., SPR%) are being developed within the length-based model. The values for the interim reference points are given in the Advisory Report Table 2.

*Uncertainty*

There are two sources of uncertainty in the reference points: structural and data. The structural uncertainty stems from the fact that the empirically-based current and interim proposed reference points lack a theoretical, biological basis. The other source of uncertainty arises from combining data without regard to the underlying error distributions. When the length-based model is developed to the stage where it can run MCMC simulations successfully, then aspects such as growth can be evaluated on how they influence the variability in abundance or exploitation. If the assessment had provided projections, one could at least determine whether the stock was expected to increase or decrease given the current rates.

*Stock status*

Because neither the current nor the interim proposed reference points are biologically based, the stock status is uncertain. We can compare the results from the 2009 stock assessment to the measures and note whether the average of the three most recent years have met those measures. The Panel emphasizes that if recruitment does not continue at the high levels of recent years, the fishery could become overfished quite quickly. It is necessary to monitor recruitment annually as an early warning system.

*Additional comments*

Extensive management strategy evaluations need to be conducted to evaluate existing regulations and to explore the efficacy of alternative actions.

Using the stock indicators on an annual basis is important for this fishery considering its reliance on recruitment. **The Panel recommends developing pre-recruit indices from the survey data and that the pre-recruit indices are reviewed annually to prevent surprises from recruitment.**

**Term of Reference 6. Identify research recommendations to improve future assessments. Update status and progress of previous research recommendations.**

The investment in lobster fishery research is out of balance with the lobster fishery's value (>$400 M). Thus, we strongly urge substantially increased investment in acquiring stock assessment and biological research to ensure sustainability of this valuable fishery. We put forth the following research recommendations with respect to data, model, and management reference points, respectively.

**Recommendations regarding data**
Good performance of assessment models depends heavily on the quality of all input data, including biological parameters (growth, mortality, and reproduction), fishery-dependent catch, effort, size distributions, and fishery-independent abundance indices and size samples.

**HIGH PRIORITY:** The growth process is the heart of the length-based model at the core of the assessment. The 2009 Panel recommends continued effort and funding to support growth research, including 1) recasting the growth matrix in a probabilistic context and resampling the growth matrix in the MCMC runs; 2) using the extensive Canadian tag database for obtaining better estimates of growth and molt frequency; and 3) applying biochemical assessment of lipofuscin content to help estimate growth. Natural mortality influences greatly the dynamics of lobster stocks, yet understanding of *M* is poor because this parameter is difficult to estimate. Much like growth, both intra- and inter-annual variation in natural mortality may occur. We identified three research areas that can potentially help refine our understanding of *M* and improve the stock assessment: 1) using the Canadian tag database for estimating *M*; 2) exploring environmental factors (e.g., temperature) which may be incorporated as independent variables in

the stock assessment to explain abundance and recruitment variation; and 3) incorporating *M* with a prior distribution in the length-based model rather than as a fixed value.

**HIGH PRIORITY:** While improvements such as mandatory dealer reporting have been made, the 2009 Panel feels commercial landings and fishing efforts continue to be recorded piecemeal over the stock range. We recommend that they be standardized. The Panel recommends a statistically-designed survey (rather than current ad hoc approach) be implemented for collection of biological characteristics of the catch. The Panel commends the improvement in the spatial coverage of sea and port biological sampling from commercial landings since the last stock assessment, but stresses the need to continue this sampling so as to achieve representative coverage of all segments of the fishing fleet. These data were especially helpful in evaluating Georges Bank stock status in the 2009 stock assessment. In particular, the Panel recommends annual reporting by state agencies of the data needed for the assessment model be implemented so that data are readily available for annual updates of stock indicators to be presented to the Lobster Management Board and for assessment model updates every five years.

**HIGH PRIORITY:** While fishery-independent data are important for monitoring stock status, the Panel urges exploring the reliability of the fishery-independent trawl surveys even in areas where lobster are less common. One recommendation is to map catch rates to determine if consistent spatial patterns exist and that would also suggest, to some extent, survey reliability. **The Panel strongly recommends ventless trap surveys be continued to obtain good abundance indices of the inshore areas where the fishery primarily occurs.** Additionally, the Panel believes it will be helpful to include information on the stock status of the adjoining Canadian stock in future analyses and presentations.

**MEDIUM PRIORITY:** While growth and mortality are key factors influencing population dynamics, recruitment often is the driver behind population resilience. The lobster stock assessment models define recruitment as entry into the fishery and thus bypass the early life stages. Nevertheless, we think research into larval mortality and distributions should be carried out. In particular, the biophysical coupled modeling approach (Xue et al. 2008) that simulates the patterns of egg production, temperature-dependent larval growth, stage-explicit vertical distributions of larvae, and mortality in a realistically simulated physical environment should be extended to other areas to understand recruitment sources for the U.S. lobster stocks. It will likely provide insight for the assessment team with regard to stock connectivity and shed some light on the conundrum of unusual stock resilience. In particular, the Panel recommends use of the model to understand whether larval sources are the same for below average and strong year classes. Identifying sources of recruits may provide managers with options to help ensure the continued resilience of this stock.

**Recommendations on models**

The 2009 Panel concluded the length-based model provided a reliable, scientifically-sound foundation for assessment work. On the other hand, the CSM has a simple structure and few assumptions, with potential as a resilient and reliable assessment model. The Panel concluded the CSM continues to provide a useful, aggregate summary of patterns in lobster stocks and thus recommends continued use of the CSM.

The Panel agrees the length-based model has reached a sufficient level of development to provide management advice. A next step is to estimate a stock-recruitment relationship within the model so that population projections can be carried out. The Panel recommends continued funding to support model refinement and performance evaluation. For future modeling, the Panel identified the following crucial research areas.

**HIGH PRIORITY:** Include an option to estimate a stock-recruitment relationship within the length-based model.

**HIGH PRIORITY:** Explore sensitivity to assumptions of model structure and parameter values (such as catchability, selectivity).

**HIGH PRIORITY:** Implement MCMC and in particular resample the growth matrix in the MCMC runs in order to fully evaluate parameter uncertainties, which now are unrealistically narrow.

**HIGH PRIORITY:** Examine the implications of varying the weightings on components of the overall likelihood on model fits. Such exploration is considered good practice in assessment modeling. With respect to model output presentation, the Panel also would have liked to have seen the actual likelihood values from the base case and alternative model runs, rather than just relative differences.

**LOW PRIORITY**: Use “un-filled” data rather than “gap-filled” data in all stock area models.

**LOW PRIORITY**: Allow more surveys as input.

**Recommendations on management reference points and MSE**

The 2009 Panel strongly recommends the development of reference points that are not based on trend analysis but rather have a sound biological basis.

**HIGH PRIORITY:** The success of MSE relies heavily on the assumed stock-recruitment relationship. The Panel recommends completing a meta-analysis of stock-recruitment relationships for long-lived crustaceans so that some reasonable parameter estimates for the stock-recruitment relationship may be identified for the lobster stock, and then be implemented in the MSE.

## III. Advisory Report

The Panel and the assessment team recommended the current use of trend-based reference points, in the absence of more defensible, biologically-based reference points. Inherent in the use of trend-based reference points is the assumption that the productivity currently supporting the different fisheries will be maintained. However, we lack any credible scientific foundation to support this assumption and productivity has been lower in the past. For instance, landings in the GOM, which comprises the bulk of the coast wide fishery, oscillated without trend around a value of approximately 20 million lb from 1930-1990. These landings were substantially lower than current levels, possibly due to low recruitment and production. The current levels of fishing

effort and harvest will not be sustainable if the stock returns to lower levels of recruitment and production. **Thus, the Panel recommends managers be particularly vigilant of recruitment patterns in these stocks and stand ready to impose substantial restrictions should recruitments decline.** Of particular concern to the Panel is the difference between the level of exploitation calculated for a potential, reasonable biological reference point to maintain 10% of the virgin spawning potential which would suggest limiting exploitation to about 30% of the available lobster annually, and the observed and apparently stable removal of approximately 50% of the available lobster annually. This discrepancy is the central conundrum facing managers. How are the higher exploitation rates that characterize the fishery sustained, and how much risk is assumed by continuing exploitation at these levels?

**Status of Stocks**

The American lobster fishery has been an important component of the region's economy for hundreds of years. The lobster fishery is unusual because the fishery has persisted despite high fishing mortality. The sustainability of juvenile lobster production and thus the lobster fishery is uncertain.

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

*Gulf of Maine*

The GOM stock appears to be stable; current abundance and exploitation have been similar to their medians for the 22-year time series. However, recruitment, effort, and landings have been high and low recruitment could rapidly cause the stock status to deteriorate.

*Georges Bank*

The GBK stock has increased recently. Current abundance is above and exploitation is below their medians for the 22-year time series.

*Southern New England*

The SNE stock abundance is low compared to the 20-year time series, while exploitation is similar. The pattern of low population abundance is well established. The Panel recommends a reduction in exploitation and implementation of a fishery rebuilding plan for the SNE stock.

**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).

## Management Unit

The management unit for American lobster is the entire Northwest Atlantic Ocean and its adjacent inshore waters where lobster are found, from Maine through North Carolina. The ASMFC 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 (Figure 1).

## Landings

The U.S. lobster fishery is conducted in each of the three stock units: the GOM, GBK, and SNE. Each area has an inshore and offshore fishery component, with the inshore fishery dominating in the GOM and SNE, and the offshore fishery dominating in GBK. Total landings were relatively constant at about 14,000 mt through the late 1970s (Table 1). Since then landings have more than doubled, reaching a high of 42,500 mt in 2006. Preliminary landings of 37,200 mt were reported in 2007.

*Gulf of Maine*

The GOM supports the largest fishery, constituting 76% of the U.S. landings between 1981 and 2007 and 87% of landings since 2002. Landings in the GOM were stable between 1981 and 1989, averaging 14,600 mt, then increased dramatically from 1990 (19,200 mt) to 2006 (37,300 mt). Landings averaged 33,000 mt from 2000-2007.

*Georges Bank*

The GBK constitutes the smallest portion of the U.S. fishery, averaging 5% of the landings from 1981 to 2007. Between 1981 and 2002, landings from the GBK fishery remained stable (average 1,300 mt). Landings almost doubled between 2003 and 2007, reaching a high of 2,400 mt in 2005 and have remained high since.

*Southern New England*

The SNE has the second largest fishery, accounting for 19% of the U.S. landings between 1981 and 2007. Landings increased sharply from the early 1980s to the late 1990s, reaching a time series high of 9,900 mt in 1997. Landings remained near the time series high until 1999, when the fishery experienced dramatic declines to an average of 2,600 mt between 2003 and 2007. From 2000 to 2007, landings accounted for only 9% of the U.S. landings, reaching a time series low of 6% in 2004.

## 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, Rhode Island, 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, and ventless trap survey data from Maine, New Hampshire, Massachusetts, Rhode Island, and New York.

In this assessment, the statistical catch-at-length model was used to estimate abundance and exploitation of male and female lobster by size for each stock unit. The CSM used in the 2006 assessment was updated as well. In addition, trends in a suite of non model-based stock status indicators of mortality, abundance, and fishery performance were examined using a 'traffic light approach'.

**Biological Reference Points**

The Panel rejected the limit reference points based on median values proposed in the assessment. Median values calculated from empirical data were considered inappropriate as limit reference points, because it would be expected that 50% of observations would fall below the median value. If medians are used, a well managed fishery would exceed the reference points half of the time, thereby providing no useful management guidance.

The Panel recommends revisions to these reference points. Revised reference points include recasting the median reference abundance and the median exploitation rate as target reference points for sexes combined over the fixed time period of 1982-2003 in GOM and GBK and 1984-2003 in SNE. The Panel recommends the threshold reference point for determining whether a stock is overfished should be one-half the median reference abundance and the threshold reference point for determining whether overfishing is occurring should be the $90^{th}$ percentile of the distribution of exploitation rates. The Panel further recommends that stock status be determined by comparing the average reference abundance and average exploitation rate for sexes combined during the most recent three years to stock-specific values.

Based on these reference points, 'overfishing' would occur if the average effective exploitation rate during 2005-2007 were higher than the stock-specific $90^{th}$ percentile of the distribution of exploitation rates. A stock would be 'depleted' if average reference abundance during 2005-2007 fell below half of the median threshold level. In either of these cases, corrective management action should be implemented.

The panel noted that the trend based reference points are acceptable interim measures until more defensible, biologically-based reference points can be developed.

The GOM stock is in favorable condition based on the recommended reference points (Table 2). The stock is above the reference abundance target and slightly below the effective exploitation target. ***Therefore the GOM lobster stock is not depleted and overfishing is not occurring.***

The GBK stock is also in a favorable condition based on the recommended reference points. The stock is above the reference abundance target and below the effective exploitation target. ***Therefore the GBK lobster stock is not depleted and overfishing is not occurring.***

The SNE stock is in poor condition based on the recommended reference points. The stock is below the reference abundance target and near the reference abundance threshold and below the effective exploitation target. Model runs that incorporated increasing trends (50%-100%) in natural mortality (*M*) also predicted reference abundance below the median. ***Therefore the SNE lobster stock has been declining and is near depleted but overfishing is not occurring.***

**Fishing Mortality**

Recent exploitation rates for the GOM stock have been comparable to the past (Figure 2). The exception for the GOM stock is statistical Area 514 which has continued to experience very high exploitation rates. Recent exploitation rates for the GBK stock are at a record low (Figure 3). Exploitation rates for the SNE stock have declined since 2000 (Figure 4). The Panel recommends further harvest restrictions for the SNE stock and Area 514 of the GOM stock because of persistent low recruitment.

**Recruitment**

Recruitment of the GOM stock overall has steadily increased since 1997. The exception is statistical Area 514 which has continued to experience declines in recruitment. Recruitment has remained high in GBK since 1998. Recruitment has remained low in SNE since 1998.

**Spawning Stock Biomass**

Current abundance of the GOM stock overall is at a record high compared to the 26-year time series (Figure 2). The exception is statistical Area 514 which has continued to experience declines in abundance. Current abundance of the GBK stock is at a record high compared to the 26-year time series (Figure 3). Sex ratio of the population in recent years is largely skewed toward females for unknown reasons (~80% from 2005 to 2007). Current abundance of the SNE stock is the lowest observed since the 1980s (Figure 4).

**Bycatch**

All indications are that 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).

## IV. Sources of Information

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Collie, J. S., and M. P. Sissenwine. 1983. Estimating population size from relative abundance data measured with error. Canadian Journal of Fisheries and Aquatic Science **40**:1871-1879.

Kanaiwa, M., Y. Chen and C. Wilson. 2008. Evaluating a seasonal, sex-specific size-structured stock assessment model for the American lobster, *Homarus americanus.* Marine and Freshwater Research **59**: 41-56.

Miller, T. J., S. J. D. Martell, D. B. Bunnell, G. Davis, L. A. Fegley, A. F. Sharov, C. F. Bonzek, D. A. Hewitt, J. M. Hoenig, and R. N. Lipcius. 2005. Stock Assessment of Blue Crab in Chesapeake Bay: 2005. Final Report Ref: [UMCES]CBL 05-077. UMCES Tech. Ser. No. TS-487-05-CBL., University of Maryland, Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, MD.

Xue, H., L. Incze, D. Xu, N. Wolff, and N. Pettigrew. 2008. Connectivity of lobster populations in the coastal Gulf of Maine. Part I: Circulation and larval transport potential. Ecological Modelling **210**:193-211.

Table 1. Landings by stock area for American lobster in metric tons from 1981 to 2007.

| Year | GOM | GBK | SNE |
|---|---|---|---|
| 1981 | 14,777 | 1,165 | 1,842 |
| 1982 | 14,669 | 1,301 | 2,680 |
| 1983 | 15,069 | 1,447 | 3,788 |
| 1984 | 13,797 | 1,496 | 4,254 |
| 1985 | 14,558 | 1,489 | 3,961 |
| 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 | 19,245 | 1,431 | 7,620 |
| 1991 | 20,216 | 1,580 | 7,086 |
| 1992 | 17,738 | 1,703 | 6,233 |
| 1993 | 18,802 | 1,545 | 6,008 |
| 1994 | 23,655 | 1,346 | 6,774 |
| 1995 | 22,962 | 1,214 | 8,004 |
| 1996 | 22,122 | 1,141 | 9,388 |
| 1997 | 26,624 | 1,215 | 9,935 |
| 1998 | 25,769 | 1,196 | 9,376 |
| 1999 | 29,905 | 1,441 | 9,013 |
| 2000 | 31,797 | 1,184 | 6,073 |
| 2001 | 26,497 | 1,407 | 4,465 |
| 2002 | 33,800 | 1,563 | 3,652 |
| 2003 | 29,129 | 1,787 | 2,554 |
| 2004 | 37,021 | 1,979 | 2,484 |
| 2005 | 35,058 | 2,394 | 2,601 |
| 2006 | 37,297 | 2,240 | 2,989 |
| 2007 | 32,700 | 2,064 | 2,435 |

Table 2. Revised target and threshold reference points with stock status variables for lobster in each stock area. Abundance is the number of lobster at the beginning of the year and exploitation is the ratio of catch in numbers to abundance.

| **Variable** | **GOM** | **GBK** | **SNE** |
|---|---|---|---|
| Exploitation target | 0.49 | 0.51 | 0.44 |
| Exploitation threshold | 0.53 | 0.62 | 0.47 |
| Recent exploitation 2005-2007 | 0.48 | 0.30 | 0.32 |
| Exploitation below target? | YES | YES | YES |
| Exploitation below threshold? | YES | YES | YES |
| Abundance target | 72,030,500 | 1,912,355 | 25,372,700 |
| Abundance threshold | 36,015,250 | 956,178 | 12,686,350 |
| Recent abundance 2005-2007 | 116,077,000 | 4,698,670 | 14,676,700 |
| Abundance above target? | YES | YES | NO |
| Abundance above threshold? | YES | YES | YES |

Figure 1. Stock units for American lobster: Gulf of Maine (GOM), Georges Bank (GBK), and Southern New England (SNE) and management areas.

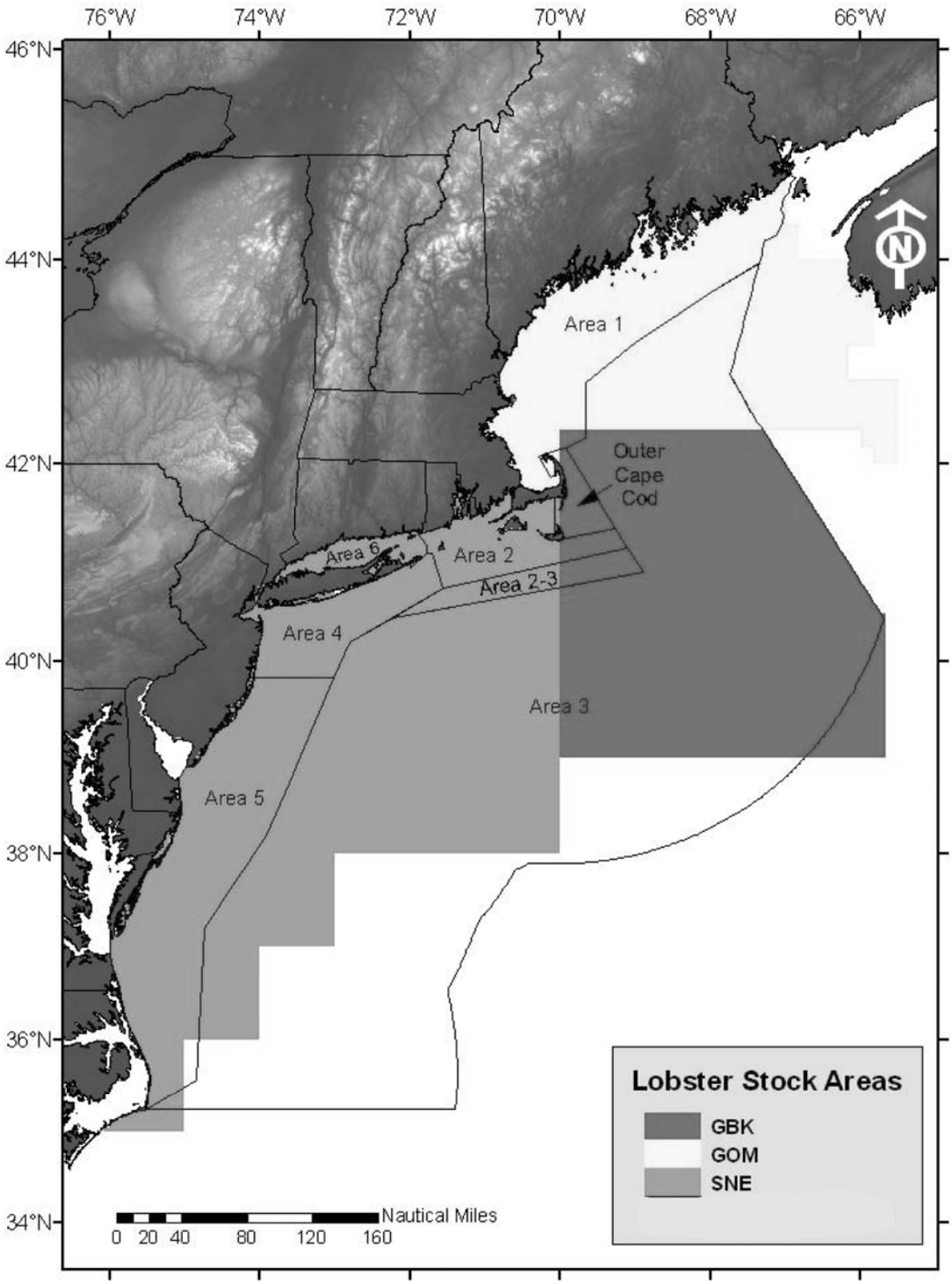
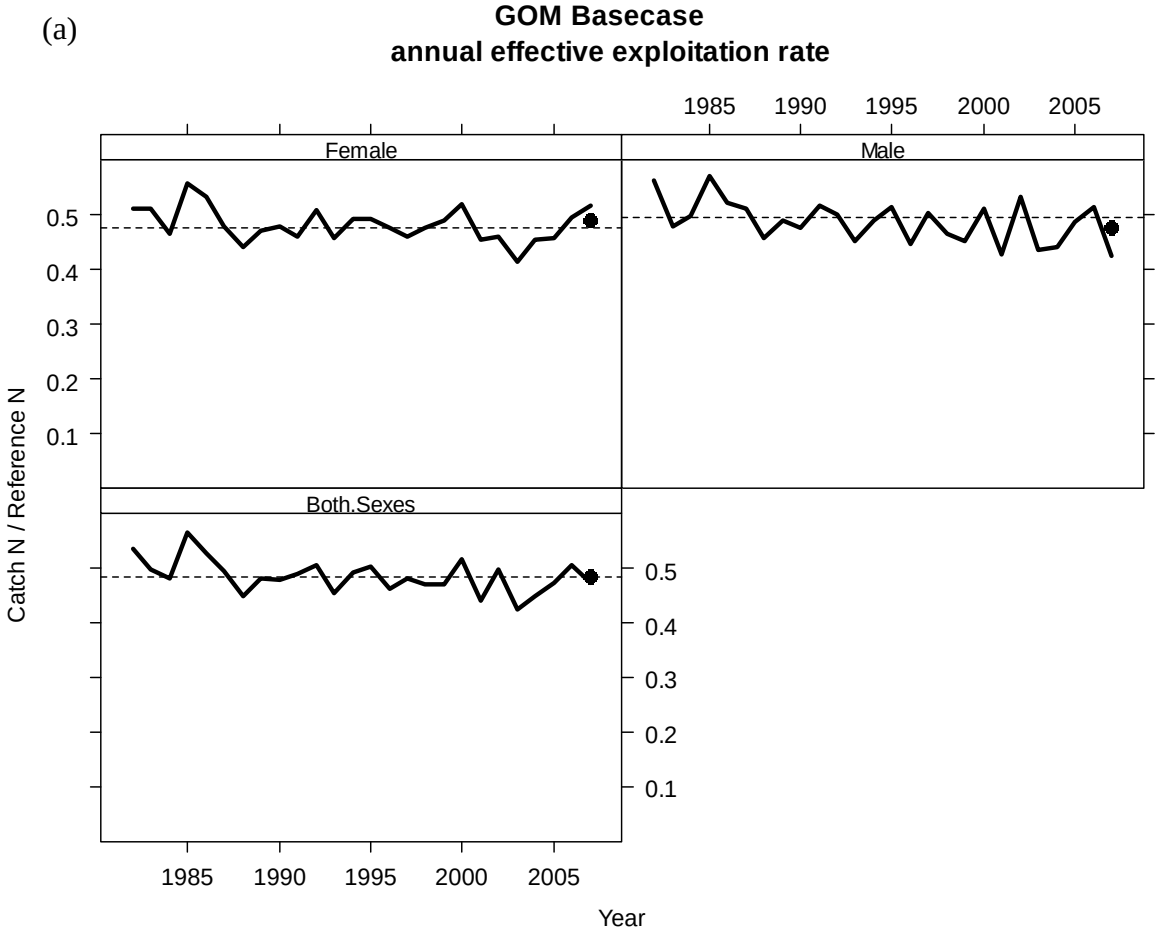
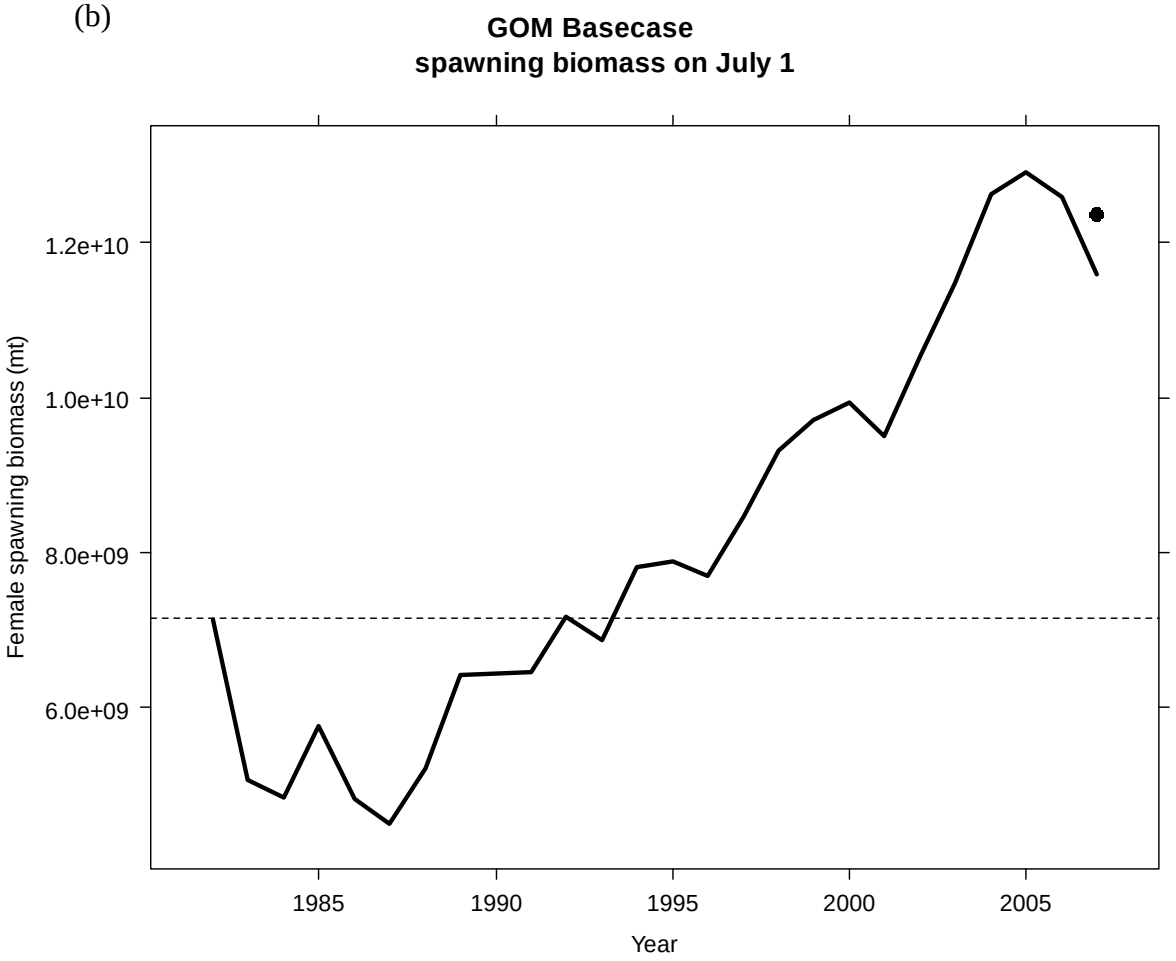


Figure 2. (a) Annual effective exploitation rate, (b) spawning biomass, and (c) reference abundance with associated trend based reference point (median 1982-2003) and status measure (mean 2005-2007) from the base case model for Gulf of Maine.

(a)

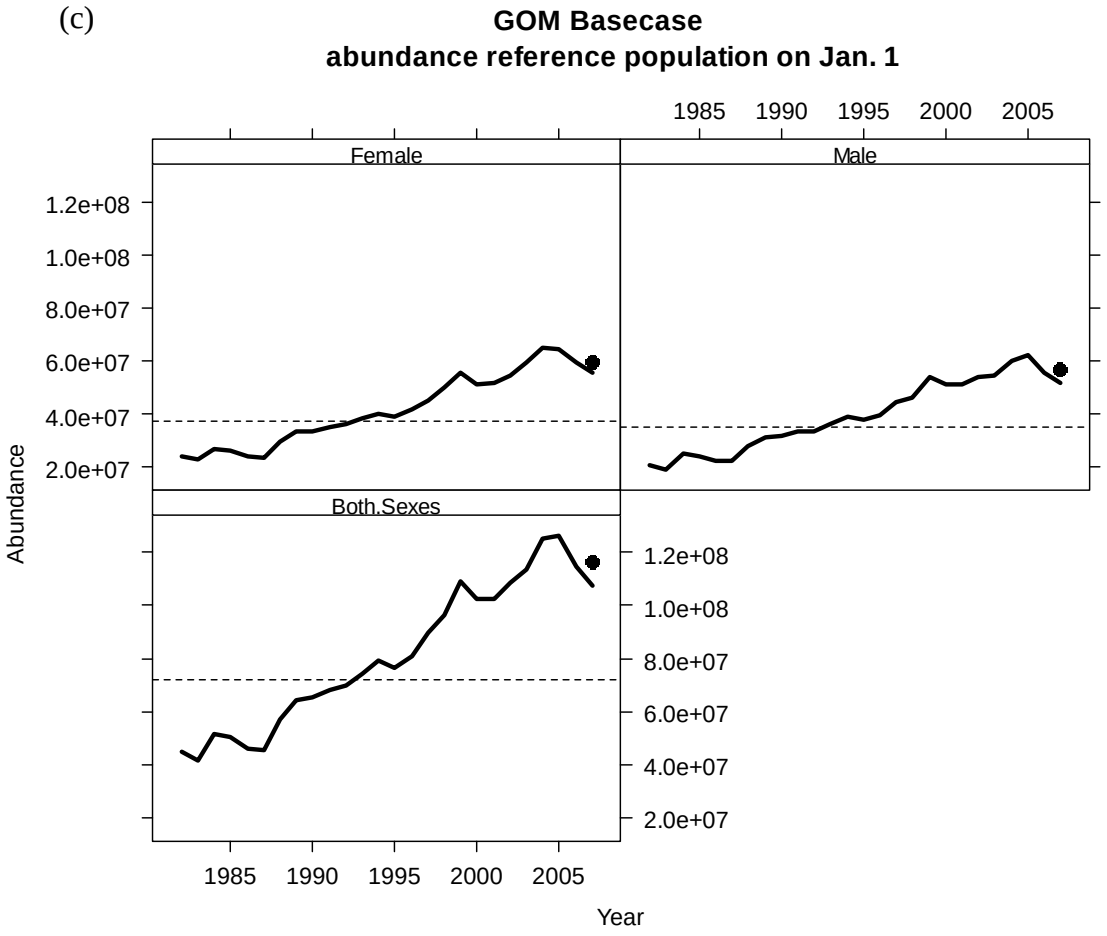


(b)




**Horizontal line at median for 1982 to 2003 ; circle at mean for 2005 to 2007**

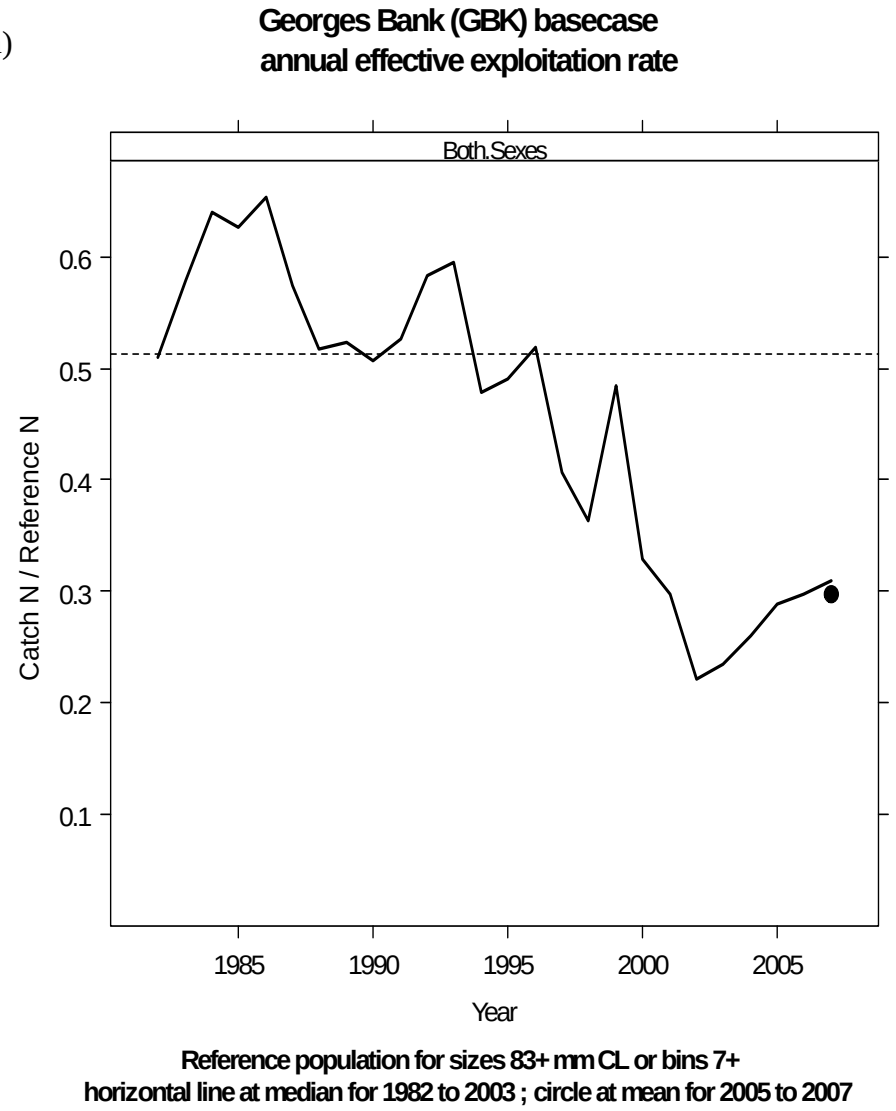
(c)



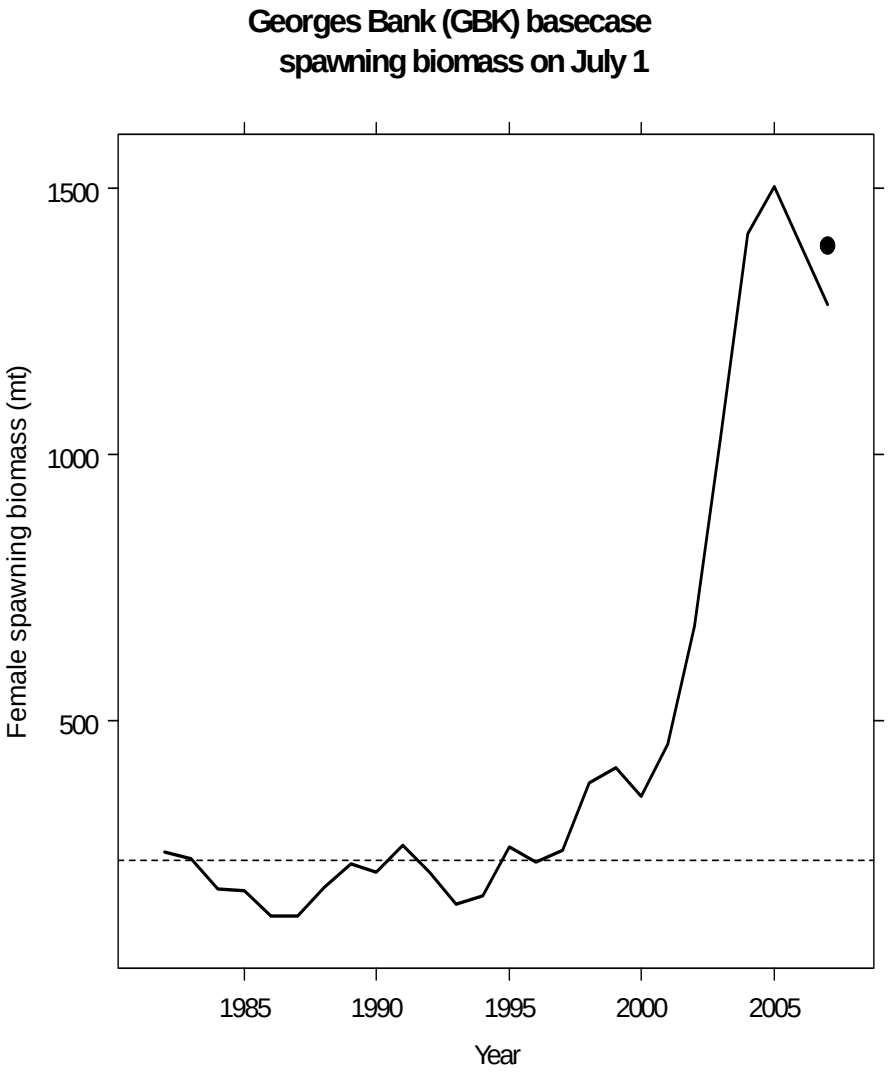

**Reference population for sizes 78+ mm CL or bins 6+**
**horizontal line at median for 1982 to 2003 ; circle at mean for 2005 to 2007**

Figure 3. (a) Annual effective exploitation rate, (b) spawning biomass, and (c) reference abundance with associated trend based reference point (median 1982-2003) and status measure (mean 2005-2007) from the base case model for Georges Bank.

(a)



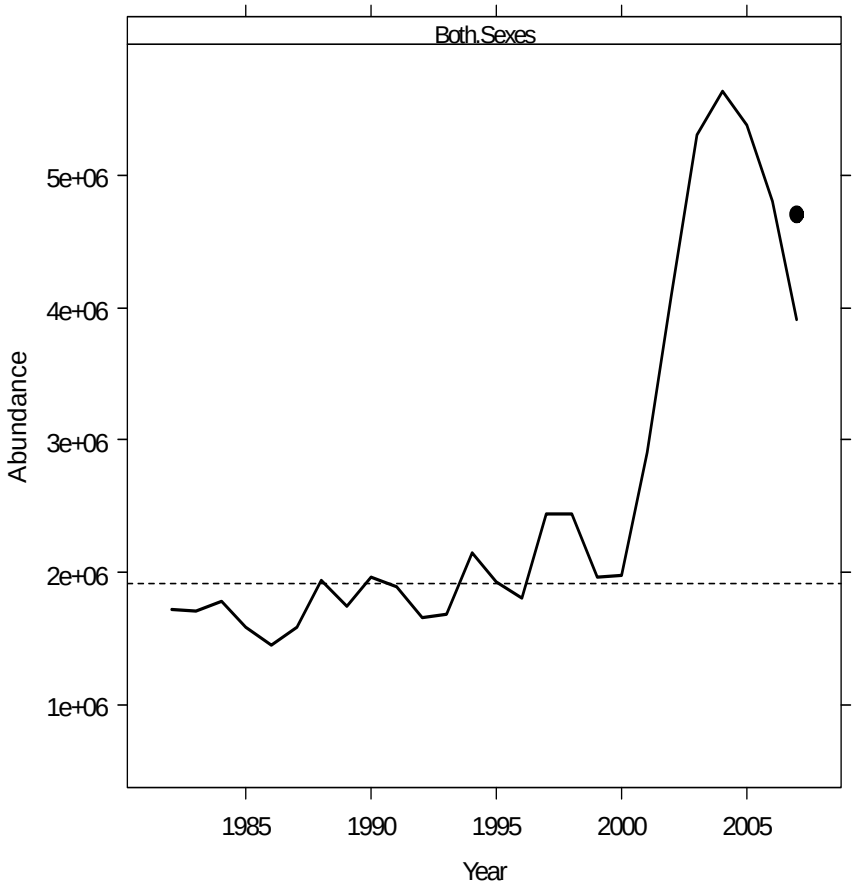
(b)




**Horizontal line at median for 1982 to 2003 ; circle at mean for 2005 to 2007**

(c)

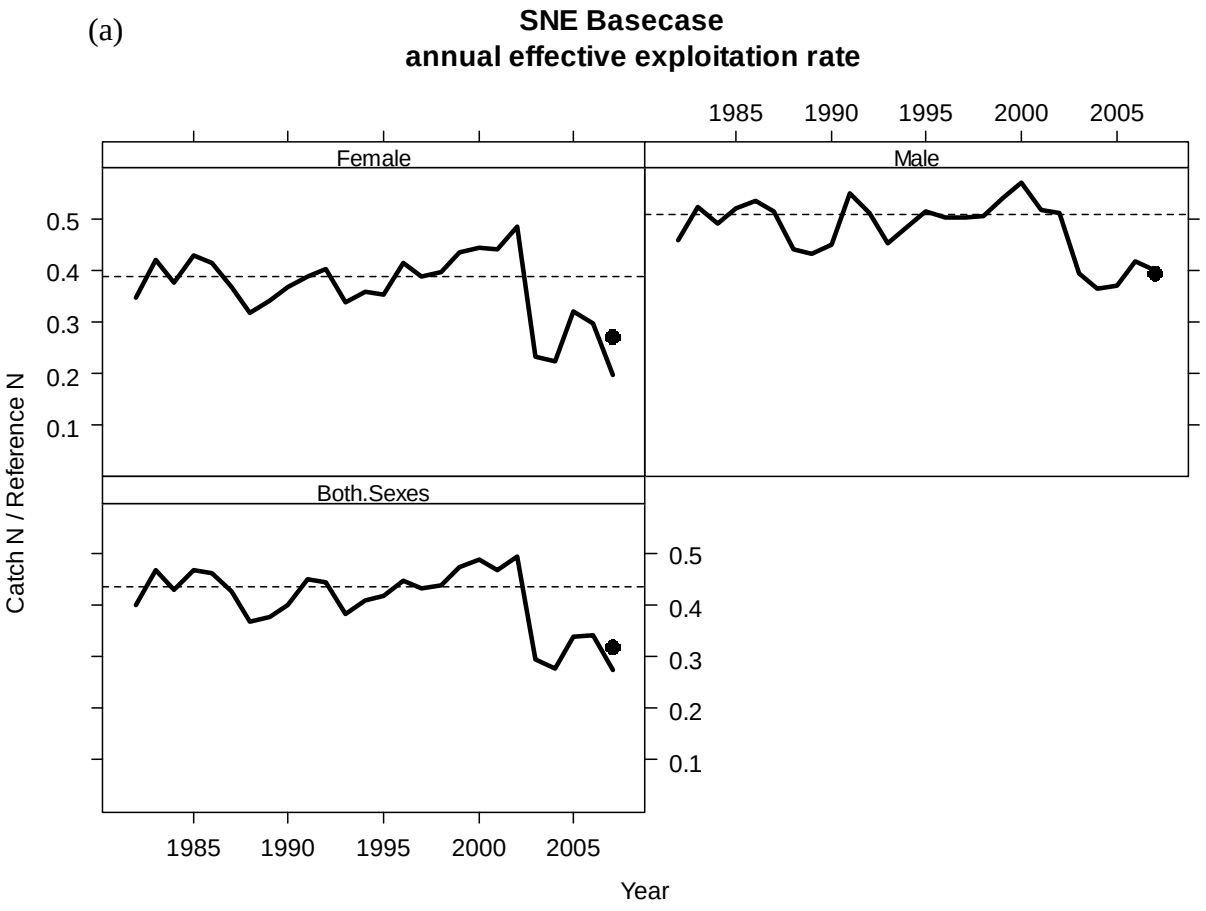
**Georges Bank (GBK) basecase**
**abundance reference population on Jan. 1**



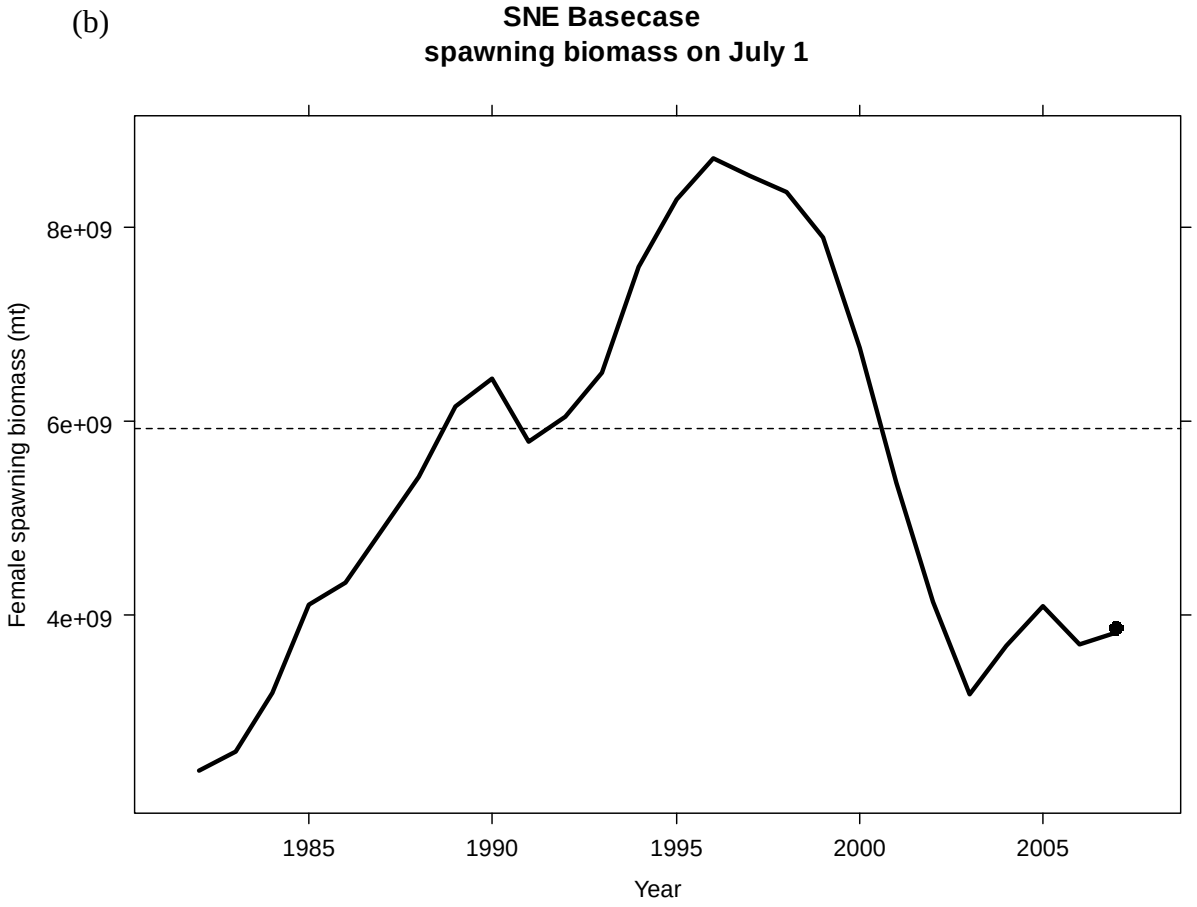

**Reference population for sizes 83+ mm CL or bins 7+**
**horizontal line at median for 1982 to 2003 ; circle at mean for 2005 to 2007**

Figure 4. (a) Annual effective exploitation rate, (b) spawning biomass, and (c) reference abundance with associated trend based reference point (median 1982-2003) and status measure (mean 2005-2007) from the base case model for Southern New England.

(a)

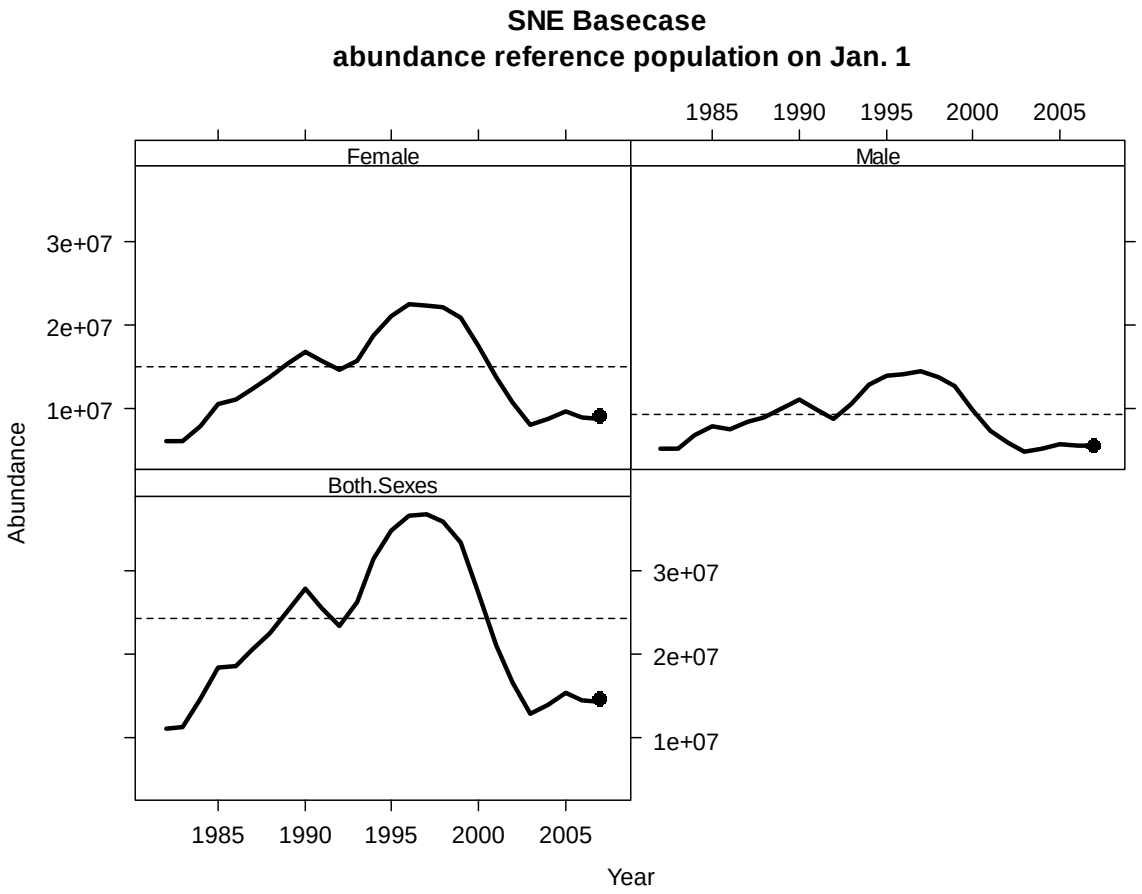


(b)




**Horizontal line at median for 1982 to 2003 ; circle at mean for 2005 to 2007**

(c)




**Reference population for sizes 78+ mm CL or bins 6+**
**horizontal line at median for 1982 to 2003 ; circle at mean for 2005 to 2007**