Southern New England Lobster Fishery Review

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Completed for the Center for Independent Experts

Executive Summary

This review does not support the conclusion that the Southern New England Lobster Fishery is experiencing recruitment failure. While recruitment failure is one possibility, overfishing is a stronger possibility. Recent abundance of lobsters is low in the fishery although equivalent to the early 1980s when records began. In the 1990s there was a large increase in abundance of lobsters which has been removed from the fishery through a concurrent increase in fishing effort. Thus there is uncertainty whether the abundance levels in the 1980s and 2000s are normal and the fishery experienced an unusual period of high recruitment OR whether routine periods of higher recruitment is a normal part of the dynamics of the fishery. If it is the former, then all the means, percentiles, thresholds and targets are positively biased by the inclusion of the recruitment period. A longer time series is required to determine if high recruitment periods are routine components of the fishery in this region. In addition to the current model runs, comparative model runs should be undertaken where the recruitment peak is removed from the analysis to demonstrate what a long-term fishery based on the 10 – 15 million lobsters looks like.

Irrespective of which scenario is correct, the current effort in the fishery is too high and is approximately 50% higher than when the abundance was a similar level in the early 1980s. A 50 – 75% reduction in effort is recommended immediately.

If the recent stabilization and slight increases in the catch rates recorded for 2004 – 2006 have been maintained from 2007 to 2010, then a 50% reduction may suffice. An economic cost-benefit analysis should be undertaken to look at the optimal MEY for a fishery between 8 (based on projections from YOY) and 14 million lobsters.

Future management should consider a decision rule approach that is accepted by both industry and government. The YOY and CPUE indices appear to be reasonable indices to base a decision rule on.

As the SNE fishery is at the southern limit of the "commercial" distribution of lobsters then any changes in physical properties related to warming are likely to move the southern extent of the "commercial" fishery further north. The increased warming recorded in the 2000s is of concern for the longer-term viability of the fishery.

Future research should focus on the YOY estimates and improved fishery dependent and fishery independent information that are depth stratified. Increased spatial and temporal sampling of water temperatures needs to be obtained through both increased permanent recording sites and from the fishery dependent and independent surveys (e.g. attaching thermistors to the ventless trap surveys and fisher's traps).

Background

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 (TC) 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.

The review evaluated 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 was asked to consider the merits of this recommendation.

Description of the Individual Reviewer's Role in the Review Activities

Three CIE reviewers were selected to conduct an impartial and independent peer review in accordance with the SoW and ToRs. Tasks included reading all documents in preparation for the peer review, conducting the independent peer review in accordance with the SoW and ToRs, and completing an independent peer review report in accordance with the SoW. Each CIE reviewer was to complete the independent peer review according to required format and content as described in Annex 1 and to complete the independent peer review addressing each ToR as described in Annex 2. This review report was completed and submitted to the CIE on 11 October 2010.

Summary of Findings for each ToR (weaknesses and strengths)

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.**

Temperature data:
The temperature anomalies presented indicate a consistent increase in the number of days that temperatures exceeded 20^oC across all four sites in the last decade. The warmer period (since 1999) corresponds with the increased incidence of shell disease. However, many of the other indices (total abundance from both models, MADMF, RI & CT recruits) all indicate that the fishery has been in a similar, or worse, state previously when water temperature anomalies were not similar to the last decade.

This warmer period (since 1999) corresponds with the continued lower than average lobster recruitment indices for the western and eastern long island sound recruitment time series (Fig. 1). However, the large recruitment index in 1999 at both sites occurred during the year with the highest number of days $>20^o$C at the Millstone Power Station – the same location that the ELIS data is obtained. Similarly, in 1997, a period of low recruitment occurred during the year when there were the fewest days above 20^oC. Similarly, peaks and troughs in the recruitment indices are not correlated with days $>20^o$C. Whether the sustained change in periods above 20^oC has impacted the WLIS and/or ELIS sustained low recruitment indices is uncertain. However, the interpretation of the WLIS and ELIS indices is questioned in Section 4. The young of year (YOY) which provides a better correlation with future abundance in the fishery does not appear to be correlated with temperature change.

Thus for interpreting the current observed changes in the fishery, the temperature data appears of little value. However, this population of lobsters is on the southern (warmer) extent of its distribution. While the species has been found further south, the SNE population is the southernmost commercial population. Thus, overall increases in temperature are likely to impact the fishery making these regions less likely to support commercial populations and this is discussed further in the review. As such, I believe that the inclusion of the temperature data is warranted in understanding the dynamics of the SNE population and, as recommended in further research, should become a core component of monitoring the stock.
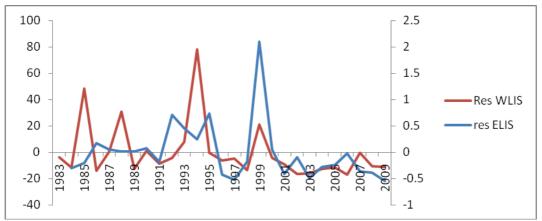

Fig. 1. Anomalies in the recruitment indices from WLIS and ELIS. Positive anomalies indicate periods when recruitment was higher than the 1983-2009 average.

Redistribution of spawning females:
The data on redistribution of spawning female are inadequate.

I cannot find any "evidence" that the distribution of spawning females has changed. Appendix A and the statement on page 10 of the report ("In 1984-1991, the geometric mean catch at sites <30ft depth was comparable to the mean for sites >90ft; in 2000-2008, the mean catch at shallow sites was less than half the mean for the deep sites.") indicate that effort has shifted to deeper waters and this is most likely to be a result of fisher's chasing improved catch rates. The increase in the % of the females in the marketable catch (Table 2 page 22) shows that only in CT has there been an increase in the % of females.

However, it is not the percentage of marketable catch in each region that is the issue; it is the overall number of potential mature females that are removed from the resource. For example, from Table 3.2.4.1 of the American Lobster Stock Assessment Report (ALSAR) it is possible to obtain the landings by year for the three regions: CT, RI and MA. By applying the percentages obtained in each year from Table 2 of the Recruitment failure report it is possible to determine the overall proportion of females removed from the resource. There is very little change in the contribution of females (Fig. 2) despite substantial changes in the contribution of each of the three regions to the overall catch (Fig. 3). Caveats to this analysis include the lack of information for the percentage of females that comprised the catch in the actual years shown (1981, 1999 and 2006) and landings may not adequately represent the proportion of females due to different average size of females or different size:weight ratios.

There is no information to relate Table 2 to deep water regions. While there has been a shift into MA regions which have a higher percentage of females harvested (which appears to be the case since 1999 – Fig. 3), there is less overall landings coming from MA in 2007 compared to 1981 when the SNE fishery was producing equivalent landings.
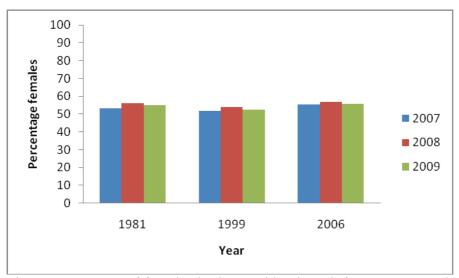

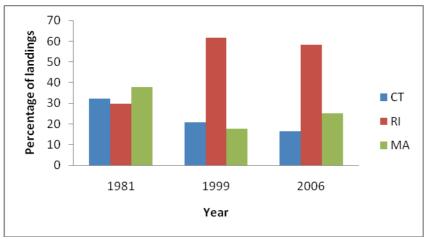Fig. 2. Percentage of females in the combined catch from CT. RI and MA.

Fig. 3. Percentage contribution of CT, RI and MA to the combined SNE catch (CT+RI+MA).

Quantitative data should be available from the fishery independent surveys (ventless traps, trawl surveys) which should have information on catch rate by sex and depth. These data need to be analyzed to provide quantitative information to support the theory that the fishery has moved to deeper waters and that this has resulted in an overall increase in the harvest of females.

I am uncertain what information is reported in the fisher's logbooks. If catch, effort and depth are recorded then quantitative information should also be available from these logbooks for comparison with the fishery independent data.

Additional techniques:
The authors appear to have focused on models and fishery independent methods. While the ALSAR identifies concerns over the use of trap lifts as a form of effort, catch rate data (catch per unit of effort - CPUE) is necessary for interpreting catch data.

Fisheries science is not a precise science and confidence is often gained more from different sources of data showing similar trends than from one single piece of information. Thus I would encourage the authors to use trap data as a measure of effort and then use CPUE as an additional piece of information. Importantly, it does give an indication of trends in the fishery derived from the fishing sector.

Table 7.5.2.3.3, Column 13 of the ALSAR provides gross CPUE data for the SNE fishery and it is acknowledged that Rhode Island (RI) effort is only available for the latter part of the time series. From Tables 3.2.4.1 and 3.2.4.2 of the ALSAR it is possible to obtain CPUE data for the Connecticut (CT), Massachusetts (MA) and New York (NY) regions from 1884 and RI from 2000. Irrespective of which CPUE data are used, there are general trends in the data. Catch rates are relatively flat and variable with peaks in 1990 and 1996-1999 before a decline until the mid 2000s after which they have shown slight improvements (Fig. 4). As described in section 2b, this information is important in interpreting changes in the status of the fishery and the recruitment failure report would have benefitted from these figures being updated.

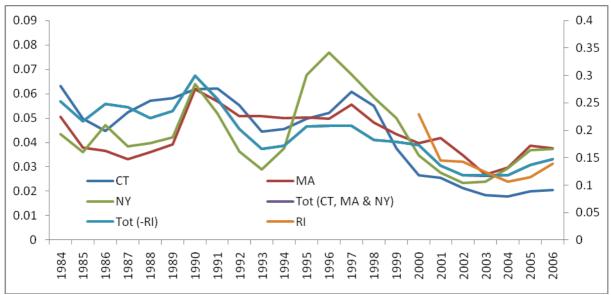For this review I have use the CPUE trend from the Tot (CT, MA & NY) data.

Fig. 4. Standardised catch rates from 1984 to 2006. RI data was only available since 2000 and RI standardized catch rates are provided on the secondary y-axis.

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.**

Stock status: Both the CS and UM models both show an increase in abundance in the mid 1990s. Whether this is due to a strong recruitment pulse or discovery of new unfished regions is not stated. However, as this fishery has been exploited for a long period in time it is unlikely that new grounds would have been discovered – as such this review assumes that the increased abundance in the 1990s is due to a period of high recruitment. Throughout the report reference levels have been based on medians and percentiles that represent the entire period including the large recruitment period. If this recruitment pulse is not normal in the fishery, then the medians and percentiles should be based on the normal fishery (early and mid 1980s and 2000s). I do not believe that these medians and percentiles are a true reflection of the fishery and have therefore not discussed these *per se*. Instead I have based my discussion on what had occurred previously in the fishery.

Abundance, landings and effort all increased from the mid-1980s to the late 1990s. Since the late 1990s abundance, landings and effort have declined (Fig. 5). Unfortunately effort did not decline at the same rate and in 2007 the fishery was using about twice the effort that was used to catch the same number of lobsters as in the early 1980s. Over these three decades it is considered that the unit of effort (fishing power) would have become more effective due to technological advances such as global positioning systems and echosounders. Thus effective effort is potentially greater than twice that of the early 1980s for the same amount of catch. The catch rate has declined to be lower than that of the 1980s when the total catch was similar (Fig, 4). However, recent trends in the catch rates (2004 – 2006) show slight

increases in CT, MA, NY and RI suggesting recent improvements in abundances. These are consistent with the UMM abundance estimates that show a slight increase and stabilization since 2003.
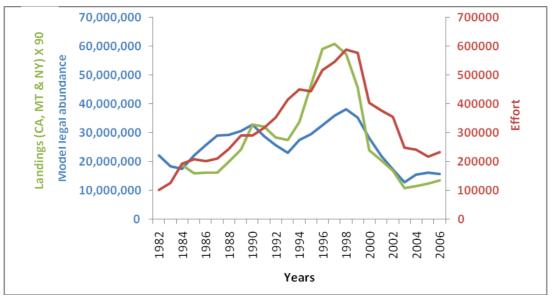

Fig. 5. Comparison of Model estimated abundance, landings and effort. Landings and effort are for CA, MT and NY combined.

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.**

Spawning stock biomass (SSB): The bulk of the catch comes from the CT region where SSB indices indicate that the spawning stock has been consistently lower than previously recorded since 2002. Both the magnitude and duration of these low indices are of concern. However, the University of Maine model (UMM) indicates that the abundance of females since 2003 was estimated to be similar to the early 1980s (Fig. 6). The differences in these trends should be investigated. An inflated value for the UMM model could be due to the UMM model being total females (i.e. mature and immature). However this would suggest that there is currently a large number of smaller females which would imply forthcoming recruitment of females. As mentioned above the use of the median and 25th percentile are potentially biased high given that the large recruitment period in the 1990s may not be a "normal" component of the fishery and means and percentiles based on the SSBs in the 1980s and 2000s may be a more accurate reflection of the status of the spawning stock.
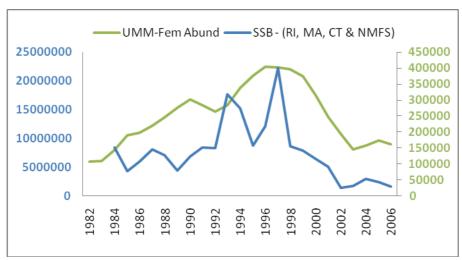
Fig. 6. Comparison of female abundance estimates from the UMM and spawning stock biomass.

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.**

The value of pre-recruit indices is determined by how well the indices relate to observed changes in the fishery or other indices to ensure that what is being measured is not an artifact of area sampled, method used etc. A difficulty with using these indices is the uncertainty as when the larvae or YOY animals will recruit into the fishery. It has been suggested that this can vary from 5-8 years. As the time interval is expected to decline with increased temperatures (i.e. assuming faster growth) I have used a 6 year lag period. Correlations between the larval and YOY indices show only a minor correlation between ELIS and WLIS and a moderate correlation between YOY and WLIS (Table 1). The lack of correlation is surprising as there is substantial variation between years. This would suggest that there are very localized recruitment patterns, which makes it difficult to link any index with the dynamics of the fishery as a whole. The strength of the ELIA:WLIS and WLIS:YOY correlations is based on the leverage of one of the twenty-five data points. Thus correlations between the indices are weak. Only the YOY appears to provide a reasonable correlation with future catches (Table 2 and Figs 7 & 8). The improved catch rates in the 2003-2006 period for most regions (Fig 4) would be associated with the higher YOY values in 1997-2000. The consistently lower values since 2000 and especially the 2009 value (Figure 5 of the report) would indicate that abundance and CPUE are expected to further decline over the next 6 years.

Table 1. Correlations between recruitment indices.

	Years compared	Correlation
ELIS:WLIS	1984 – 2009	0.31
ELIS:YOY	1989-2006 (ELIS) 1990-2007 (YOY)	0.11
WLIS:YOY	1989-2006 (WLIS) 1990-2007 (YOY)	0.42

Table 2. Correlations between recruitment indices and exploited indices.

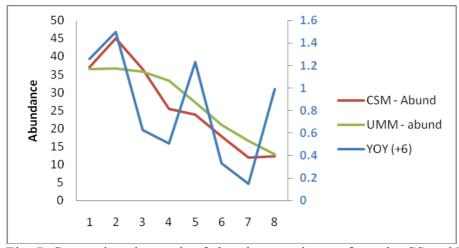|	Years used	CPUE	ELIS	WLIS	YOY
Abundance (UMM)	1991-2007	0.74	0.05	0.13	0.46
CPUE	1991-2007		-0.05	0.28	0.60
ELIS	1985-2001			0.19	0.00
WLIS	1985-2001				0.35
YOY	1985-2001				

Fig. 7. Comparison in trends of abundance estimates from the CS and UM models and YOY index. The YOY index was advanced 6 years as an estimate between YOY and recruitment to the fishery.
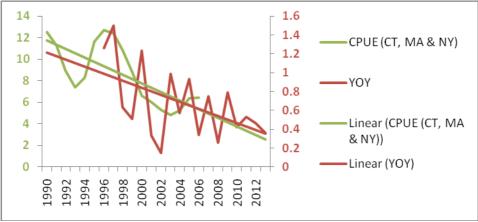

Fig. 8. Comparison in trends of catch rate (CPUE – CT, MA & NY) and YOY index. The YOY index was advanced 6 years as an estimate between YOY and recruitment to the fishery.

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.**

The shift in spawning females from inshore to deep waters is difficult to assess in the current document (see section 1). If females have shifted distribution then it is possible that the currents in the relocated area are different from the original area and thus there could be an impact on recruitment. Currently there is no evidence to support a shift in spawning females.

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.**

In general, a strong correlation should exist between the catch rates of recruits of a specific year and the catch rates of legal sized animals of the following year. While correlations between the catch rate of recruits and legal sized lobsters in the following year for the RI, CT, MA and NEFC Fall fishery independent surveys is moderate, the correlation between recruits and legal sized lobster for the same year in all surveys is stronger (Table 3). This is of concern as there are strong individual peaks in the recruits which would be expected to recruit (molt) into the legal category in the following year. Strong correlations for the same year indicate that differences between years may not be solely due to recruitment compared to changes in events that affect both size classes equally such as catchability. Catchability changes could be due to biological events (e.g. increased catchability with increased water temperature, increased concentration of lobsters on fishing grounds due to increased immigration to fishing grounds) or technological improvements (e.g. GPS, improved echosounders). It is assumed that because these are fishery independent surveys that technological improvements can be ruled out.

For the CT, NJ, MADMF and NEFC surveys the recent trends in legal size and recruits have been lower than previously recorded in the fishery. With the exception of CT and NJ legal-sized lobsters, all other surveys show strong peak(s) in catch rates in the 1990s suggesting positive recruitment periods during the 1990s. While the overall trends in catch rates for legals or recruits are non-significant due to the variability in catch rates, the trends in all regions except RI are negative with the majority of the recent data points being below the trend lines.

Table 3. Correlations between the catch rates of recruits and catch rate of legal lobsters in the same year or the following year obtained from fishery independent trawl surveys.

Fall Trawl Survey	Legal catch rate of flowing year	Same year
NMFS	0.40	0.77
RI	0.49	0.85
CT	0.48	0.80
MA	0.46	0.74

The accuracy or usefulness of the trawl surveys is their value in indicating changes in the fishery. Moderate correlations exist between the regional catch rates derived from Tables 3.2.4.1 and 3.2.4.2 and the regional trawl survey catch rates (Table 4). Stronger correlations

were obtained between the regional trawl survey catch rates and the abundance estimates from the UMM for NY and RI. Thus the recent declines in the trawl survey catch rates provide additional support that the fishery is performing poorly. The only positive note is that the RI values did not show a declining trend over time and this region of the fishery accounted for 43% of the catch in 2007.

Table 4. Correlations between regional trawl survey catch rates and CPUE and abundance indices. The percentage that each region contributes to the catch is also presented.

	CT	MA	NY(NJ)	RI	NMFS
CPUE	0.69	0.37	0.56	0.37	
Abundance (UMM)	0.61	0.06	0.76	0.54	0.44
% landings in 2007	10	16	17	43	14

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.

Interpretation of the fishery status based on landings is inadequate. Comparison of landings between regions or years is only valid if effort is constant during the comparisons. Standardization of landings is usually achieved by conversion to catch rates by dividing the catch by the effort. For example, the increase in landings in the three statistical areas in figure 9 could reflect increases in effort or increased recruitment to the fishery. The one year lag in peak catches from statistical area 611, 613, 539 could be due to changes in the fishing fleet as it shifts to new regions as catches start to decline or, it may represent changes in the peak time of recruitment (e.g. regional delays from a single larval recruitment period due to temperature impacts on growth). Similarly the increase in landings in 616 could be due to an increase in effort.

The use of the percentiles is also inappropriate as they assume that the fishery has experienced relatively average recruitment. Clearly this is not the case and the fishery has experienced a large recruitment period in the 1990s. Either side of this recruitment the landings and effort are substantially lower. It is likely that this is the normal condition of the fishery and thus expectations should be based on these lower levels. As has been mentioned previously and reiterated below, the poor performance in the fishery is exacerbated by the higher effort that remains in the fishery compared to when there were equivalent landings in the 1980s.

However, it was possible to obtain catch rates from tables 3.2.4.1 and 3.2.4.2 of the ALSAR for different states/units (Fig. 10). In all regions, the catch rate is declining but it is declining more rapidly in CT than either NY or MA. Caution is needed in interpreting the trend in RI as reliable data were only available from 2000. Interestingly, the recent catch rates have started to improve in all regions (Fig. 11). More recent data would be beneficial to determine if these upward trends continue.

By comparing the catch rates (CPUE) against effort (Fig. 12) it is possible to gain insights into the dynamics of the fishery in each of the regions. For MA and CT CPUE remained relatively stable as effort substantially increased from the mid 1980s to the late 1990s. Thus fishers were able to immediately adjust their effort to harvest an increasing legal sized biomass. This increase in legal sized biomass was either due to improved recruitment to the fishery or fishers locating new ground. It is assumed that it is the former as the fishery has operated for a considerable period in time and it would be expected that new undiscovered grounds are unlikely. In NY there was a slight increase in CPUE as effort increased indicating that fishers were slower in responding to improved catches than in the other regions. In all regions there has been a decline in CPUE with reducing effort since the late 1990s. This has resulted in the CPUE being equal (NY) or lower (CT, MA, RI) for the equivalent effort in the 1980s. Thus for the equivalent effort there are fewer legal sized lobsters available suggesting that recruitment is lower than previously. However, during the last few years (Fig. 11) CPUE has increased slightly indicating that recruitment has been slightly better recently than the lows of the early 2000s.
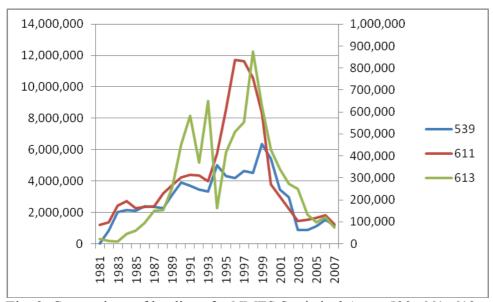

Fig. 9. Comparison of landings for NMFS Statistical Areas 539, 661, 613.
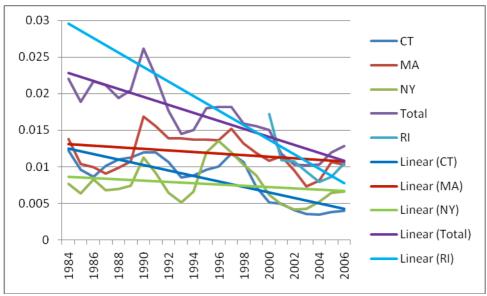
Fig. 10. Trends in catch rates in 4 states from 1984 to 2006. Note that the trend for RI is only based on the data since 2000 (6 years only).
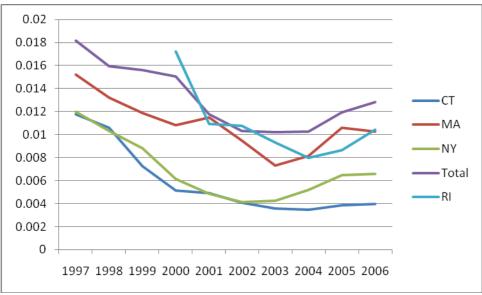

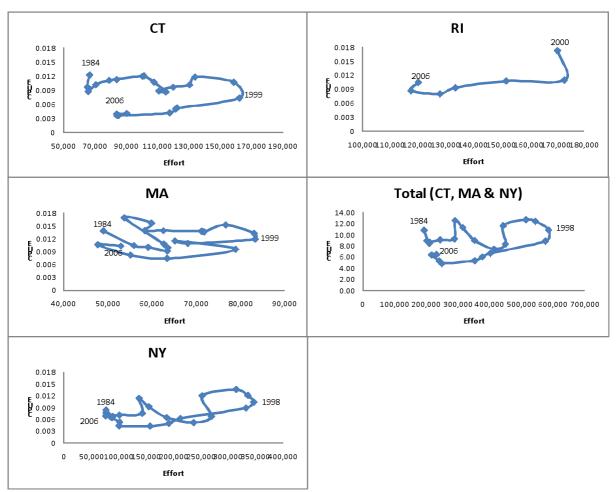Fig. 11. Recent trends in catch rates for the SNE lobster States.

Fig. 12. Comparison of catch rates and effort

c.   Impediments to rebuilding
        There has been a widespread increase in the area and duration of water temperatures above 20^0C 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 20^0C causes respiratory and immune system stress, increased incidence of shell disease, acidosis and suppression of immune defenses in lobster. Lobsters avoid water greater than 19^0C.

The information provided in the documentation clearly indicates the increase in the number of warmer days. The scientific papers cited indicate that these warmer periods would be less favorable for lobsters and this is also supported by the natural distribution of the species. As SNE is on the equatorial margin of the natural distribution of the species, then it is plausible that any warming would see this margin become less favorable (i.e. the environmental envelope for the species moves north). It is the same theory that has seen a large number of more mobile species move poleward due to warming waters around the world.

However, lobsters do have the option to move into cooler deeper waters. It is currently unknown if lobsters are distributing themselves in deeper waters, or if lobsters settle in deeper water, or if suitable settlement and juvenile habitat is available.

15

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

Given the maps in appendices A and B it should be possible to provide a table of potential habitat in each of [say] 10-meter bins.

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.**

While this is a reasonable theory, there is no evidence to support this either by reference to the literature or data. Furthermore, there is no evidence provided to indicate that these species eat lobsters, in what quantity or what size range.

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.**

There is no evidence to suggest that females have re-distributed themselves in deeper waters. However, if this is the case then it is reasonable to accept these statements.

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.**

What appears to have occurred in this fishery is a large recruitment event that has increased the number of lobsters on the fishing grounds during the late 1990s. Fishers have responded to this increase by increasing their effort (Fig. 5). Once the recruitment pulse had been exploited the landings declined and this is followed by a decline in effort. The effort has not returned to the same level of the early 1980's when the landings were similar to today. In many fisheries worldwide, it is recognized that there have been several significant advances in technological that has increased catch efficiency. Examples of this include global positioning systems and echo sounders. While it is uncertain how these technologies would have impacted on the lobster fishery, it is reasonable to expect that the efficiency of effort in recent years is greater than in the early 1980s. Since the high landings of the late 1990s it is reasonable to expect that catching efficiency would have improved as effort has declined in the fishery. It is normally the less efficient fishers that leave the fishery first or fishers remove their least efficient traps from the fishery first. Thus current catch rates are likely to overestimate abundance compared to the 1990s and 1980s. This implies that recruitment to the fishery is lower than in the 1980s. While there are encouraging signs that catch rates are improving, effort is approximately twice what it was in the 1980s and needs to be reduced to improve legal sized biomass.

While decreasing effort should see an improvement in catch rates and thus profit per trap for the fisher, stock rebuilding will be a result of an increased proportion of the existing lobsters being left on the fishing grounds due to lower exploitation rates. Stock rebuilding associated with improved recruitment to the fishery will only occur with decreasing effort if there is a

stock recruitment relationship. Correlations between SSB and YOY of the following year have minor positive correlations for all regions (RI, CT, NMFS, MA) (Table 5). However, there are no correlations between the SSB and the catch rates in six or 7 years time (Table 5) or total SSB and total abundance (UMM) in 6 (r=-0.22) or 7 (r=-0.42) years. These suggest that there is no relationship between SSB and future recruitment to the fishery. While this is not surprising as stock recruitment relationships in lobster fisheries globally have proven to be elusive, the large spawning stock in the late 1990s would be expected to result in improved recruitment in the 2000s. This would suggest that recruitment to the stock is most likely affected by post-spawning issues (e.g. environment) and that improving SSB is likely to have limited value. However it would be beneficial to know if the SSB is substantially lower than in the early 1980s (which resulted in high recruitment in the 1990s) as indicated by the fall trawl surveys or is above the 1980s as indicated by the UMM estimates of female abundance.

Table 5. Correlations between regional SSB estimates and YOY of the following year and regional catch rates in 6 or 7 years.

	RI	CT	NMFS	MA
YOY+1	0.28	0.12	0.37	0.31
CPUE+6	-0.36	-0.50	0.02	0.16
CPUE+7	-0.36	-0.63	-0.10	-0.05

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.

The information provided is inadequate. It is not the percentage of marketable catch in each region that is the issue; it is the overall number of potential females that are removed from the resource. See TOR 1 regarding the contribution of spawning (egg bearing) females.

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.

From the information provided in the "Recruitment failure in the SNE lobster stock" and the "American Lobster Stock Assessment Report" the SNE stock appears to be in a poor state. The recruitment indices (Fig. 1), YOY index (since early 1990s) and catch rates (Figure 4) all indicate that recruitment and catch rates have been declining since the early 1980s. The lack of rebuilding of the stock after effort has been reduced since the late 1990s (Fig. 12) also indicates that recruitment to the stock is less than has occurred previously. In the early 1980s when the landings were equivalent to what they were in 2004-2007, the effort was half of what it is in 2007 (Fig 13). Similarly, for the equivalent average effort expended in 2003-2007, fishers were obtaining 67% more catch in 1984-1988.
The effort is too high for the current abundance and the indices available to the reviewer indicate that recruitment to the fishery is declining.
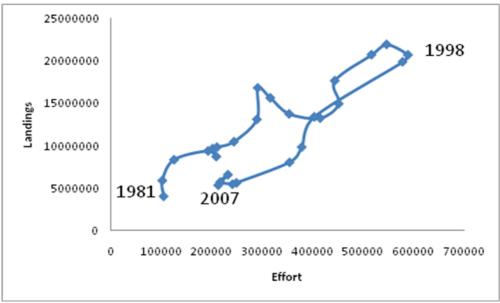
Fig. 13. Comparison of total landings and total effort from 1981 to 2007.

b. **It is this recruitment failure in SNE that is preventing the stock from rebuilding.**

The larval and YOY indices are all declining since the early 1990s (Figure 14). However, the lack of correlation between these indices suggests that either the settlement is very localized and different between regions or that these indices are not representative of future catches (see Section 4). The improvement in regional catch rates in 2005 and 2006 in all regions of the fishery indicate that there is improving recruitment to the fishery (Figure 11). It is unfortunate that updated figures for 2007 – 2009 are not available. Thus while recruitment is low, and has been low in the fishery for several years, there is no solid evidence for recruitment failure. For species at the edge of their distribution it is not unusual for recruitment to be highly variable and often limited to large peaks when all the favorable conditions come together at the same time. The pattern observed in the fishery over the last 30 years is a fishery that has responded to one larger recruitment pulse (when all conditions influencing recruitment appeared to be favorable). However, on either side of this period abundance, as estimated by the CSM and UMM, is at a lower level. If this lower level is more normal for the fishery then recruitment has returned to its relatively normal level. However, the comparisons between effort and CPUE for all regions except NY indicate that there are fewer lobsters than in the 1980s and thus recruitment now is lower than at this time. Thus the stock is currently experiencing lower recruitment than expected. However, recent positive trends in catch rates from 2004 – 2006 indicate that recruitment might be improving.
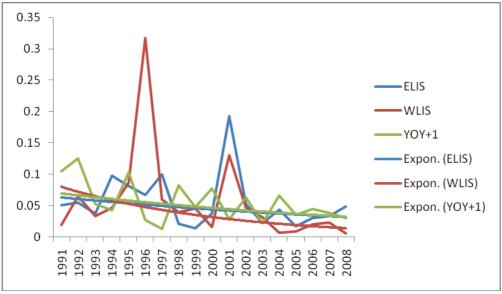
18

Fig. 14. Relative larval and YOY (lagged by one year)

c.   Overwhelming environmental and biological changes coupled with continued fishing greatly reduce the likelihood of SNE stock rebuilding

The evidence for environmental and biological changes preventing the stock from rebuilding is low. The evidence for fishing pressure to prevent stock rebuilding is higher. Compared to the early 1980's when the catch was similar to the last 4 years, current effort is nearly twice that of the early 1980s. The slight improvement in catch rates in the last two years of available data (2005 & 2006 – Fig. 11) indicate that despite this higher effort there is a slight improvement in the stock.

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

In the documentation provided, the only indication of a metric for splitting inshore and offshore water is the NEFC survey which is considered the best survey of offshore areas. Thus it is not possible to link recruitment indices to inshore and offshore regions. Thus I will comment on the applicability of recruitment indices to forecast future recruitment and landings.

Correlations between WLIS and ELIS larval abundance indices, YOY, catch rates of recruits and legal-sized lobsters from the fall fishery independent surveys and UMM estimated abundance and CPUE have been discussed in section 2a(ii) & (iv).

Neither larval index provides a correlation when lagged by 6 years. In contrast the YOY provide moderate correlations for legal catch rates for all regions except MA (Table 6). The correlation for recruits is improved for the deeper water site and weaker for the shallower sites. There was a substantial improvement in correlation between YOY and recruits at MA compared to legal lobsters. Catch rates for the fishery only showed a meaningful correlation with CT.

These results would suggest that the YOY is the only useful recruitment index for predicting regional and total catch rates from fishery independent and fishery dependent data sources respectively.

Table 6. Correlations between legal and recruit lobsters from the regional trawl surveys and larval, YOY, CPUE and abundance estimates.

	Legal				Recruits			
	NEFC	RI	CT	MA	NEFC	RI	CT	MA
Abundance (UMM)	0.46	0.55	0.63	0.13	0.61	0.57	0.79	0.40
ELIS	0.05	-0.09	-0.05	-0.01	0.03	-0.04	0.03	-0.08
WLIS	-0.06	-0.09	0.14	0.23	0.04	-0.05	0.13	0.39
YOY	0.53	0.62	0.64	0.27	0.69	0.54	0.54	0.45
CPUE	0.38	0.06	0.60	0.29	0.25	-0.12	0.23	0.20

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

Closing the fishery will increase stock rebuilding fastest if the recruitment decline is associated with fishing. If the recruitment decline is associated with environmental issues such as rising temperatures, which are expected to increase with global warming, then the fishery in this region has a limited future. Under a global warming scenario, the prospects for a fishery in deeper water will only occur if the larvae can settle, survive and recruit to the fishery in deeper water.

There is no information provided on the social and/or economic status of the fishers. Do the fishers have access to other regions of the fishery (GOM, GB)? If not, fishers and their families will be removed from the income derived from the fishery. If they do have access to other regions then managers need to consider what the re-direction of effort to these regions is likely to do to the overall stock.

Effort has been too high in the fishery for too long and needs to be reduced at a minimum by 50% to be equivalent to the effort that was harvesting an equivalent abundance in the early 1980s. However, given the increase in the efficiency of the effort which would be expected with improvements in fishing technology, a greater than 50% reduction in effort is required. Doubling of the efficiency in fishing effort since the early 1980s is not unreasonable and many fishers are prepared to acknowledge this. If this were the case then a 75% reduction in effort would be a minimum target to enforce immediately. A recommendation would be to try to survey fishers to determine what they consider their improvement in efficiency is. However, there is a positive correlation between the YOY and catch rates in the fishery lagged by six years. The recent YOY indices indicate that the overall catch rates in the fishery are likely to fall from approximately 25-27 to approximately 20-23 pounds per trap fished. The viability of fishers with reduced catch rates and reduced number of traps needs to be ascertained.

Whether a substantial cut in effort or a total closure is required is a socio-economic question. If effort is a primary cause of the declining stock then the more effort that is removed the faster the stock will recover but the greater the impost on fishers, processors and others activities that service the fishing industry. A recommendation would be for a detailed socio-

economic study to be undertaken to determine the implications of substantial effort reductions (e.g. 75%) and total closure on the fishery.

Given the uncertainty of the drivers for the decline (i.e. fishing mortality or environmental) a specified closure time period seems inappropriate. Instead it would be recommended that a decision rule be implemented that is transparent and agreed to by both managers and fishers. If fishing is allowed then the decision rule could be based on YOY and CPUE indices such that a decline in a combination of these would result in further restrictions on effort in the fishery. If fishing is completely stopped, then the decision rule would need to be based on YOY and recruits from the fall trawl surveys.

The fishery also appears to have been sustained in the past by a large recruitment event that resulted in increased catches in the late 1990's. Large and irregular recruitment fluctuations at the edge of a population's distribution are not uncommon. If recent environmental changes are not influencing recruitment to the fishery then it is likely that large recruitments will occur in the future. Management of effort during such an event would be required to maximize the benefit of the recruitment pulse to enhance stock rebuilding.

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.**

The concept of a sustainable long term fishery needs to be determined. If environmental factors aren't preventing normal recruitment to the fishery then the fishery can be sustainable at its current level with a reduction in effort. What is uncertain in the fishery is what an appropriate abundance level is. If the abundance levels obtained in the 1990's are due to a recruitment period that is an abnormal event then a sustainable fishery at higher abundance levels is unlikely. If the abundance levels of the early 1980s and mid-2000s are normal then the current fishery is likely to be at a more normal abundance level. The recent improvement in catch rates indicates that the stock is beginning to respond to the reduced effort although the last couple of YOY estimates suggest that at least a couple of years of lower than expected catch rates can be expected.

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.**

Larval sampling appears to provide no benefit in the understanding of the stock and should be the lowest priority for future monitoring. The Rhode Island YOY appears a good index and should be continued. The Massachusetts YOY index appears a low priority as the number of YOY encountered is small and variable. Spawning stock biomass (SSB) indices are not correlated with RI YOY for the same or following year (Table 5). No correlation

exists between the SSB and CPUE of the fishery in six years time. The fishery independent trawl surveys do correlate with estimates of current abundance.

The ventless traps surveys have not been underway for sufficient time to determine their potential. However, using a sampling gear similar to the fishery has considerable merits, especially if the fishery is to be closed.

In addition to these surveys it is recommended that future surveys be depth stratified so that catch by depth can be obtained.

If not available, maps on available lobster settlement habitat within the region need to be determined with a focus on identifying potential areas for lobsters to settle in deeper cooler waters. Once identified, these areas would need to be surveyed to determine if juvenile lobsters are utilizing these areas. This may pose difficulties as divers are restricted by depth so other juvenile estimation techniques may need to be developed.

Bottom temperature data need to be improved by the establishment of reference stations that are depth stratified (these could be thermistors that are attached to time release buoys and retrieved annually). Thermistors should also be attached to sampling gear (ventless traps, trawl gear) to increase knowledge of the bottom water temperature values.

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.**

The "faith" in the projections is reliant on two main factors. Firstly, how well the model estimates the actual data for the periods of overlap (1982 – 2007) and, secondly, how realistic are the parameters used to project forward.

The model is strongly correlated with the landings (catch) data ($r^2 = 0.82$, Fig. 15). Generally, landings are considered an inappropriate measure of abundance as it can reflect changes in effort which is independent of abundance. While there are concerns over the use of traps as an indication of effort, the large changes in effort since the 1980s would suggest that landings cannot be a true reflection of abundance. The correlation between CPUE and model estimated legal abundance is high ($r^2 = 0.61$, Fig. 16). Thus the UMM model appears to be able to represent the past relatively well and thus there should be confidence that it will also predict the short term future relatively well providing that the biophysical relationships that the model assumes remain constant. Thus if increased warming inhibits recruitment to the fishery then the model will have no "knowledge" of a change in the recruitment relationship.

There is no support for the statement "The major conclusion to be drawn from these projections is that if poor environmental conditions continue, dampening the abundance of both spawners and recruits, only current abundance levels may be attainable even in the

absence of fishing". As indicated in this review, there is no firm evidence for poor environmental conditions and the most likely current situation is that the fishery is returning to a "normal" level after a period of elevated recruitment. The low recruitment and reduced effort (quarter F) scenario in Fig. 5 of the Stock Projections Report is potentially the "normal" situation (i.e. low recruitment is actually normal recruitment) and the number of legal lobsters tends to be stabilizing at approximately the current level. As it is uncertain what "very low recruitment" is, the low recruitment scenario may well be too low. Any increase in recruitment above the "very low" scenario would result in the number of legal lobsters stabilizing at a higher value.

The target and threshold levels in the fishery are based on the fishery that was dominated by a high recruitment period in the 1990s. If this recruitment is not normal for the fishery then the threshold and target values would be biased high. Targets and thresholds based on the low recruitment of the early 1980s and 2000's should also be developed.
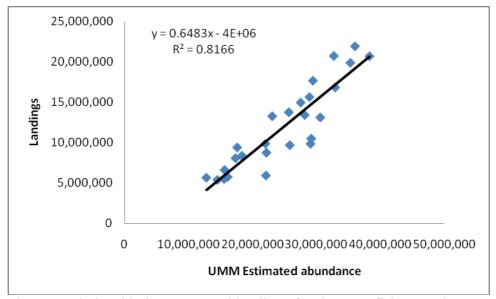

Fig. 15. Relationship between total landings for the SNE fishery and UMM estimated abundance.
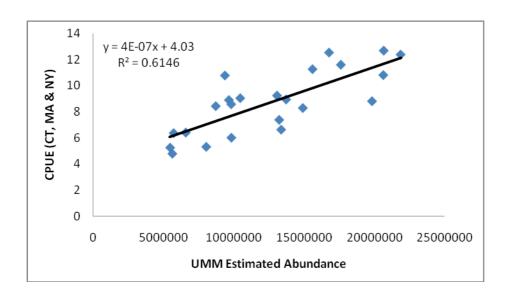

23

Fig. 16. Relationship between CPUE for the CT, MA & NY regions of the SNE fishery and UMM estimated abundance.

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

As already indicated, the current fishing effort is substantially higher than when the abundance of legal lobsters was at an equivalent level in the early 1980s. Quarter and half F scenarios are similar to what this review has suggested in Section 2b. As a moratorium is being suggested then no fishing also needs to be a scenario. All models assuming constant or average F are inappropriate as they do not reflect the dynamics of the fishery – that is, they are based on a large recruitment event that has passed through the fishery. There is uncertainty whether such an event has occurred previously or will occur again and over what time period (i.e. was it a 1in 50 year event?).

The fishery experienced a recruitment event in the 1990s that led to the increased landings and effort in the late 1990s after which it has returned to similar levels as was the case in the early 1980s. For populations at the edge of their distribution, large scale recruitment events can occur at sporadic intervals. However, it is inappropriate to manage the fishery on the expectation of such an event. As such, it is inappropriate to use a recruitment relationship that incorporates this large recruitment event as it will be overly optimistic as indicated by the authors of the report. Rather, recruitment in the model should be restricted to periods either side of this peak. Fortunately this is covered in the model by the "very low" recruitment scenarios although there is no indication as to what "very low" is. Is "very low" equivalent to 50% of the BH estimate? The authors need to justify what the "very low" value is and how it compares to the BH-based R value.

It is plausible (and highly likely) that values lower than the BH-based R are not low recruitment but normal recruitment and that the BH-based R is high (and unrealistic) recruitment.

The following scenarios are those that should be considered:

Natural Mortality	Recruitment	Fishing mortality
High M	Low R	Half
Moderate M		Quarter
		None

As model abundance and CPUE tend to track each other (Fig. 7) and CPUE and YOY (Fig. 8) also track each other the authors should consider incorporating YOY as a recruitment index in the model to produce short-term (6 year) future predictions.
Projections that incorporate V notching (Fig. 6 of the Stock Projection Report) also need to incorporate half or quarter F and not constant average catch as current effort levels in the fishery are considered too high for the number of animals available.

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

The main issue with the projections is that the targets and thresholds are based on a fishery that has seen a large recruitment period in the 1990s and is now returning to pre-1990s status. While a longer time series would be ideal, the recruitment is just as likely to be an

abnormally high event rather than what is "normal" for the fishery. Thus the thresholds and targets, which incorporate this large recruitment as "normal" would be too high for a "normal" fishery that does not incorporate the large recruitment event.

Unfortunately there appeared to be no attempt to constrain effort when the recruitment period occurred and passed through the fishery. As a result the catch rates rapidly declined in the late 1990s to the mid-2000s after which they appear to be stabilizing. If the slight improvements in catch rates in all regions from 2004 – 2006 (Fig 11) are continuing after 2006 then reductions in the effort to half or quarter F should see improvements in the fishery. As can be seen in figure 5 of the Stock Projections Report, the low recruitment scenarios tend to be stable after an initial increase and decrease in the number of legal lobsters. Thus the long term future of the fishery is likely to be at this level (between 8 – 14 million legal lobsters) if the low recruitment value is accepted. However, while I have argued that recruitment lower than the BH-based R is required, it is uncertain what the low R used in the model is based on, or how much lower than the BH-based R it actually is. If the low R value was too low, the predicted number of legal lobsters would stabilizing at a lower value than expected.

Projections that incorporate V notching (Fig. 6 of the Stock Projections Report) indicate that the BH-Based recruitment has a large positive bias due to the incorporation of the large recruitment period in the fishery in the 1990s. The low recruitment scenario which this reviewer believes is more "normal" in the fishery (but see concerns above about what low actually is) indicates that v-notching has limited value under the constant average catch scenario. This is not surprising as all the evidence indicates that the current effort in this fishery is too high and needs to be reduced by between 50 and 75%. Scenarios with half and quarter F would need to be determined. However, the reductions in the catch that result from the decreased effort would possibly be equivalent to the v-notching program and thus may not be too different to the projections in figure 5 of the Stock Projections Report.

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

The threshold and target values are based on a fishery that has seen a large recruitment period in the 1990s. Prior to (1980s) and after this event (2000s) recruitment has been low in the fishery as reflected in the abundance estimates of the models. What is "normal" in the fishery is debatable and a longer-time series is required to determine this. Managing the fishery on the average threshold and target values will be overly optimistic if recruitment is consistently high as in the 1990s and be overly pessimistic if the recruitment is low as in the 1980s and 2000s. Thus I believe that the current target and threshold values are too high for the current fishery. To meet any of the targets would require recruitment to be an average of the high and low periods. The most likely scenario is that the lows of the 1980s and 2000s are the normal pattern and the highs of the 1990s were a period of improved recruitment. How often these improved recruitment scenarios occur is unknown. From a precautionary perspective, the fishery should be managed assuming that the low recruitment is the normal recruitment to the fishery. Unfortunately the projections do not indicate how low recruitment has been adjusted to for use in the "low R" scenarios. The low R scenario is possibly too low as the recent catch rates in the fishery (2004 – 2006) indicate minor improvements. Data beyond 2006 would be useful to see if this trend is continuing.

However, despite these concerns the projections do indicate that a substantial reduction in fishing mortality is required and this is supported by other trends in the fishery.

This review supports the use of the projections in the SNE lobster stock management as one "line of evidence" as the model is one piece of information amongst several other indices. It is the strength of the patterns observed in all indices that provide the robustness for management decisions. However, targets and thresholds are required for a low R fishery and greater transparency is required to determine what "low R' actually is.

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

The M sensitivity analysis is a good addition to the assessment. However, caution needs to be used in interpreting what this actually means. Most models have difficulty in separating M from F. Thus, would an increase in fishing mortality from 1998 – 2007 and leaving M at 0.15 produce the same results?

It is possible that the increased deaths in the fishery are a result of improved efficiency of the fishing gear or F not accounting for the rapid reduction in legal lobsters and slower reduction in effort that occurred from 1998 as the recruitment pulse was fully exploited by the fishery.

From the model outputs, an increase in total mortality (M + F) is accounted for in the model which, whether M or F, should provide more realistic outputs. However, if the increase in M is really an increase in F then the required reductions in F to meet an appropriate F reference point would need to be greater.

If the authors can be 100% certain that M is completely independent of F in the model then the increase in M would suggest that environmental issues (water temperatures, predation rates) have negatively impacted on the fishery. I would recommend that further studies are required to gain an understanding of how to attribute the increase in mortality between M and F.

The increase in shell disease is definitely an indication of increased mortality to the fishery in this region which would imply that M is higher than prior to the 2000s. The incorporation of an increased M in the stock assessment projections is an appropriate inclusion and well justified.

Conclusions and Recommendations (in accordance with the ToRs)

TOR 1
Temperature is likely to be important in a warming world and the SNE population supports the most southern distribution of the species that is commercially viable. Increases in temperature are likely to move the southern limit of the fishery north.

Recommendation 1: It is recommended that increased temperature stations be established and that temperature measurements be routinely collected as part of fishery dependent and independent surveys. Consideration should be given to ways of encouraging fishers to also link bottom temperature with catch (e.g. volunteer logbook).
There is insufficient information to be conclusive about the redistribution of females or a shift of the population to greater depths.

Recommendation 2: It is recommended that a more formal analysis of catch rates at depth be undertaken and that future surveys be depth stratified. Consideration should be given to ways of encouraging fishers to record depth with catch (e.g. volunteer logbook).

Although there are concerns over the use of trap lifts as effort, catch rate (catch per unit of effort [CPUE]) data is an important metric for standardizing and interpreting catch data.

Recommendation 3: It is recommended that CPUE data be used as an additional metric in assessing the fishery.

TOR 2
The UMM abundance estimates provided in the "Recruitment Failure in the Southern New England lobster stock" report and the CPUE estimates described in this review do not support the conclusion that the SNE stock is continuing to fall.
There is inconsistency between the female abundance estimates from the UMM model, which indicates that the abundance of females is greater in the 2000s than in the early 1980s, and the model used in the report to produce Fig. 3, which indicates that the recent SSB estimates are lower than the 1980s.

Recommendation 4: It is recommended that these models be investigated to determine which estimates are most likely.

The WLIS and ELIS larval indices show no correlation with each other or with other indices of the fishery such as abundance, CPUE or YOY indices. The WLIS and ELIS are considered to be of limited value for assessment or prediction in the fishery. The Rhode Island (RI) YOY was found to be correlated with abundance and CPUE. The Massachusetts (MA) YOY index has no power for correlation or prediction due to the low and variable numbers recorded during surveys.

Recommendation 5: It is recommended that YOY be prioritized as the preferred recruitment index for the fishery. Further effort should be directed to expanding this index to other regions and that the MA YOY survey sites are altered to a region where improved numbers of YOY are encountered.

Part 2a (iii) of TOR 2 is addressed by recommendation 2.

The trawl surveys are weakly to moderately correlated with CPUE (CT and NY) and UMM model abundance estimates (CT, NY and RI). Only the CT and NEFC surveys, which are in regions that account for less than 25% of the catch, have catch rates lower than reported in the early 1980s. The weaker correlation that exists between recruits of one year and legal sized lobsters of the following year compared to correlations between recruits and legals of the same year needs further explanation.

Recommendation 6: It is recommended that a study be undertaken to determine why there is a weaker correlation between recruits of a year and the legal sized lobsters of the subsequent year.

Recommendation 7: It is recommended that the MA survey be relocated to a region where it is a better prediction of abundance and CPUE in the MA region.

The use of the landings data as an abundance index is biased without an understanding of the effort.

Recommendation 8: It is recommended that more reliable effort data is routinely collected from the fishery and that CPUE replace landings in assessing the fishery.

Recommendation 9: It is recommended that the regional CPUE data used in this review is updated to 2009.

The fishery has experienced a large increase in recruitment that was reflected in the landings. As recruitment and landings have returned to lower levels equivalent to the early 1980s, effort has not reduced to the equivalent level in the 1980s.

Recommendation 10: It is recommended that effort be reduced in the fishery to a level equivalent to the 1980s and that a socio-economic study be implemented to determine the economic viability of effort reductions.

Part 2c (i) of TOR 2 is addressed by recommendation 1
Part 2c (ii) of TOR 2 is addressed by recommendation 2
Part 2c (iii - 1) of TOR 2 is addressed by recommendations 8 & 9.
Part 2c (iii – 2) of TOR 2 is addressed by recommendation 2

TOR 3
Although recruitment to the SNE fishery is lower in the 2000s compared to the 1990s, there is no overwhelming evidence that the stock is experiencing recruitment failure. Rather, it is most probable that the fishery is returning to "normal" recruitment that was evident in the early 1980s. While abundance estimates are equivalent between the early 1980s and the mid to current 2000s, current effort in the fishery remains substantially higher than in the early 1980s. See recommendation 10.

TOR 4
YOY is the best of the recruitment indices to predict regional and total catch rates from both fishery independent and fishery dependent data sources respectively. See recommendation 5.

TOR 5

The fishery is currently at an abundance level similar to the early 1980s. Only the SSB index for CT (which is derived from the CT fall surveys) indicates that abundance is lower than the early 1980s. The other abundance indices including the UMM abundance estimates indicate that the current abundance in the fishery is slightly higher or equivalent to the early 1980s. Projected low YOY in 2009 would see the fishery decrease to the UMM abundance estimate of 1982 & 1983. Recent regional CPUE estimates indicate a slight recovery in the fishery in the 2004 – 2006 period (see recommendation 9). While abundance is equivalent to the 1980s, fishing effort is almost double the 1980s effort and needs to be reduced (see recommendation 10).

If the changes in environment are affecting larval recruitment (i.e. the free swimming phase) then the fishery has limited future. If the environment is affecting the settlement or post-settlement phase (e.g. water is too warm) then the fishery in this region only has a future if settlement and post-settlement can occur in deeper (cooler) waters. Further information is required to determine this (see recommendation 2).

The SNE fishery is the southern range of the commercial fishery and increased warming in this region is expected to shift the southern boundary of the commercial fishery further north. Understanding the longer term effects of global warming is required.

Recommendation 11: It is recommended that a study be undertaken to investigate the longer term future of the fishery. This could be achieved by using the downscaled IPCC climate models.

There is limited support for a total closure or for a closure for a defined period. There is a need to substantially reduce effort (see recommendation 10) with reviews undertaken to adjust effort if required. Consideration of an agreed decision rule process is recommended.

Recommendation 12: It is recommended that a decision rule process be considered that involves both government and industry and that incorporates both fishery independent (e.g. YOY) and fishery dependent (e.g. regional CPUEs) indices.

TOR 6

The UMM provides good correlations with fisheries performance attributes such as total landings and CPUE. Future projects need to be based on recruitment and F scenarios that are realistic for the current fishery. Estimates that are averaged over the history of the fishery factor in a large recruitment event in the 1990s which will inflate future projections. While the low recruitment scenario addresses the need to consider the future of the fishery based on low recruitment, it is uncertain how "low" the low recruitment value is in the projections.

Recommendation 13: It is recommended that several low recruitment scenarios be determined and included in the projections. Each scenario needs to define what the recruitment value is compared to a base case (e.g. the BH-R).

Recommendation 14: Targets and thresholds should be determined for the low (normal) recruitment scenarios.

TOR 7

Natural mortality (M) is a difficult parameter to estimate and separate from fishing mortality (F). Thus it is uncertain if some of the increase in M could be attributed to increases in F. The increased incidence of shell disease would increase M although it is unknown if this

would account for the increase from 0.15 to 0.285. While the model projections will remain appropriate if the increase in mortality is assigned to F or M, the management implications will be different. Essentially management can influence F but seldom M.

Recommendation 15: Further studies are undertaken to attempt to separate F from M.

Appendix I: Background Material

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

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

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.

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

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

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.

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

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).

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. Stewart Frusher

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 November 2010	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:

William Michaels, Contracting Officer's Technical Representative (COTR)
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Key Personnel:

NMFS Project Contact:

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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:

4. Identify issues impeding stock rebuilding in SNE,
5. Develop a suite of measures to begin stock rebuilding in SNE,
6. 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.

8. **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.**

9. **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 20^0C 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 20^0C causes respiratory and immune system stress, increased incidence of shell disease, acidosis and suppression of immune defenses in lobster. Lobsters avoid water greater than 19^0C.

    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.

10. **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

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

12. **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.

13. **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.**

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