External Independent Peer Review

Center for Independent Experts

Recruitment Failure in the Southern New England Lobster Stock

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Executive Summary

- The ASMFC Lobster Technical Committee (TC) collated data on sea temperature, lobster shell disease and distribution of spawning females within the Southern New England (SNE) stock area. There is clear evidence that sea temperatures in excess of 20°C have been more frequent since the late 1990s and that chitinoclastic shell disease has increased from low levels prior to the late 1990s up to 25-35% in more recent years. Evidence of a redistribution of lobsters from shallow inshore waters to deeper waters further offshore over recent years is less clear, but data from the Ventless Trap Survey, a trawl survey in Long Island Sound and the Massachusetts Sea Sampling program indicate that such a shift probably has occurred. There is a need for a fuller presentation of the results of more comprehensive analyses.
- The TC report provides evidence from recent stock assessments, fishery landings, trawl surveys, spawning stock biomass indices and recruitment indices that the SNE lobster stock is at a very low level of abundance and experiencing very low levels of recruitment. Stock indicators are provided back to the early 1980s and recent values are in most cases at or near their lowest levels over this period. Taken individually, many of the indicators appear highly uncertain, but the combined picture shows that it is highly probable that the SNE stock is at a depleted level compared with the 1990s, and that this situation is being exacerbated by low levels of recruitment.
- The TC argue that a shift of spawning activity to deeper waters will be adverse for lobster recruitment because larvae released in offshore areas are likely to be transported away from favorable inshore settlement areas. This is supported by the results of satellite tracking of drifters deployed in different areas. There is a need for wider scale observations and hydrographic modeling to validate this picture of reduced settlement success resulting from an offshore shift in spawning.
- The TC concludes that there has been recruitment failure of lobsters in SNE, driven by overwhelming environmental and biological changes. This scenario is consistent with the available data for SNE and with current knowledge of lobster biology and ecology. However, the available data provide a limited historical perspective against which to compare recent observations, and there is a need to consider alternative scenarios such as a return to previous productivity levels after a period of much higher productivity during the 1990s. Sea temperature and disease incidence provide the strongest evidence that current conditions are different from those prevailing during the early 1980s, and thus that the TC scenario of recruitment decline is the most likely one.
- Environmental changes rather than fishing mortality are implicated in the recent stock decline and lower recruitment levels, i.e. stock abundance is probably low because recruitment has declined, as opposed to recruitment having declined because fishing has depleted the spawning stock. However, the TC identifies fishing mortality as an impediment to rebuilding the stock. Given other pressures on larval production and successful settlement, including disease incidence, increased sea temperatures, likely increases in natural mortality, and likely offshore shift of spawning females, removal of fishing mortality is the one opportunity available to managers to influence the likelihood of rebuilding the stock.
- Recruitment indices are an important tool for forecasting future stock and fishery trends and for providing an early indication of the success of management actions aimed at protecting spawning potential. It is essential that current recruitment indices are maintained and intensified, and if possible a spatially comprehensive overview of recruitment processes across the SNE stock area

should be attempted. Passive postlarval collectors represent a promising tool for measuring settlement indices.

- A five-year moratorium on the lobster harvest in SNE is put forward by the TC as providing the highest likelihood of rebuilding the stock to its target levels. This management action can be justified in a risk-based approach, considering (a) the probability that the TC's scenario of environmentally-driven recruitment decline is true, and (b) the risks under this scenario that rebuilding will not occur if management actions other than a moratorium are imposed. On the basis of the analyses presented by the TC, I would assess the probability of their recruitment failure scenario being true as being high and the risk of failing to rebuild if the moratorium is not imposed as high. However, it must be stressed that this is just an assessment of the most likely levels of probability and risk - *responses* to probability and risk are the domain of managers rather than scientists.
- There is a need to provide an improved evidence base for the TC scenario of environmentally-driven recruitment decline, together with an assessment of the likelihood of other conceivable scenarios being true (e.g. return to previous productivity levels).
- In the event of any harvest moratorium, monitoring activity needs to be continued and intensified. Sentinel fishing activities may be appropriate to compensate for the loss of fishery-related indices during any moratorium. The success of a moratorium should continually be assessed, with consideration of alternative management options that may allow some harvest to occur.
- The TC undertook stock projections involving reduced or eliminated fishing mortality and/or continuation of the Rhode Island v-notching scheme. The projections were highly sensitive to assumptions about natural mortality and future recruitment patterns, and indicated that under the most likely (or at least most pessimistic) scenario, rebuilding of the stock is unlikely to occur even if a complete moratorium on lobster harvest is imposed. An improved understanding of spatial dynamics and the role of spawning stock biomass in determining recruitment is needed to improve the utility of future projections.
- The TC infers an increase in natural mortality for 1998-2007 based on decreases in negative log-likelihood for the University of Maine length-based model. This increase is plausible given changes in environmental conditions, disease incidence and predator abundance, but there is a need to support this analysis with a fuller review of mortality factors and of the components of fit within the model.

Background

The American Lobster Stock Assessment Report for Peer Review (Doc8) was released in March 2009 and the report was accepted under Peer Review (Doc9) in May 2009. The assessment indicated that, unlike the lobster stocks in the Gulf of Maine and Georges Bank, the Southern New England (SNE) lobster stock was severely depleted. The American Lobster Board assigned the Atlantic States Marine Fisheries Commission Lobster Technical Committee (TC) with the following tasks:

(1) identify issues impeding stock rebuilding in SNE;

(2) develop a suite of measures to begin stock rebuilding in SNE; and

(3) develop deterministic projections of stock abundance using the University of Maine model that assume: (a) both *status quo* and reduced fishing scenarios, and (b) *status quo* recruitment, low, declining recruitment, and a stock recruitment relationship.

The TC had three months to report back to the American Lobster Board on their findings, and the result of their work was the report *Recruitment Failure in the Southern New England Lobster Stock* (Doc1). With the exception of temperature data and information on the redistribution of spawning females, all other fishery independent and dependent data used in this report were peer reviewed and accepted during the most recent (March 2009) ASMFC Benchmark Stock Assessment (Doc8, Doc9).

This report represents a review of the TC's report and associated documentation on stock projections and higher levels of natural mortality. The Terms of Reference for the review are included in the Statement of Work in Appendix II.

Description of Review Activities

The Statement of Work (Appendix II) and review documents (Appendix I) were supplied on 30 August 2010. I was able to read the review documents over the period 1-30 September 2010 and to collate my responses and write this report over the period 1-11 October. The review documentation and its references were comprehensive and necessitated no further queries.

Summary of Findings

1. Evaluate the quality and completeness of the data gathered since the assessment (temperature data and redistribution of spawning females); if inadequate, specify additional techniques that should have been considered.

Data collated on sea temperature and incidence of shell disease are adequate to demonstrate recent changes in conditions experienced by the SNE lobster stock. Data collated on the distribution of the lobster stock are strongly suggestive of a redistribution of spawning females, but a fuller description of available data sources, and of the spatio-temporal patterns evident within and between these sources, would be needed to demonstrate the existence of this redistribution with high probability.

A critical element in the TC's interpretation of a recent change in the productivity of American lobsters in SNE is the inference of a shift in the spawning distribution of females from shallow inshore grounds to deeper offshore areas. Three lines of supporting evidence are presented in Doc1:

(i) the Connecticut trawl survey in Long Island Sound showing recent (2000-08) catch rates much lower in shallow (<30ft) areas than deeper (>90ft) areas, compared with an earlier period (1984-91) when catch rates in the two areas were similar (Doc1 p.10);

(ii) the regional Ventless Trap Survey showing higher abundance in deeper strata in SNE, contrasting with the Gulf of Maine where higher abundance is seen in shallower strata (Doc1 p.10, Appendix A); and

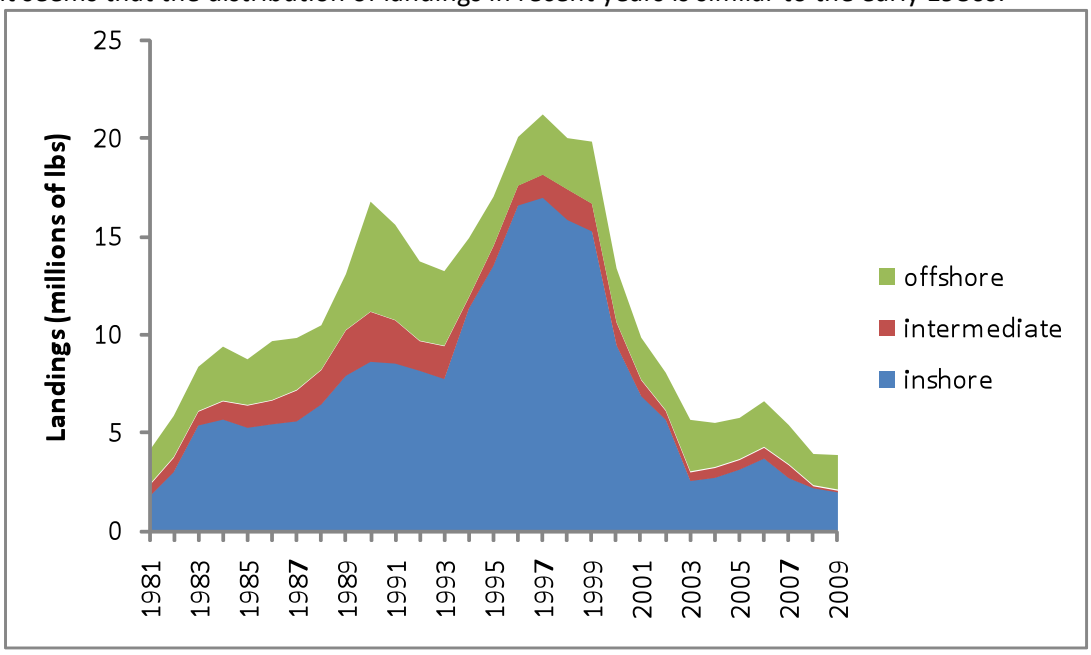
(iii) results of the Massachusetts Sea Sampling program, showing a shift in the lobster fishery from shallow inshore to deeper offshore waters, with spawning females increasingly seen in the deeper areas near the mouth of Buzzards Bay and in Vineyard Sound rather than in the shallower waters within the Bay itself (Doc1 p.10, p.19, Appendix B).

From the information given in Doc1, it is difficult to judge the quality and completeness of the data gathered in evidence of the shift in spawning distribution. The three items highlighted certainly point towards greater catches or catch rates (and hence, presumably, greater abundance) of lobsters in deeper water, but without a fuller presentation it is hard to judge how selective are these pieces of information and what contrary evidence might also exist. Item (i) is an excerpted statistic, not shown against the context of patterns in the whole data set. Quantitative values are not given and there is no information on the precision of catch rate estimates. Item (ii) is more convincing, in that I can see for myself that, particularly in SNE-LCMA2, the smaller bubbles on the maps (lower CPUE) are located in shallower waters, closer inshore, whereas the larger bubbles are located in deeper waters, further offshore. However, the Ventless Trap Survey lacks an historical perspective to show whether or not this pattern is typical of past decades or does in fact represent a real offshore shift. Item (iii) provides a longer perspective, at least back to 1998. Without any explanation of the data presented in Appendix B it is hard to know exactly how to interpret the plots, but I am presuming that the red spots show sampled lobster fishing locations and are considered representative of the distribution of the fishery (but is the sampling spatially stratified?). If this is the case, I can certainly see the fishery shifting out of the inner parts of Buzzards Bay and into Vineyard Sound between 1998 and 2006.

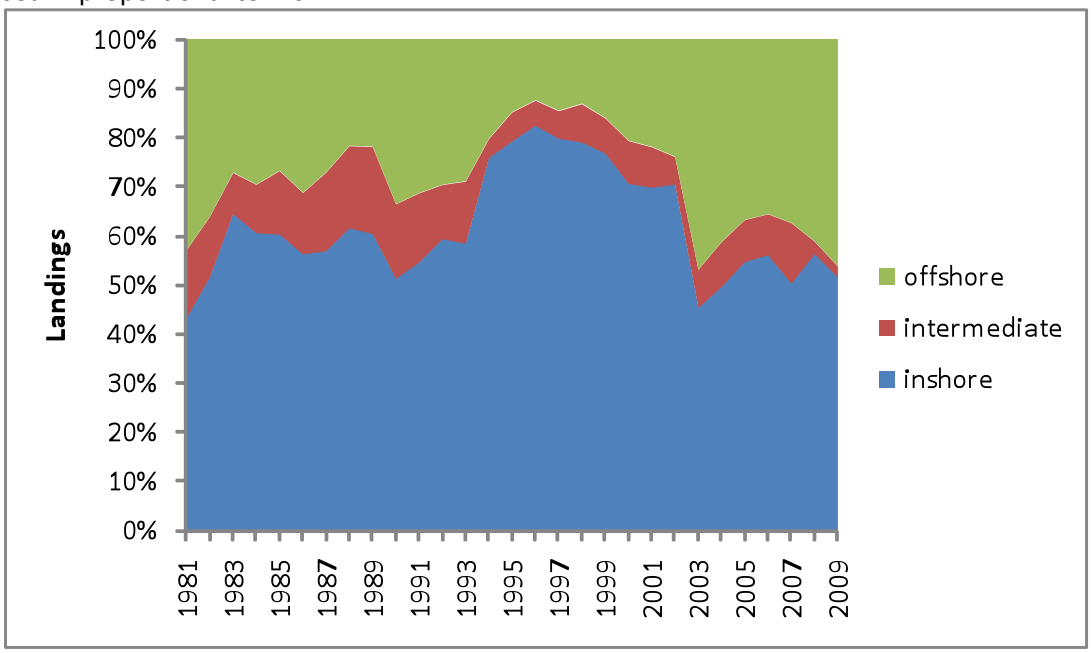
In general, I conclude that *on the basis of the data presented in Doc1* there does appear to be a movement of lobsters offshore and into deeper waters over recent years, at least over relatively short spatial scales. However, these data represent only snapshots rather than a full spatial and historical overview of distributional patterns, and must be regarded as a somewhat slender basis for robust inference. For the case to be truly convincing there needs to be a fuller presentation of all available data, and **I recommend that the TC be given the opportunity to conduct a comprehensive analysis** at an early opportunity. This analysis should include:

- Indices stratified by depth and/or distance for all available trawl survey series and presented with appropriate measures of uncertainty. Analyses should aim to provide the maximum historical *and* spatial perspectives. Candidate surveys might include the CT trawl survey in Long Island Sound, from which only a small excerpt was quoted as item (i), and the NEFC Fall trawl survey which is stated to give the best coverage for offshore areas in SNE (Doc1 p.11).
- Where it is not possible to provide both historical and spatial perspectives *within* individual surveys, effort should be made to make contrasts *between* surveys. This may be hampered by differences in methodology and catchability between surveys, but it should at least be possible to identify the spatial patterns of dominant temporal trends by using techniques such as dynamic factor analysis (Zuur *et al.* 2003, Zuur & Pierce, 2004) or principal components analysis.
- Fuller use of data from the Massachusetts Sea Sampling program, including the longest possible time series (Doc8 p.35 mentions the DMF program collecting data from 1981 – is this the same survey as referred to in item (iii) and does it cover SNE over these dates?). In addition to the distributional data shown in Appendix B of Doc1, CPUE data could be analyzed, stratified by depth and inshore/offshore.
- Tables or graphs of Ventless Trap Survey catch rates should be presented, stratified by depth and region.

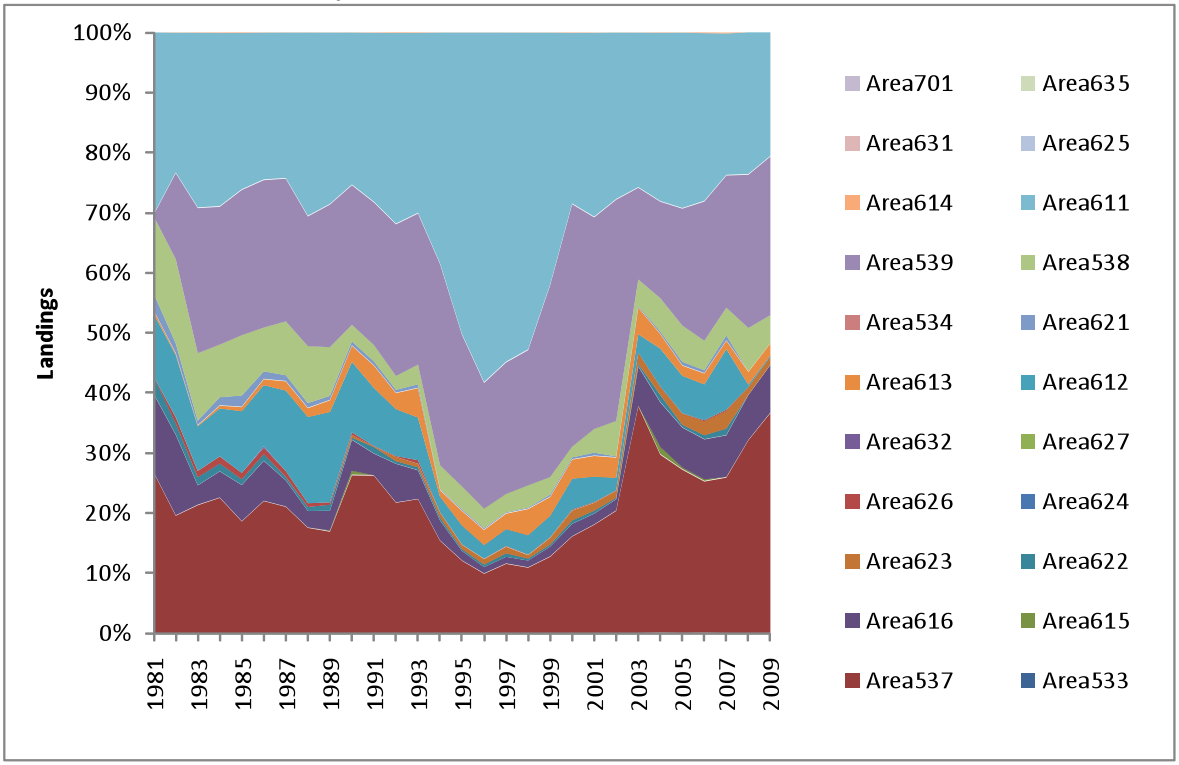
Aside from the Massachusetts Sea Sampling program data, strong evidence of an offshore fishery shift is not shown in the TC's report. Purely on the basis of landings by statistical area (data from Doc1, Figures 9-13), it seems that the distribution of landings in recent years is similar to the early 1980s:



In this figure, Statistical Areas 533, 537, 615, 616, 622, 623, 624, 626, 627 and 632 have been classified as 'offshore', 534, 538, 539, 611, 614, 625, 631, 635 and 701 have been classified as 'inshore', and 612, 613 and 621 have been classified as 'intermediate'. The distributional pattern is even clearer when expressed in proportional terms:



This shows 'inshore' landings dominating in the mid to late 1990s, but a roughly equal split between 'inshore' and 'offshore' in the early 1980s and over recent years. If the data are labeled by individual Statistical Areas, it is clear that just three Statistical Areas dominate:



Statistical Area 611 (Long Island Sound) accounted for up to 30% of landings in the early 1980s, similar to recent levels, but increased to almost 80% of the landings in the mid to late 1990s. Statistical Area

537, which I interpret as offshore on the basis of the map in Appendix C in the TC's report (Doc1), shows the opposite pattern, and much of the remaining landings were from Statistical Area 539. Of course, it would be possible to improve on my *ad hoc* classification of Statistical Areas as 'inshore' or 'offshore', and this classification has been made without any knowledge of the distribution of landings *within* Statistical Areas. Possibly, it is the fine-scale distributional patterns that are relevant, rather than the gross differences between reporting areas. This is hinted at in the analysis under item (i), which refers to patterns *within* Long Island Sound, and similarly the interpretation of data from the Ventless Trap Survey appears to consider patterns over a spatial scale that is small in relation to the size of SNE as a whole. If a robust case is to be made for strong management action on the basis that the current pattern of the lobster fishery/population is something different from what has been observed before rather than a return to a previous state, the supporting analyses must make very clear exactly what is the nature of the change that is observed – where are the distributional shifts, and over what spatial scales?

Data were also presented on sea temperature trends in SNE. *Assuming that these are the only data series available for the area*, this data gathering exercise appears to be complete and of high quality. Sea surface temperature data are presented for Woods Hole, two series of bottom temperature data are presented for Buzzards Bay and one series of bottom temperature data is presented for Long Island Sound. Two very minor queries arise in relation to these series: firstly, how does sea surface temperature relate to bottom temperature at Woods Hole, and would it be sensible to choose a higher threshold than 20°C at the surface to represent the suitability of the bottom conditions for lobsters? Secondly, why was 18°C rather than 20°C used as the threshold for the deeper Buzzards Bay site? However, neither of these queries detracts from the main message of the data presentation (Doc1 Figures 14-17) that SNE sea temperatures have been consistently warmer during the period from the late 1990s to present than in previous decades. If other data series exist, these should certainly be analyzed in a similar way, and every attempt made to collate a comprehensive spatio-temporal overview of bottom temperatures that could be used to map the thermal boundaries of lobster habitat in SNE waters. Further, I recommend making an explicit link between lobster distribution and sea temperature by including temperature variables as covariates in the analyses suggested above for lobster abundance indices. Generalized linear models, generalized additive models and dynamic factor analyses would all be suitable frameworks for such analyses. Large scale climatic variables, such as the North Atlantic Oscillation (NAO) index could also be used in this context.

In addition to data on temperature and lobster distribution, the TC also collated information on the incidence of chitinoclastic shell disease in SNE lobster catches. Data series for Rhode Island and Eastern Long Island Sound showed a consistent pattern of increased incidence from very low levels in the early to mid-1990s to 15-35% since the late 1990s. A shorter time-series for Massachusetts is also shows a consistent picture of high incidence levels recently. These data provide useful supplementary information on factors that may be implicated in any recruitment declines. It is to be hoped that information on disease incidence will continue to be collected (using survey samples), even during any commercial fishery closures.

Finally, new data were also presented on the regional incidence of females in the commercial SNE lobster catches. Whilst not informative of stock trends or shifts in distribution, these data are a useful demonstration of the potential for the fishery to remove females from the population, particularly in the deeper areas to which the fishery may be shifting.

2. Determine the appropriateness of the findings drawn in the TC report, if deemed inappropriate, provide alternative findings with justification.

I agree that the findings of the TC report are appropriate with respect to the current status of the SNE lobster stock, current low recruitment levels and factors likely to limit recruitment.

The TC report (Doc1) presents a great deal of information about trends in abundance, spawning stock biomass, recruitment, larval production and fishery landings of lobsters in SNE. Trends are reported, in most cases, back to the early 1980s, and the main findings are that recent values of stock indicators are, in most cases, at or near their lowest levels over this period. Taken individually, many of the indicators appear highly uncertain, often owing to low catch rates or low sample numbers, and some of the indicators have very restricted spatial coverage. However, taken in aggregate, a strong overall message emerges that the SNE lobster stock is currently at a low ebb with very low levels of recruitment and larval production.

Stock status is inferred principally on the basis of the University of Maine length-based model. This is an accepted peer-reviewed assessment and the model is considered to be statistically rigorous and the best current basis for inference about stock status (Doc8, Doc9). I concur with this view. The assessment has acknowledged issues related to uncertainty about the growth matrix and resolving apparently conflicting survey indices (arising because regional indices are treated as representing the whole assessment area). However, the gross picture emerging from the assessment is similar to that from results of Collie-Sissenwine analyses aggregated over different areas, and shows a close correspondence with trends in overall landings. On this basis, I consider that the current assessment of stock status provides a sound basis for the evolution of management advice and hence provides a reliable picture of stock trends as a background to the TC's report. I note that the threshold abundance used by the TC, being the 25th percentile of the 1984-2003 reference period, differs from the threshold proposed by the peer review panel (Doc9), which was half of the median abundance, considered more consistent with the ½ B_{MSY} threshold used in other assessments. This value is considerably lower than the 25th percentile and would result in the SNE lobster stock being considered not to be overfished (in addition to overfishing not occurring)[1]. However, I do not have a strong opinion on what would be the better choice of threshold, and given the lack of information on the form and parameters of a stock-recruitment relationship I believe this is largely an operational consideration for managers. I find the 25th percentile to be a useful flag for all the stock indicators presented by the TC, whether or not this is used as the basis for reference points.

Spawning stock biomass indices based on trawl surveys show different trends between areas, but there is a very general pattern of higher values during the 1990s and low values recently. Presumably the different trends are due to both statistical uncertainty and regional differences – it would be useful to see confidence intervals around estimates and some maps of the spatial coverage of each survey, to provide some insight into these sources of variation. Also, as noted above (p.7), it would be useful to integrate these surveys into a combined analysis to extract and interpret the dominant overall trends. The same points can be made about the overall abundance indices from the trawl surveys. Differences in the Rhode Island indices are highlighted in the report, attributed to the success of a v-notching scheme.

[1] It is worth noting that, if the Collie-Sissenwine analyses were used as the main basis for stock assessment, the SNE lobster stock *would* be considered overfished, whichever definition of threshold was used.

Young-of-year settlement indices presented by the TC are restricted in their spatial coverage and appear to have a low statistical power of detecting changes, largely owing to low catch rates and small numbers of samples. However, taken together they provide a consistent picture of low recent abundance of larvae in the areas covered.

Taking all the stock indices together, I agree with the TC that there is a high probability that the SNE lobster stock is at a depleted level when compared with the 1990s, and that this situation is being exacerbated by lower levels of recruitment. The TC provide a detailed and useful discussion of the factors that may have limited recruitment and may continue to limit recruitment in the future. Central to their thesis is the idea that American lobsters are at the southern end of their geographical range in SNE waters, and that recent trends of increasing water temperature are shifting the thermal boundaries of optimal lobster habitat. A concise but thorough and convincing account of the implications for lobster physiology and immunocompetence of sea water temperatures in excess of 20°C is given in Doc1, and as noted above (p.9) there is good evidence that sea temperatures have exceeded this level in inshore waters of SNE more frequently since the late 1990s than in the previous few decades. I agree with the TC that a shift in spawning distribution from shallow inshore areas to deeper offshore areas is consistent with this change in temperature regime. This is notwithstanding the need to strengthen the evidence base for such a shift noted under ToR1, above (p.7).

The TC argue that a shift of spawning activity to deeper waters will be adverse for lobster recruitment because larvae released in offshore areas are likely to be transported away from their traditional inshore settlement areas. This inference is supported by the results of satellite tracking of drifters deployed at locations chosen to represent previous and current spawning areas. Whilst I agree that this is certainly a plausible, and even likely, explanation of recent low recruitment levels, the evidence base for this contention needs to be strengthened. A recent conference presentation on American lobster stock-recruitment relationships (Chang *et al.* 2010, quoted by permission of the lead author), emphasized the role of hydrographic processes in determining the scale at which stock-recruitment relationships apply in the Gulf of Maine. In the west of this area, stock-recruitment relationships appear to operate at relatively small spatial scales (<10 km), whereas in the eastern Gulf of Maine, where the coastal current is stronger, the relationships appear to operate at larger scales (>30 km). From the reports available for this review, it seems likely that the data are not available to repeat this analysis for SNE, but it would be instructive to examine large and fine-scale hydrographic models for the region and attempt to model larval transport based on different release locations. **I recommend that a modeling study of lobster larval transport in SNE be undertaken, supported by further drifter deployments as appropriate**. An improved understanding of the relationship between the parental lobster stock and subsequent recruitment in SNE is crucial as a scientific underpinning of any strong management action aimed at limiting the capacity of the fishery to reduce spawning stock size. Such understanding needs to include both a spatial component (location of spawners versus location of recruits) and a larval production component (quantity of spawners required to produce sufficient larvae).

3. Determine the appropriateness of conclusions drawn in the TC report; if deemed inappropriate; provide alternative conclusions with justification.

I believe that the conclusions drawn in the TC report are appropriate with regard to the environmental and biological conditions most likely to be prevailing in the SNE lobster stock, but I consider that the evidence basis for these conclusions needs to be strengthened and that other scenarios should also be considered. I believe that the conclusions in the TC report with regard to impediments to stock rebuilding are appropriate *under this most probable scenario of environmental and biological conditions*.

Two types of conclusion may be distinguished here. Firstly, the TC draws conclusions about the current lobster population regime in SNE – overall lobster abundance, spawning stock biomass, recruitment levels and the environmental drivers that may define the current production capacity of the stock. Secondly, the TC draws conclusions about the role of fishing mortality in determining the lobster population regime.

With regard to the conclusions about the lobster population regime, I believe the TC's conclusions are appropriate in the sense that the most probable explanation of the current evidence is that there has been an environmentally driven shift in spawning distribution away from areas favorable to successful settlement of juveniles, and that this has been exacerbated by increased natural mortality from disease and other factors. This scenario is consistent with the available data on SNE lobster trends and with current scientific understanding of lobster biology, although there is certainly scope for strengthening of some components of the evidence base, notably regarding the offshore spawning shift and larval transport. However, this does not exclude the possibility of alternative scenarios.

One feasible scenario is that the SNE lobster stock is currently returning to a previous, lower productivity regime, after an episode of much higher productivity in the 1990s. The reference period for which 25th percentile values of stock indicators are illustrated in the trend plots of Doc1 is only 20 years, over which many of the indicators show a very simple trend: low values in the early 1980s, increasing two- or three-fold to higher levels by the late 1990s before a return to lower values in the most recent years. Recent values of many stock indicators are at or close to their lowest levels – levels typically prevailing in the early 1980s. Thus, it could be argued, current values of, for example, spawning stock biomass or recruitment are at levels from which the stock has previously 'recovered' to much higher levels. The obvious question is: how representative of 'normal' lobster stock dynamics in SNE was the period during the mid to late 1990s? Was this a period of exceptionally high productivity, so that the current situation is simply a return to lower productivity levels rather than a recruitment failure as such? Is the median stock abundance over the 1984-2003 reference period an unrealistic target for rebuilding the stock? What needs to be demonstrated is that there is something about the most recent decade that is fundamentally different to the conditions experienced during the early 1980s. Temperature and disease incidence records presented in Doc1 are the most convincing evidence that such a change has happened: current temperatures and incidence of shell disease have been much higher in recent years that was evident for the early 1980s. The evidence of an offshore shift in spawning distribution is at least suggestive, as is the use of drifter observations to show the implications for settlement success of a changed location for larval release. There is at least statistical evidence that natural mortality levels are currently much higher than in previous years (Doc3), and such an increase is certainly plausible in the light of temperature effects on lobster biology, observations of disease incidence and trends in predator abundance. Altogether the TC report paints a plausible picture of a lobster stock at the southern end of

the geographical range for the species declining as a result of environmental change and its ecological consequences. If true, and if this local environmental change is part of a larger pattern of climate change, then the outlook is indeed bleak for SNE lobster stocks and fisheries.

On the basis of the evidence presented by the TC, I believe that there is a significant probability that this scenario may be true, and that fishery management action should proceed on the basis of this risk. However, in my view it is very important that the evidence base be strengthened (or otherwise) by a more extensive and rigorous examination of the available data (as recommended under ToR1). It is also important that other possible scenarios are considered in this analysis, and that the risks for future stock trajectories associated with each scenario are quantified to the extent possible given the available information. A risk-based approach to fishery management needs to be a two-pronged approach: (i) to consider the probability that any given stock scenario is the correct one; and (ii) to quantify the risks under any scenario that any given management action will fail to achieve a desirable outcome.

The TC's report appears not to be suggesting that fishing mortality has played a role in the decline of lobster stock abundance since the late 1990s. Stock abundance is inferred as being low as a result of low recruitment, rather than recruitment having declined as a result of fishing driving down the size of the spawning stock. However, fishing mortality is very firmly identified as an impediment to rebuilding, particularly given the prevalence of females in the catches in the deeper water areas to which the fishery has shifted. Under the TC's recruitment failure scenario, it is certainly true that any increase in spawner mortality could adversely affect production of larvae. At higher levels of spawning stock biomass, there may well be recruitment bottlenecks that mean that the levels of successful settlement are not strongly related to the quantity of larvae release, provided that the quantity is 'enough'. At lower stock levels, attaining 'enough' larval production becomes a much more important issue, particularly if the probability of larvae reaching favorable inshore settlement areas is much reduced. The success of the Rhode Island v-notching program attests to the importance of local larval production (although I note that the benefits appeared to be short-lived, with declines in recruitment after 2005). The report also highlights that disease may affect spawning success in both males and females, and that larvae produced by first-time spawners may have lower survivability than those from older/larger females. All these factors mean that any increased pressure of mortality on the spawning stock will decrease the ability of the SNE lobster stock to rebuild itself from depleted levels. Thus, I concur with the TC that, *under the environmentally-driven recruitment failure scenario*, fishing mortality will be an impediment to rebuilding. Of course, this would not necessarily be true under other scenarios for the SNE lobster stock, such as a return to previously experienced levels of stock productivity.

Notes to the ToR for this review (Appendix II) summarize the main TC conclusions as:

a. *The TC contends that the stock is experiencing recruitment failure caused by a combination of environmental drivers and continued fishing mortality.*
b. *It is this recruitment failure in SNE that is preventing the stock from rebuilding.*
c. *Overwhelming environmental and biological changes coupled with continued fishing greatly reduce the likelihood of SNE stock rebuilding.*

In summary:

- I accept conclusion (a) as being demonstrated as the most probable explanation of the evidence available, but I believe that this needs to be strengthened by a more detailed examination of the available data together with a consideration of alternative scenarios such as a return to previously (early 1980s) prevailing productivity levels.

- Under the TC's scenario, I agree that continued recruitment failure would prevent the stock from rebuilding.
- Under the TC's scenario, I agree that there is a low likelihood of the SNE stock rebuilding if current environmental and biological conditions continue to prevail, and that fishing mortality would be likely to exacerbate the difficulties of rebuilding the stock.

4. Comment on the applicability of the recruitment indices to forecast future recruitment and landings to the inshore and offshore areas.

I believe that recruitment indices are of at least potential applicability in forecasting short-term recruitment and landings.

The TC's report describes four recruitment indices for the SNE area: two larval surveys in Long Island Sound and two young-of-year settlement surveys, one for Narragansett Bay and Rhode Island Sound, one for Buzzards Bay. All of these surveys, with the possible exception of the Rhode Island young-of-year survey, appear to be low in statistical power, and thus likely to be of limited applicability in forecasting recruitment. However, the surveys were able to show at least some features consistent with the inference of current low recruitment levels, and would presumably have some power to detect increased larval production and settlement levels that might give early warning of the success of any management measures. However, in addition to low statistical power, it must be recognized that the surveys are limited in their spatial coverage and thus must be of limited applicability in forecasting future recruitment in SNE as a whole and landings for both inshore and offshore areas.

Given the importance of recruitment to future stock trends, any early indication of a change in recruitment levels is highly useful as a guide to the success of current management in protecting spawning output and to how management should proceed in the immediate future. **It is thus imperative that present lobster recruitment surveys should be continued into the future, and if possible their sampling intensity should be increased to enhance their power to detect changes in larval or young-of-year abundance**. The TC report highlights work by Wahle *et al.* (2009) with passive postlarval collectors. Given the linkage between lobster settlement and subsequent recruitment to the fishery, this methodology would seem to have a great deal of potential as a tool for monitoring recruitment trends and forecasting future stock and fishery trends in SNE. **I recommend that the TC give consideration to designing new surveys within SNE using passive postlarval collectors**, with a view to developing a spatially comprehensive view of settlement processes. Such a survey would: (a) give some insight into recruitment processes in the area as a whole; (b) provide feedback for management actions; and (c) allow forecasts of recruitment and landings for both inshore and offshore areas. Such a spatially comprehensive overview could not currently be possible with the existing surveys.

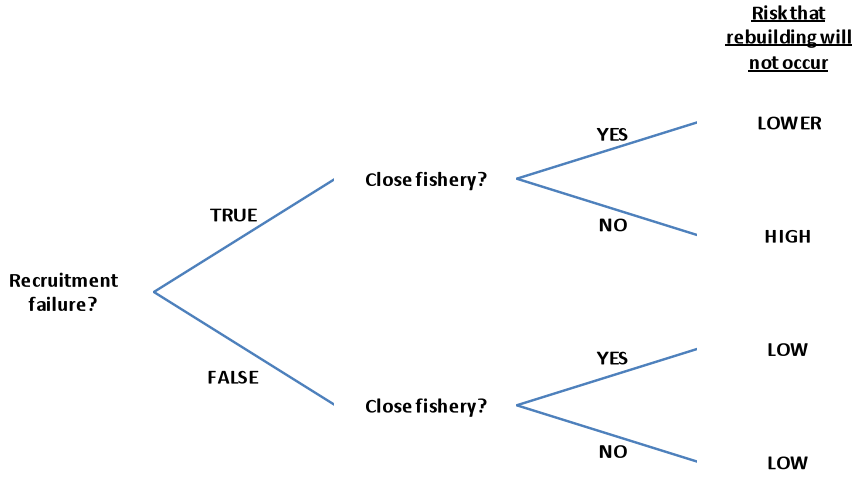
Finally, it is worth noting that, from the point of view of understanding recruitment processes, it is important that there be an improved understanding of larval transport within SNE (see comments above under ToR2, p.11). Set alongside such an improved understanding, monitoring of larval production and settlement has the potential to provide an holistic overview of the status of recruitment processes in SNE.

5. Determine the appropriateness of the recommended action (5-year moratorium); if deemed inappropriate, provide alternative recommendations with justification.

The proposed 5-year moratorium of lobster harvest in the SNE stock area would be justified under the scenario of environmentally-driven recruitment failure. Given an appreciable probability that this scenario is true, there is a strong risk that continued fishing mortality (among a number of other factors) would be a significant impediment to rebuilding.

As noted above (p.13), under a risk-based approach to fishery management, managers must consider two aspects: (i) what is the probability that a given scenario of stock status and its drivers is true; and (ii) in terms of targets to be achieved, or limits to be avoided, under any given scenario what are the risks associated with a given management action. It is, of course, a matter for managers rather than scientists to decide what is a sufficient probability for any given scenario to act on the basis that it might be true, and to decide what levels of risk are acceptable in relation to any given outcome. At present, I believe that the TC's report (Doc1) provides evidence that the environmentally-driven recruitment failure scenario is the most likely explanation of current stock status, and it seems reasonable to suppose that the management response would proceed on this basis. However, it must be re-iterated that this is not the only possible scenario; given the far-reaching social and economic repercussions of so drastic a management action as closing the fishery for five years, it is important that the evidence for the recruitment failure scenario be strengthened as much as possible, particularly with regards to the offshore shift in spawning distribution and its implications for transport of larvae to favorable settlement locations.

Considering just the TC recruitment decline scenario, we can illustrate the decisions that will need to be made by managers in assessing the risk that rebuilding targets will not be achieved within the required timescale. Of course, assumption of scenarios other than recruitment failure may necessitate re-assessing targets to reflect realistic productivity levels, and this will affect the definition of rebuilding and the probabilities of it being achieved.



According to this very notional decision tree, and depending on what view managers took about risks and probabilities being 'high', if the recruitment failure scenario was considered sufficiently probable the obvious course of action would be to close the fishery to achieve the 'lower' risk (noting that even in

the most optimistic case, stock projections still indicate that rebuilding is unlikely – Doc2). Depending on the terms of reference for managers, there may be other risks that would need to be traded-off against this risk of not achieving rebuilding targets.

As stated above, in my view the environmentally-driven recruitment failure scenario is the most likely explanation of the available information and a harvest moratorium is an appropriate fishery management response to this situation. The TC report states that a moratorium "provides the maximum likelihood to rebuild the stock to a level that can support a sustainable fishery". Under the assumption to the recruitment failure scenario, I agree with this statement. The TC reviews three case studies of crustacean fisheries in the NW Atlantic and concludes: (i) that there is a need to understand the consequences of fishing after a moratorium is lifted; (ii) that there must be a spatial match between the area over which a moratorium is applied and the life-history of the target species; and (iii) survey data can be used effectively to allow management action to respond to favorable environmental conditions for recruitment. I agree with these conclusions. The corollaries for SNE lobster management are that management action would be supported by an improved understanding of the spatial dynamics of the stock, particularly as regards larval transport and subsequent recruitment, that surveys and monitoring should continue unabated, and preferably intensified, during any moratorium, and that the case for a moratorium needs continually to be revisited during the course of any fishery closure. Fishery closure inevitably involves a loss of fishery-related indices from any status assessment. This gap may partially be filled by sentinel fishery activities, and there may be scope for further industry participation in survey activities. The scope for such surveys should be investigated. The TC's report highlights the continued importance of ventless trap sampling, young-of-year surveys, larval surveys and trawl surveys in monitoring any recovery. I agree that these activities are highly important, and wholeheartedly concur with the TC's view that "new surveys and research are needed to further characterize lobster settlement and habitat in SNE".

Some of the possible management actions other than a complete harvest moratorium are considered in the stock projections undertaken by the TC (Doc2). Options include reduced levels of fishing mortality and continuation of the Rhode Island v-notching scheme. The main outcome of the projections is to show their sensitivity to assumptions about natural mortality and future recruitment, so it is difficult to comment on the appropriateness of management actions other than a complete harvest moratorium. Under the worst case scenarios, it appears that reduced (as opposed to eliminated) fishing mortality and v-notching will contribute little to stock rebuilding. However, **I recommend that further data- and model-based exploration of all feasible management actions be conducted with a view to modifying the management response in the future**. This should include consideration of v-notching, seasonal closures, closed areas within SNE, and maximum and minimum legal sizes. Some of these explorations may be contingent on an improved understanding of spatial stock dynamics. In the TC report there are some reservations expressed about the effects of discard mortality if technical measures such as maximum legal sizes are imposed. Discard mortality needs to be adequately characterized in any projections involving relevant technical measures.

6. Evaluate the stock projection scenarios conducted to complete the task as outlined by the Board.

a. Evaluate the deterministic projections conducted using the University of Maine Model.

i. The Board directed the TC to provide projections within an extremely short time frame. Although stochastic projections and estimates of uncertainty (e.g. MCMC confidence intervals) could have been provided, the time frame for decision-making was too short to complete a more thorough analysis.

b. Evaluate the chosen suite of fishing and recruitment scenarios presented in the report; if insufficient, provide suggestions for alternative scenarios.

c. Determine if projection results and the TC's interpretation provided in the report are consistent with assessment model results.

d. Comment on the reliability of the deterministic projections for use in SNE lobster stock management.

The TC undertook stock projections based on the University of Maine length-based model for SNE lobsters. Projections involved reduced or eliminated fishing mortality and/or continuation of the Rhode Island v-notching scheme, under different scenarios of natural mortality and future recruitment. In my view the projections were both appropriate (proper consideration of management and stock scenarios) and reliable (within the limitations of the assessment model, its spatial structure and the information available). This being said, the projections were mainly informative about sensitivity to assumptions about natural mortality and future recruitment. Owing to time constraints, the TC was unable to perform stochastic projections. Although it will be important to provide such projections in the future (based on MCMC rather than estimated assessment model uncertainties) to quantify the risks and uncertainties associated with proposed management actions, I believe that the current fundamental uncertainties are such that stochastic projections would add little to the present debate.

The main conclusion from the projections is that "if poor environmental conditions continue, dampening the abundance of both spawners and recruits, only current levels may be attainable even in the absence of fishing" (Doc2 p.3). Under the most likely level of natural mortality (i.e. the value with most statistical support in Doc3), stock abundance (for an average stock trajectory) is likely to remain below both target and threshold levels in 2017, even under the most optimistic assumptions about recruitment (Beverton-Holt stock recruitment relationship). Under a more pessimistic view where recruitment remains at current low levels, which view could be justified in a risk-based management framework, the stock is projected to decline to much lower abundance levels, with very little prospect of rebuilding without a major change in mortality and/or recruitment regimes. Rebuilding only appears to be possible under a scenario of lower natural mortality than currently seems likely to be prevailing. The only scenarios where rebuilding occurs without a total cessation of fishing are those in which natural mortality is at moderate levels and recruitment responds to increased stock abundance through a Beverton-Holt stock recruitment relationship.

These projections paint a stark picture. In my view, although it is certainly possible to define additional management scenarios to explore, the projections outlined in Doc2 take the debate as far as it is possible to go at present[2]. The projections are based on the same population dynamics module as the

[2] One slight *caveat*: it is not clear whether the starting positions for the projections were consistent with the levels of natural mortality assumed to prevail into the future. If not, they should have been, i.e. projections with high *M* should assume that *M* has been high since 1998.

assessment module, and I am satisfied that the model and its application are technically sound. The main improvements to be aimed for in the future include:

- inclusion of spatial structure in both stock assessment and projections;
- improved information about natural mortality and its sources of variation;
- improved information on how changes in stock biomass translate to changes in recruitment;
- incorporation of environment-recruitment linkages, with projections performed under various future environment scenarios
- stochastic projections to allow risk assessment of management options.

The most important of these is perhaps the stock-recruitment relationship, since without knowledge of such a fundamental relationship we will always remain very uncertain about future stock trajectories.

As a background for management, these projections are mainly useful in highlighting the main issues and uncertainties rather than presenting realistic management options. This is necessarily so at present, but it is to be hoped that improved knowledge of SNE lobster dynamics (particularly in a spatial sense) and biological parameters will allow management to be better supported by projections in the future.

7. Review the M sensitivity analysis of the model that indicated a higher M as suggested in the 2009 assessment.

Natural mortality rates for a *k*-selected species such as American lobster would be assumed to be relatively low, but it is plausible that the SNE stock could be experiencing elevated natural mortality rates due to the effects of increased temperature, increased disease incidence and changes in the abundance of potential predators. In terms of estimating relative stock trends, the University of Maine length-based model is likely to be relatively robust to different assumptions about natural mortality, but the goodness-of-fit of the model may nevertheless be informative about its most likely levels. On this basis, the TC have demonstrated that an increase of 1.9 times the base level of $M = 0.15\ yr^{-1}$ up to $M = 0.285\ yr^{-1}$ for the period 1998-2007[3] provides the lowest negative log-likelihood of all the models considered (Doc3).

This is a useful analysis, and I am happy with it so far as it goes, but I would like to see some further exploration of the source of this improved fit. Given acknowledged model deficiencies, such as uncertainty about the growth matrices and the lack of spatial structure in the model, does this apparent change in *M* play proxy for some other biological change (e.g. increased growth rate) or spatial shift that is not accounted for within the model structure? Stock assessment models rarely have much power to estimate natural mortality rates, and inferences about natural mortality from model fit should be treated carefully. It would have been useful to see stock and recruitment trends estimated from the alternative models to see whether the estimates remained within the realms of plausibility. Further, it would be useful to see some discussion of how the likelihood components contributed to the overall change in fit. For example, the commercial female catch appears to have the biggest contribution, and would support a higher *M* still. This appears to be traded off against other components such as the

[3] The wording in Doc3 is somewhat ambiguous here, stating that "alternative model runs differed from the basecase only in that the assumed value of M was higher". I have assumed that this statement is intended to apply to 1998-2007 rather than the entire assessment period of 1984-2007.

length composition of males in survey 1 and the commercial catch. Is there any case for weighting these components differently, e.g. using estimates of survey precision? Is there any case for considering males and females separately, e.g. the possibility that females may be more vulnerable to increased mortality factors because of greater molting frequency? The projections outlined in Doc2 are highly sensitive to the assumed values of *M*, so it is very important to map out the real uncertainty associated with this parameter, as well as what are the most likely values.

In summary, I accept the case made by the TC that natural mortality of American lobsters is likely to have increased over recent years. The analyses undertaken by the TC using the length-based model provide some limited support for this inference, but further support could be provided by:

- an account of natural mortality factors for American lobsters in SNE, together with quantitative information on trends in these factors (e.g. predator abundance);
- consideration of trade-offs between *M* and other factors (growth uncertainty, spatial heterogeneity) in determining the fit of the length-based model;
- examination of whether it would be appropriate to weight the data sources differently in computing the overall negative log-likelihood for the model;
- examination of whether model fit can be improved by using different natural mortality values for males and females.

Conclusions and Recommendations

The main conclusion of my review is that the TC presents a coherent and plausible scenario of an American lobster stock at the southern of its geographical range experiencing recruitment failure owing to environmental and biological changes. I accept this scenario as the most likely explanation of the current evidence on stock and environmental conditions in SNE, including indices of stock abundance, spawning stock biomass and recruitment at much lower levels than the 1990s, unprecedentedly high levels of disease incidence, and evidence of a shift in spawning distribution to deeper, offshore locations unfavorable for successful recruitment. This takes place against a background of higher sea temperatures than previously seen, with implications for lobster mortality and reproduction. However, there needs to be further consideration of alternative scenarios, notably the possibility that current productivity is returning to previously seen lower levels after a period of higher productivity during the 1990s. I believe that there is currently sufficient information for fishery managers to make risk-based management decisions. However, if drastic management action is to be imposed, in the form of a five-year moratorium on the SNE lobster harvest, it is right that every effort should be made to strengthen the evidence base for the recruitment failure scenario, concentrating particularly on the offshore shift in spawning distribution and the implications of this shift for successful settlement. A spatially comprehensive model of the SNE lobster stock needs to be assembled, together with the data resources to support it.

Recommendations are given in the text under each Term of Reference for the review, and also assembled below:

- The TC should be given the opportunity to conduct a comprehensive analysis of distributional patterns in the survey data in order to make more robust inferences about any changes in spawning distribution. Suggestions for these analyses are given on p.7 and should include: survey indices stratified by depth and distance offshore; extraction of dominant survey trends using dynamic factor analysis or similar; fuller presentation of results from the Massachusetts Sea Sampling program; and tables or graphs of Ventless Trap Survey catch rates stratified by depth and region.
- Any new analyses of lobster trends distribution should attempt to make an explicit linkage of lobster habitat with environmental conditions by incorporating sea temperature (and/or other environmental or climatic variables such as the North Atlantic Oscillation Index) as model covariates.
- If there exist sea temperature data that have not been considered in the TC's report, these should be collated and analyzed in a similar way. Attempts should be made to collate a comprehensive spatio-temporal overview of bottom temperatures (possibly including physical modeling results) that could be used to map the thermal boundaries of lobster habitat within SNE.
- A modeling study of lobster larval transport in SNE should be undertaken in an attempt to improve the understanding of the spatial scales over which recruitment occurs and the relationship between the abundance and location of the parental lobster stock and subsequent recruitment. Such a study is likely to have a strong modeling component, e.g. particle tracking within hydrographic models, but should also be supported by satellite tracking of drifter deployments as appropriate.
- Lobster recruitment surveys should be continued into the future, and if possible their sampling intensity should be increased to enhance their power to detect changes in larval or young-of-year abundance. New surveys are also recommended to give a spatially comprehensive picture of spawning patterns across SNE. Deployment of passive postlarval collectors is a promising

methodology for such surveys. These surveys should be used (a) to improve understanding of recruitment processes, (b) to provide early feedback on the success of management measures aimed at protecting spawning potential, and (c) to allow forecasts of recruitment and landings for both inshore and offshore areas.

- The scope for instituting a sentinel fishery monitoring program should be investigated in the event that a harvest moratorium is imposed. The focus should be on plugging any gaps that will be left by the absence of fishery-dependent information during any moratorium.
- Feasible management alternatives to a harvest moratorium should continue to be investigated, particularly as new information comes in on the spatial dynamics of the SNE lobster stock. This should include consideration of v-notching, spatio-temporal input controls and technical measures. Discard mortality should be adequately characterized when technical measures are considered – this may involve the collection of new data.
- The projection methodology should be improved along the lines suggested on p.18. This includes incorporation of spatial structure, improved information about natural mortality, improved information on stock-recruitment relationships, incorporation of environment-recruitment linkages and stochastic projections based on MCMC.
- Qualitative and model-based information should be collated in evidence of a change in patterns of natural mortality. As suggested on p.19, this might include an account of mortality factors for lobsters in SNE, consideration of trade-offs between *M* and other factors (such as growth uncertainty and spatial heterogeneity) in the fit of the length-based model, examination of weighting factors for model likelihood components and consideration of sex-specific *M*.
- Finally, it is strongly recommended that the TC be given the opportunity to undertake a longer review of lobster stock and recruitment patterns in SNE, including consideration of evidence for alternative scenarios (e.g. return to lower productivity levels) in addition to strengthening the evidence for the environmentally-driven recruitment failure scenario.

Acknowledgments

I would like to thank Manoj Shivlani of the Center for Independent Experts for his usual efficiency in making all arrangements for this review, and Toni Kerns of the Atlantic States Marine Fisheries Commission (ASMFC) for making all review documents available in a timely manner. I would also like to thank the members of the ASMFC Lobster Technical Committee for undertaking the analyses and producing documents over what was clearly a very demanding time schedule.

References

Chang, J-H., Chen, Y., Halteman, W. & Wahle, R., 2010. Impact of spatial scale on estimating stock-recruitment relationship. *ICES CM 2010/G:21.*

Wahle, R.A., Wilson, C., Parkhurst, M. & Bergeron, C.E., 2009. A vessel-deployed passive postlarval collector to assess settlement of the American lobster *Homarus americanus*. *New Zealand Journal of Marine and Freshwater Research*, **43**, 465-474.

Zuur, A.F., Tuck, I.D. & Bailey, N., 2003. Dynamic factor analysis to estimate common trends in fisheries time series. *Canadian Journal of Fisheries and Aquatic Sciences*, **60**, 542-552.

Zuur, A.F. & Pierce, G.J., 2004. Common trends in northeast Atlantic squid time series. *Journal of Sea Research*, **52**, 57-72.

APPENDIX I: Bibliography of materials provided for review

Doc1. American Lobster Technical Committee, 2010. *Recruitment failure in the Southern New England Lobster Stock*. Atlantic States Marine Fisheries Commission, April 17 2010.

Doc2. American Lobster Stock Assessment Subcommittee, 2010. *Southern New England lobster stock projection estimates.* Atlantic States Marine Fisheries Commission, unpublished working document.

Doc3. American Lobster Stock Assessment Subcommittee, 2010. *Southern New England – University of Maine Model natural mortality (M) profile.* Atlantic States Marine Fisheries Commission, unpublished working document.

Doc4. American Lobster Technical Committee, 2010. *Recruitment Failure report figure data.xlsx*. Excel data file to support Doc1.

Doc5. American Lobster Stock Assessment Subcommittee, 2010. *newSNEprojections.xlsx.* Excel data file to support Doc2.

Doc6. Chen, Y., 2010. *A description of the projection model in the University of Maine statistical length-structured stock assessment model for American lobster.* Atlantic States Marine Fisheries Commission, unpublished working document.

Doc7. American Lobster Stock Assessment Subcommittee, 2010. *Model code.zip.* AD Model Builder code for lobster stock assessment models and projections.

Doc8. American Lobster Stock Assessment Subcommittee, 2009. *American lobster stock assessment for peer review.* Atlantic States Marine Fisheries Commission, Stock Assessment Report No. 09-01 (Supplement).

Doc9. American Lobster Stock Assessment Review Panel, 2009. *Terms of Reference and Advisory Report to the American Lobster Stock Assessment Peer Review.* Atlantic States Marine Fisheries Commission, Stock Assessment Report No. 09-01.

APPENDIX II: CIE Statement of Work

Attachment A: Statement of Work for Dr. Michael Bell

External Independent Peer Review by the Center for Independent Experts

Recruitment Failure in the Southern New England Lobster Stock

Scope of Work and CIE Process: The National Marine Fisheries Service's (NMFS) Office of Science and Technology coordinates and manages a contract providing external expertise through the Center for Independent Experts (CIE) to conduct independent peer reviews of NMFS scientific projects. The Statement of Work (SoW) described herein was established by the NMFS Project Contact and Contracting Officer's Technical Representative (COTR), and reviewed by CIE for compliance with their policy for providing independent expertise that can provide impartial and independent peer review without conflicts of interest. CIE reviewers are selected by the CIE Steering Committee and CIE Coordination Team to conduct the independent peer review of NMFS science in compliance the predetermined Terms of Reference (ToRs) of the peer review. Each CIE reviewer is contracted to deliver an independent peer review report to be approved by the CIE Steering Committee and the report is to be formatted with content requirements as specified in **Annex 1**. This SoW describes the work tasks and deliverables of the CIE reviewer for conducting an independent peer review of the following NMFS project. Further information on the CIE process can be obtained from www.ciereviews.org.

Project Description: The review would evaluate a report written on April 17, 2010 by the American Lobster Technical Committee (TC) of the Atlantic States Marine Fisheries Commission (ASMFC), entitled "Recruitment Failure in the Southern New England Lobster Stock" and the supplemental stock projection document, entitled "Southern New England Lobster Stock Projection Estimates". The report concludes that the stock is critically depleted, experiencing recruitment failure, and cannot rebuild. The cause is thought to be a combination of "environmental drivers" and continued fishing mortality. The TC recommends a five year moratorium on harvest. The review would be asked to consider the merits of this recommendation. The supplemental document provides stock estimates under various F scenarios and recruitment conditions. The Terms of Reference (ToRs) of the peer review are attached in **Annex 2**.

Requirements for CIE Reviewers: Three CIE reviewers shall conduct an impartial and independent peer review in accordance with the SoW and ToRs herein. CIE reviewers shall have a combination of working knowledge and recent experience in the application of marine ecology, lobster biology and life history, recruitment dynamics, and population assessment. Each CIE reviewer's duties shall not exceed a maximum of 10 days to complete all work tasks of the peer review described herein.

Location of Peer Review: Each CIE reviewer shall conduct an independent peer review as a desk review, therefore no travel is required.

Statement of Tasks: Each CIE reviewers shall complete the following tasks in accordance with the SoW and Schedule of Milestones and Deliverables herein.

Prior to the Peer Review: Upon completion of the CIE reviewer selection by the CIE Steering Committee, the CIE shall provide the CIE reviewer information (full name, title, affiliation, country, address, email) to the COTR, who forwards this information to the NMFS Project Contact no later the date specified in the Schedule of Milestones and Deliverables. The CIE is responsible for providing the SoW and ToRs to the CIE reviewers. The NMFS Project Contact is responsible for providing the CIE reviewers with the background documents, reports, and other pertinent information. Any changes to the SoW or ToRs must be made through the COTR prior to the commencement of the peer review.

Pre-review Background Documents: Two weeks before the peer review, the NMFS Project Contact will send (by electronic mail or make available at an FTP site) to the CIE reviewers the necessary background information and reports for the peer review. In the case where the documents need to be mailed, the NMFS Project Contact will consult with the CIE Lead Coordinator on where to send documents. CIE reviewers are responsible only for the pre-review documents that are delivered to the reviewer in accordance to the SoW scheduled deadlines specified herein. The CIE reviewers shall read all documents in preparation for the peer review.

Desk Review: Each CIE reviewer shall conduct the independent peer review in accordance with the SoW and ToRs, and shall not serve in any other role unless specified herein. **Modifications to the SoW and ToRs can not be made during the peer review, and any SoW or ToRs modifications prior to the peer review shall be approved by the COTR and CIE Lead Coordinator.** The CIE Lead Coordinator can contact the Project Contact to confirm any peer review arrangements.

Contract Deliverables - Independent CIE Peer Review Reports: Each CIE reviewer shall complete an independent peer review report in accordance with the SoW. Each CIE reviewer shall complete the independent peer review according to required format and content as described in Annex 1. Each CIE reviewer shall complete the independent peer review addressing each ToR as described in Annex 2.

Specific Tasks for CIE Reviewers: The following chronological list of tasks shall be completed by each CIE reviewer in a timely manner as specified in the **Schedule of Milestones and Deliverables**.

1) Conduct necessary pre-review preparations, including the review of background material and reports provided by the NMFS Project Contact in advance of the peer review.
2) Conduct an independent peer review in accordance with the ToRs (**Annex 2**).
3) No later than 11 October 2010, each CIE reviewer shall submit an independent peer review report addressed to the "Center for Independent Experts," and sent to Manoj Shivlani, CIE Lead Coordinator, via email to shivlanim@bellsouth.net, and David Sampson, CIE Regional Coordinator, via email to *david.sampson@oregonstate.edu*.

Each CIE report shall be written using the format and content requirements specified in Annex 1, and address each ToR in **Annex 2**.

Schedule of Milestones and Deliverables: CIE shall complete the tasks and deliverables described in this SoW in accordance with the following schedule.

The following dates are tentative, and the project contact will provide firm dates no later than 27 July 2010.

27 August 2010	CIE sends reviewer contact information to the COTR, who then sends this to the NMFS Project Contact
10 September 2010	NMFS Project Contact sends the CIE Reviewers the report and background documents
17-27 September 2010	Each reviewer conducts an independent peer review as a desk review
11 October 2010	CIE reviewers submit draft CIE independent peer review reports to the CIE Lead Coordinator and CIE Regional Coordinator
25 October 2010	CIE submits the CIE independent peer review reports to the COTR
1 November2010	The COTR distributes the final CIE reports to the NMFS Project Contact and regional Center Director

Modifications to the Statement of Work: Requests to modify this SoW must be approved by the Contracting Officer at least 15 working days prior to making any permanent substitutions. The Contracting Officer will notify the COTR within 10 working days after receipt of all required information of the decision on substitutions. The COTR can approve changes to the milestone dates, list of pre-review documents, and ToRs within the SoW as long as the role and ability of the CIE reviewers to complete the deliverable in accordance with the SoW is not adversely impacted. The SoW and ToRs shall not be changed once the peer review has begun.

Acceptance of Deliverables: Upon review and acceptance of the CIE independent peer review reports by the CIE Lead Coordinator, Regional Coordinator, and Steering Committee, these reports shall be sent to the COTR for final approval as contract deliverables based on compliance with the SoW and ToRs. As specified in the Schedule of Milestones and Deliverables, the CIE shall send via e-mail the contract deliverables (CIE independent peer review reports) to the COTR (William Michaels, via William.Michaels@noaa.gov).

Applicable Performance Standards: The contract is successfully completed when the COTR provides final approval of the contract deliverables. The acceptance of the contract deliverables shall be based on three performance standards:
(1) each CIE report shall completed with the format and content in accordance with **Annex 1**,
(2) each CIE report shall address each ToR as specified in **Annex 2**,

(3) the CIE reports shall be delivered in a timely manner as specified in the schedule of milestones and deliverables.

Distribution of Approved Deliverables: Upon acceptance by the COTR, the CIE Lead Coordinator shall send via e-mail the final CIE reports in *.PDF format to the COTR. The COTR will distribute the CIE reports to the NMFS Project Contact and Center Director.

Support Personnel:

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Annex 1: Format and Contents of CIE Independent Peer Review Report

1. The CIE independent report shall be prefaced with an Executive Summary providing a concise summary of the findings and recommendations, and specify whether the science reviewed is the best scientific information available.

2. The main body of the reviewer report shall consist of a Background, Description of the Individual Reviewer's Role in the Review Activities, Summary of Findings for each ToR in which the weaknesses and strengths are described, and Conclusions and Recommendations in accordance with the ToRs.

3. The reviewer report shall include the following appendices:

   Appendix 1: Bibliography of materials provided for review
   Appendix 2: A copy of the CIE Statement of Work

Annex 2: Terms of Reference for the Peer Review

Review of TC report: Recruitment Failure in the Southern New England Lobster Stock

The American Lobster Board (Board) assigned the American Lobster Technical Committee with the following tasks:

1. Identify issues impeding stock rebuilding in SNE,
2. Develop a suite of measures to begin stock rebuilding in SNE,
3. Develop deterministic projections of stock abundance using the University of Maine Model that assume: a) both status quo and reduced fishing mortality scenarios, and b) status quo recruitment, low/declining recent recruitment, and a stock recruitment relationship.

The Technical Committee had 3 months to report back to the Board on their findings. From the above tasks the TC drafted the report: Recruitment Failure in the Southern New England Lobster stock. With the exception of temperature data and information on the redistribution of spawning females, all other fishery independent and dependent data used in the TC's report were peer reviewed and accepted during the most recent (March 2009) ASMFC Benchmark Stock Assessment.

Terms of Reference for Peer Review Panel

The peer review will cover the April 2010 Recruitment Failure Report and related TC tasks assigned by the Board as detailed above (tasks 1 – 3). The questions are listed in bold. The other information is meant to provide additional insight.

1. **Evaluate the quality and completeness of the data gathered since the assessment (temperature data and redistribution of spawning females); if inadequate, specify additional techniques that should have been considered.**

2. **Determine the appropriateness of the findings drawn in the TC report, if deemed inappropriate, provide alternative findings with justification**. The report findings include, but are not limited to:

    a. Stock Status: Review of recent monitoring information showing that the reproductive potential and abundance of the SNE stock is continuing to fall lower than data presented in the latest assessment.
        i. SNE spawning stock biomass indicators from 2002 -2009 in general were average to poor. The spawning stock abundance from the RI trawl survey increased to levels at or above the median from 2005 through 2008, during the V-notch program, but the 2009 estimate is below the 25th percentile.
        ii. The last several years have produced larval and YOY indices below the median and at or below the 25th percentile relative to the 1984-2003 reference

years. YOY indices show a statistically significant negative slope since 1992 and the 3-6 year cyclical pattern in larval indices has been replaced with sustained low values for eight of nine recent years. Sustained poor production can only lead to reduced recruitment and ultimately to reduced year class strength and lower future abundance levels.

iii. Fishery dependent and independent data suggest that the distribution of spawning females has shifted away from inshore SNE areas into deep water in recent years. This shift may impact larval supply to inshore nursery grounds.

iv. All but one of the SNE fall trawl survey relative abundance indices for recruit and legal size lobster are generally consistent, with a peak in the 1990's and then a decline to low levels in recent years. Recent recruit and legal indices have generally remained at or below the 25th percentile since 2002.

b. Fishery Status

i. The SNE landings peaked in 1997, declined to a low in 2003 and have remained low through 2007. Landings have been below the 25th percentile of reference period (1984-2003) landings since 2002.

ii. Landings peaked and fell below the 25th percentile in different years in the different stat areas, though there were similarities among a number of areas.

iii. Offshore landings trends in NMFS statistical area 616 stand out somewhat from other areas. Trends were similar to areas 537, 612, and NJ south with a peak in the early 1990's followed by a decline and low levels in 2002. Unlike the other areas, landings increased in 2003 and stayed above median landings for a number of years. Recent estimates have declined, but are still above the 25th percentile and may be underestimated due to the lack of NJ south landings data.

c. Impediments to rebuilding

i. There has been a widespread increase in the area and duration of water temperatures above 20^{0}C throughout SNE inshore waters. Long term trends in the inshore portion of SNE show a pronounced warming period since 1999.

1. Prolonged exposure to water temperature above 20^{0}C causes respiratory and immune system stress, increased incidence of shell disease, acidosis and suppression of immune defenses in lobster. Lobsters avoid water greater than 19^{0}C.

ii. Loss of optimal shallow habitat area is causing the stock to contract spatially into deeper water

1. The shift in abundance to deeper water may reflect increased mortality in shallow water by mid Atlantic predators (e.g. striped bass, dogfish, and scup) whose abundance has increased substantially in the last decade.

2. Recent larval drift studies in area 2 suggest that the re-distribution of spawning females into deep water areas may be causing larvae to be transported away from traditional settlement areas and potentially into less favorable areas.

iii. Continued fishing pressure reduces the stock's potential to rebuild, even though overfishing is currently not occurring in SNE.
    1. Total trap hauls have declined significantly yet have not declined at the same rate as lobster abundance.
    2. Although current measures prevent the harvest of egg-bearing and v-notched lobster, the legal catch inshore and offshore represents a loss of egg production to the system.

3. **Determine the appropriateness of conclusions drawn in the TC report; if deemed inappropriate; provide alternative conclusions with justification.** The report conclusions include, but are not limited to:
    a. The TC contends that the stock is experiencing recruitment failure caused by a combination of environmental drivers and continued fishing mortality.
    b. It is this recruitment failure in SNE that is preventing the stock from rebuilding.
    c. Overwhelming environmental and biological changes coupled with continued fishing greatly reduce the likelihood of SNE stock rebuilding

4. **Comment on the applicability of the recruitment indices to forecast future recruitment and landings to the inshore and offshore areas.**

5. **Determine the appropriateness of the recommended action (5-year moratorium); if deemed inappropriate, provide alternative recommendations with justification.** The report recommendations include, but are not limited to:
    a. Given evidence of recruitment failure in SNE and the impediments to stock rebuilding, the TC recommends a 5 year moratorium on harvest in the SNE stock area.
        i. The moratorium provides the maximum likelihood to rebuild the stock in the foreseeable future to an abundance level that can support a sustainable long-term fishery.
    b. During the 5 year moratorium period, monitoring of all phases of the lobster life cycle should be intensified.
        i. Fishery dependent sampling will no longer be collected, therefore assessment of stock status will rely on current fishery-independent surveys (e.g., ventless trap, YOY sampling, larvae) which will need to be continued and intensified.
        ii. New surveys and research (e.g., sentinel industry surveys) are needed to further characterize stock status, lobster settlement and habitat in SNE.

6. **Evaluate the stock projection scenarios conducted to complete the task as outlined by the Board** (see above).
    a. Evaluate the deterministic projections conducted using the University of Maine Model.
        i. The Board directed the TC to provide projections within an extremely short time frame. Although stochastic projections and estimates of uncertainty (e.g. MCMC confidence intervals) could have been provided, the time frame for decision-making was too short to complete a more thorough analysis.

b. **Evaluate the chosen suite of fishing and recruitment scenarios presented in the report; if insufficient, provide suggestions for alternative scenarios.**
c. **Determine if projection results and the TC's interpretation provided in the report are consistent with assessment model results.**
d. **Comment on the reliability of the deterministic projections for use in SNE lobster stock management.**

7. **Review the M sensitivity analysis of the model that indicated a higher M as suggested in the 2009 assessment.**